Monitoring Program to Evaluate Water Quantity/Quality Impacts of Vegetation Restoration in the Leon River Watershed

Final Report

Texas Agricultural Experiment Station /
Blackland Research and Extension Center

720 East Blackland Road
Temple, Texas 76502
Phone 254-774-6000
Fax 254-774-6001

May, 2005

Dennis Hoffman
Research Scientist
Principal Investigator

June Wolfe, III
Assistant Research Scientist
Project Manager

BRC-05-3

Monitoring Program to Evaluate Water Quantity/Quality Impacts of Vegetation Restoration in the Leon River Watershed

Introduction:

This project was proposed as the first phase of a 5-year water quantity/quality project. Our goal was to develop a database of surface water conditions prior to and after juniper clearing operations. The database stores the water quantity/ quality conditions in the selected watersheds for the report period. Activities and site selections were coordinated by a coordinating committee headed by Texas Department of Agriculture (TDA)/ Central Texas Cattleman Association (CTCA).

Historically Central Texas grassland ecosystems consisted of lush grasses growing in a deep fertile soil profile. Poor management of grassland ecosystems has resulted in loss of native vegetation, invasion by undesirable plant species and loss of the soil profile. The tall deeply rooted warm season grasses that once dominated Central Texas grassland ecosystems included Big Bluestem, Little Bluestem, Indian Grass, Eastern Gamma Grass, Switch Grass and other species. The replacement of desirable grass species by invading woody species such as Ashe Juniper, has negative impacts on soils, native vegetation, and water quantity and quality (Dahlgren et. al. 2001). Restoration of these valuable rangelands would improve grazing, native wild life habitat, and water quality and quantities for future residents (Schilling and Thompson 2000, Wilcox 2002).

CTCA selectively cleared and restored rangelands with the cooperation of TDA, and the Texas Farm Bureau. Their goal was to restore the productivity of native rangelands, habitat for native wildlife and to ultimately improve water quantity and quality in the watershed. Activities included:

- Re-vegetation site selection using maps created by Blackland Research and Extension Center (BREC).
- Use of overhead imagery to assist in final site selection (CTCA/TDA).
- Site ground truthing to develop a database of plant and animal species present before and after clearing and re-vegetation.
- Working closely with state and federal agencies to insure the environmental correctness of activities.
- Clearing Ashe Juniper from selected sites in cooperation with landowners (CTCA).
- Monitoring and comparing water quantity and quality conditions from stormwater discharges of selected sub-watersheds.

CTCA selectively cleared Ashe Juniper to provide space for re-establishing desirable grassland species. Native grasses were reintroduced to create a vegetative cover that would improve water quantity (as decreased runoff volumes) and quality (as decreased sediment or nutrient loading in runoff water).

Summary of Activities:

Water Quantity/Quality Evaluation BREC established 4 water monitoring sites to measure surface hydrology and water quality impacts of CTCA clearing activities. The sites were established to document base line conditions prior to clearing activities (pre-treatment period) and response conditions post clearing. The selected watersheds were located in the Coryell Creek and Bullard Creek sub-watersheds of the Leon River watershed. They were evaluated using EPA's "Paired Watershed Study Design" statistical techniques (Clausen and Spooner 1993). Hydrologic and water quality conditions were monitored with ISCO 4230 flow meters and ISCO 3700 storm water samplers. This equipment continuously logged stream discharge and precipitation data while collecting water samples during storm water runoff events. Routine monthly grab sampling was planned in our proposal; however, flow at the study sites was sporadic or non-existent except during storm events prompting us to abandon this activity. Samples collected during storm water runoff events were evaluated in accordance with the Quality Assurance Project Plan (QAPP) prepared for this project.

Project Goals:

- Create a water quantity/quality database for CTCA's Ashe juniper clearing project. Emphasis for this project was to create a database to be used to evaluate the water quantity/quality effects of the Ashe Juniper clearing activities.

- Measure storm water runoff quantity/quality differences in selected watersheds before and after CTCA project activities (predicted water savings will be available to area and downstream residents).

- Estimate the potential increased water yields (water savings) that would result from implementing Ashe Juniper clearing BMPs in the Leon River watershed

Project Objectives

The major goal of this project was to present an innovative, comprehensive approach to effectively improve Central Texas water quantity and quality. To accomplish this goal, the following objectives were established:

- Provide an effective level of coordination between federal, state and local entities to meet the project goals (See Figure 1).
- Implement a public awareness campaign as an initial step in obtaining participation and support of landowners in attaining the project goals.

- Assist CTCA in implementing education and technology transfer activities to residents in the targeted watershed through field days, printed materials, training workshops, technical presentations and media coverage (Figure 1).
- Assist CTCA in implementing Ashe Juniper Best Management Practice (BMP) clearing demonstrations in selected Leon River sub-watersheds.
- Study water quantity and quality within the watersheds selected for Ashe Juniper clearing (Figure 2).
- Create a water quality database for the CTCA Ashe Juniper clearing project.
- Measure quantity of water in selected watersheds before and after CTCA project activities to quantify increased water yields (water savings which will be available to both area residents and downstream residents).
- Estimate the potential increased water yields (water savings) that would result from implementing Ashe Juniper clearing BMPs in the Leon River watershed.
- Coordinate activities with other entities within the area and link up with other programs and activities whenever possible to increase the project's impact.

TASK 1: Project Management and Coordination

Figure 1. Field tour of the Leon River Watershed

Objective: Produce an integrated team among the cooperating agencies and groups involved with the project to efficiently and effectively achieve project goals.

Subtask 1.1 Participation in team meetings to agree upon project schedule, lines of responsibility, communication needs, and other required tasks. A total of five meetings took place, here described:

- Meeting July, 2001 with local landowners to locate and establish monitoring sites in Coryell Creek (CTCA, TDA)
- Meeting/tour of clearing activities July 2001 with extension, landowners CTCA, TDA and other interested individuals.
- Meeting June, 2002 with CTCA, TDA and TAMU Range Science
- Meeting/Tour August, 2002 with landowners in Bullard Creek watershed and Texas A&M Range Science representatives
- Meeting/Tour December 2002 with Congressman Chet Edwards

Subtask 1.2 Work with CTCA and TDA to establish a coordinating committee (Watershed Taskforce) to assure project cooperation and to provide a means for unified water quality improvement efforts through end of the project. The committee met at least twice each year to provide input and to keep up-to-date on the project's progress. Committee members were invaluable liaisons, helping to increase the exposure of the project, gaining support for project goals and objectives, and identifying incentives for BMP adoption.

A meeting took place April 2001 to plan and discuss strategy for locating cooperators and sites in Coryell Creek. In April and June of 2001, field tours of the Coryell Creek watershed were completed.

Subtask 1.3 Conduct quarterly project meetings to assess progress, track task time-lines, and discuss upcoming activities. Information discussed at team meetings will be provided to the local coordinating committee as well. See Task 1.1 for a description of these meetings.

Subtask 1.4 A public awareness campaign to gain support for project goals was implemented. A meeting took place August 2, 2002 to discuss project goals and objectives with local cooperators. Another meeting was held in September 2002 by CTCA and TDA for landowners and interested local residents.

Subtask 1.5 Prepare annual and final reports for submittal to the project team to document project status (Month 1 to project completion). Quarterly and monthly reports were submitted to TWDB.

TASK 2: Monitor Water Quantity/Quality Effects

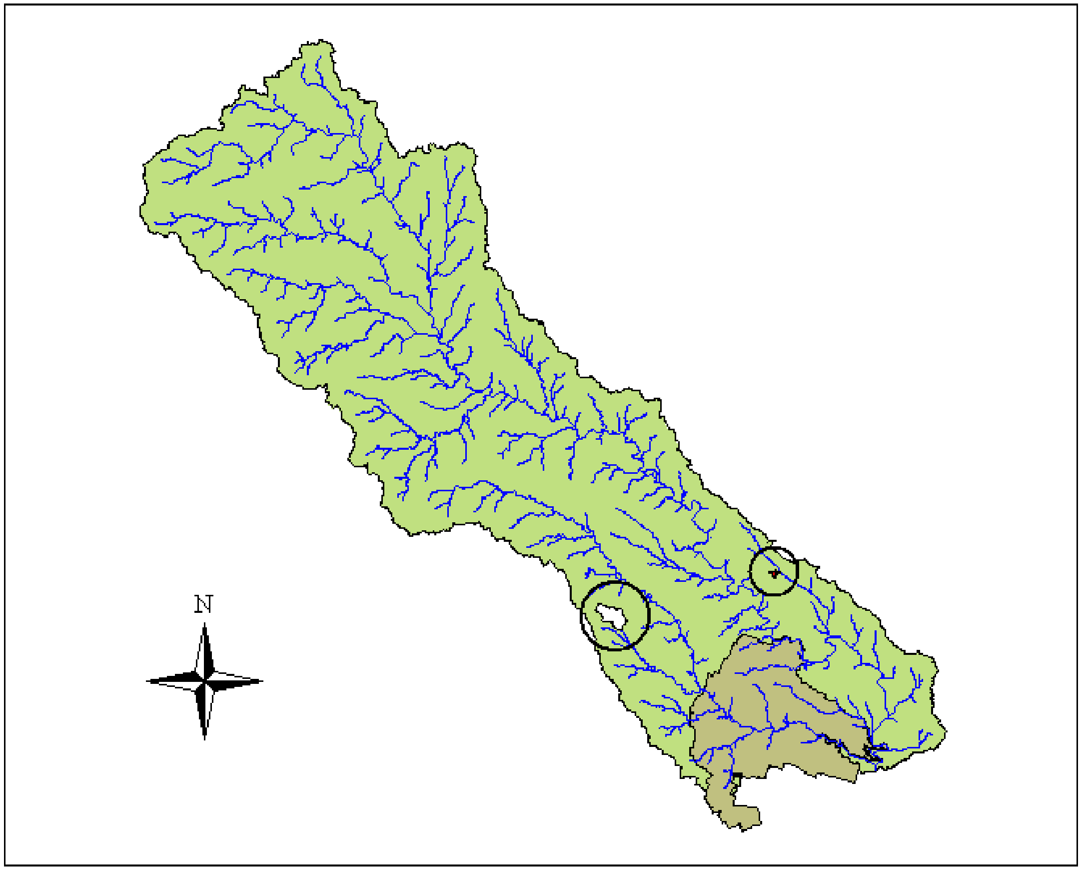

Figure 2. Water monitoring station

Objective: To determine hydrologic and water quality conditions present in selected Leon River sub-watersheds prior to brush removal treatments.

Subtask 2.1 Prepare Quality Assurance Project Plan (QAPP). This activity was completed during the first month of the project.

Subtask 2.2 The original plan called for the installation of two storm water-sampling stations equipped with automated equipment. This goal was met and exceeded by the establishment of four stations rather than two as specified. The study areas selected form paired watersheds and were located in the Coryell and Bullard Creek sub watersheds of the Leon River watershed (Map 1). These areas possessed proximity, geologic and vegetative criteria necessary to utilize a paired watershed study design (Clausen and Spooner 1993). Paired watersheds are shown in Maps 2 and 3. Each paired watershed possesses a defined drainage boundary, similar slopes and vegetative coverage. Cooperation with land owners has been attained to allow treatment or control (i.e. brush removal or no brush removal) management of the areas throughout the study duration.

Map 1: Leon River Watershed and Paired Sub-Watersheds



Water Science Laboratory
Texas Agricultural Experiment Station
Blackland Research and Extension Center
720 East Blackland Road
Temple, Texas 76502

(254) 774-6000
waterhome.brc.tamus.edu

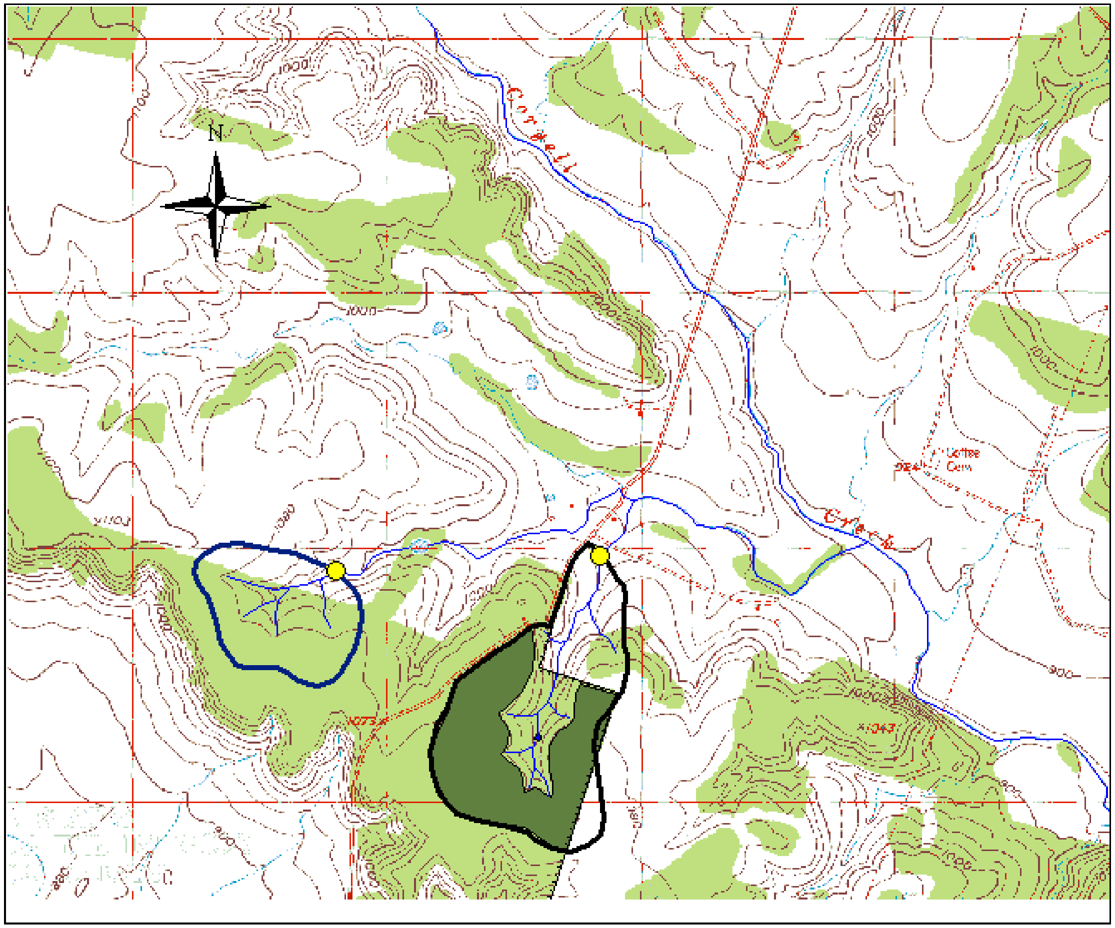
Dr. Dennis Hoffman - Project Leader
(254) 774-6040
hoffman@brc.tamus.edu

Notes: Monitoring stations one and two (Cook, Sutton) are located in Coryell Creek drainage. Monitoring stations three and four (Hall, TX183) are located in Bullard Creek drainage.

Bullard Creek Paired Watersheds
Coryell Creek Paired Watersheds
Leon Channel
Cowhouse Channel
Fort Hood Military Reservation
Leon River Watershed

Map prepared by June Wolfe, III
(254) 774-6016
wolfe@brc.tamus.edu

Map 2: Pruitt/Cook and Sutton Basins



Water Science Laboratory
Texas Agricultural Experiment Station
Blackland Research and Extension Center
720 East Blackland Road
Temple, Texas 76502

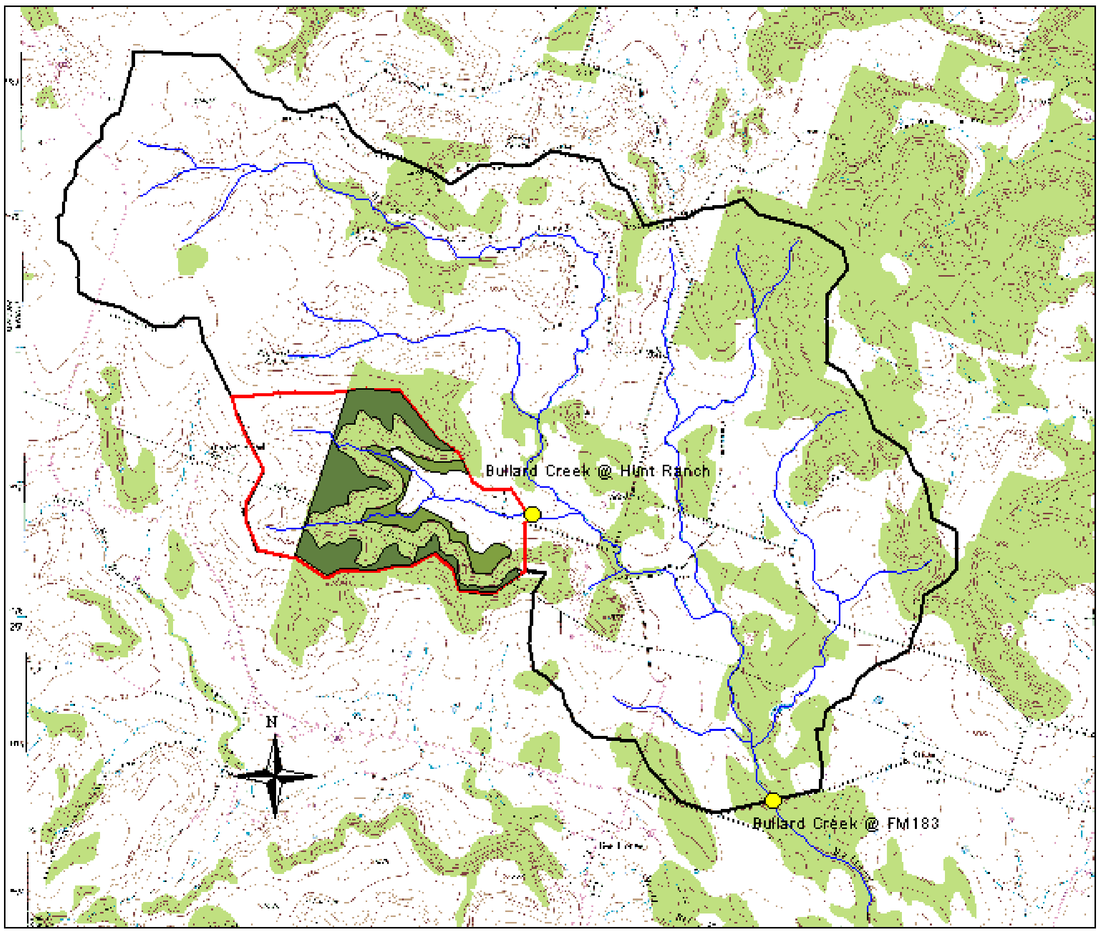
(254) 774-6000
waterhome.brc.tamus.edu

Leon River Revegetation Project
Dr. Dennis Hoffman - Project Leader
(254) 774-6040
hoffman@brc.tamus.edu

Notes: Pruitt/Cook and Sutton basins form a paired watershed. Juniper to be cleared in upland areas of Pruitt/Cook basin. Sutton basin will act as a control with no treatment.

Map prepared by June Wolfe, III
(254) 774-6016
wolfe@brc.tamus.edu

Map 3: Bullard Creek Paired Watersheds



Water Science Laboratory
Texas Agricultural Experiment Station
Blackland Research and Extension Center
720 East Blackland Road
Temple, Texas 76502

(254) 774-6000
waterhome.brc.tamus.edu

Leon River Re-Vegetation Project

Dr. Dennis Hoffman - Project Leader
(254) 774-6040
hoffman@brc.tamus.edu

NOTES:

-Total area 4869 acres

-Vegetation area 1512 acres (31%)

-Sub-watershed area 556 acres

-Sub-watershed vegetation area 306 acres (55%)

-Sub-watershed clearable area 158 acres (28%)

-Gauging stations measure and record stream discharge and precipitation. Sampler collects water samples during storm events.

- Gauging Stations
- Bullard Drainage
- Bottom Area
- Top Area
- Bullard Creek Sub-watershed (556 A)
- Bullard Creek Watershed (4869 A)

Map prepared by June Wolfe, III
(254) 774-6016
wolfe@brc.tamus.edu

- Storm water monitoring/sampling equipment and supporting items needed to achieve project goals was purchased with EPA 319(h) funding. Each sampling station was outfitted with the following equipment:

  1) ISCO 4230 Bubble Flow Meter
  2) ISCO 3700 Automated Water Sampler
  3) Texas Electronics Tipping bucket rain gauge
  4) Remote power system (180 Amp hour Deep Cycle Marine Battery and Solarex 10 watt Solar Panel)
  5) Equipment Shelter and intake lines

- BREC cooperated with CTCA and TDA representatives in selecting water quality sampling locations and installing storm water sampling equipment. Initial surveys to identify appropriate locations took place in July and August of 2002 and were conducted by BREC personnel. The Coryell Creek paired watersheds were identified and mapped in August of 2001. The Bullard Creek paired watersheds were identified and mapped in November 2001. Watershed surveys were completed through extensive field evaluation and position mapping utilizing a hand held GPS receiver. Field collected GPS points were projected with ArcView 3.2 GIS software (ESRI, Inc., Redlands, CA) utilizing the NAD27 projection and utilized to determine physical watershed area and drainage characteristics.

Monitoring station descriptive statistics

Station	**Drainage**	**Owner**	**Type**	**Size (acres)**	**Northing**	**Westing**
LRP1	Coryell	Cook	Treatment	139	34.86964	62.18479
LRP2	Coryell	Sutton	Control	65	34.86877	62.08126
LRP3	Bullard	Hall	Control	556	34.76739	58.69340
LRP4	Bullard	Texas	Treatment	4869	34.74620	58.87235

- Sampling site surveys took place on June 20, 2002. BREC personnel utilized a surveying rod, tape, and transit to determine gauging points, structure sizes, stream cross-section elevations, and channel slopes at all study locations. Stations one and four utilize storm water drainage structures (round and square culverts) as primary flow devices for discharge measurement. Stations two and three are irregular channels utilizing a cross sectional surveys determine flow at the gauging point. FlowMaster software (Haestad Methods, Waterbury, CT) was utilized to develop the rating curves for each station. Survey data and associated level to discharge rating curves are presented in Appendix 2.

Station LRP1 (Cook Canyon) – Located in the Coryell Creek Sub-Watershed. This is a treatment watershed containing approximately 140 acres with 75 acres of brush. Round culvert at the drainage point is utilized as a primary measuring device for determining storm flow.

Station LRP2 (Sutton Canyon) – Located in the Coryell Creek Sub-Watershed. This is a control watershed containing approximately 65 acres. Vegetation will not be removed until the termination of the project. A level to area discharge curve has been developed to determine storm flow at this location.

Station LRP3 (Hall Ranch) – Located in the Bullard Creek Sub-Watershed and contains approximately 550 acres. With no primary flow device available, a level to area discharge curve has been developed to measure storm flow in this irregular channel.

Station LRP4 (TX Hwy 183) – This basin is Paired with Station 3 and is located on the Bullard Creek Sub-Watershed. It contains approximately 4900 acres and drains through a large square culvert which acts as a primary measuring device for determining storm flow.

- Coryell Creek paired watershed equipment was installed August 14, 2001. The channels in these small watersheds are classified as ephemeral and only flow during periods of heavy precipitation. Data collection interval was set to 5 minutes. During storm events water sample collection was carried out by the ISCO 3700 Automated Samplers. Event initiation levels were set as low as physically possible (~0.1' – minimum level to submerge intake) at both Coryell Creek paired watersheds (Cook and Sutton) in order to collect samples from the smallest possible runoff events.

- Bullard Creek nested watershed equipment was installed between December 6, 2001 (Station 3 – Hall Ranch) and April 6, 2002 (Station 4 – State of Texas low water crossing @ HWY 183). Installation of Station 4 required cooperation with local Texas Transportation office. The area downstream of the rectangular culvert required dredging with heavy equipment to remove sediment and restore normal drainage characteristics. This was necessary so that the culvert could be used as a primary measuring device for determining stream discharge. This stream is classified as intermittent with flow occurring during wet seasons (i.e. spring and fall). It frequently dries up completely or to sub-surface flow during the summer to early fall months as noted during the period of this report.

- A Campbell Scientific MetData1 weather station purchased by EPA was used in Coryell Creek Paired Watershed on the Sutton Ranch (Station 2) during the first 12 months of monitoring. Monitored parameters included: precipitation, wind speed, wind direction, humidity, air temperature, solar radiation, and soil temperature.

- All field equipment was regularly serviced and maintained throughout the entire reporting period.

Subtask 2.3

Analyze samples for water quality parameters in accordance with the QAPP.

- Due to the ephemeral nature of streams draining the small sub-watersheds under investigation, there was insufficient flow at the monitoring stations to conduct routine grab samples. We therefore eliminated this task.

- Flow data was collected during all storm water runoff events and samples were collected from those of sufficient size to immerse water sampler intake lines. During the report period a total of 23 measurable, paired runoff events were recorded from the Coryell Creek paired watersheds and 37 from the Bullard Creek nested watersheds (Tables 1 and 2).

- Events large enough to trigger automated samplers were analyzed in the BREC laboratory for sediment concentration, expressed as Total Suspended Solids (TSS). Several early events were also analyzed for nitrate and orthophosphate concentrations but these measurements were discontinued due to the low concentrations observed (See Appendix 3 for water quality data).

- Stream flow monitoring continued until completion of the CTCA project. At that time, measured runoff volumes were compared to examine the effect Ashe Juniper clearing has upon increasing groundwater stores as a function of expected runoff reduction.

TASK 3: Data handling and analysis.

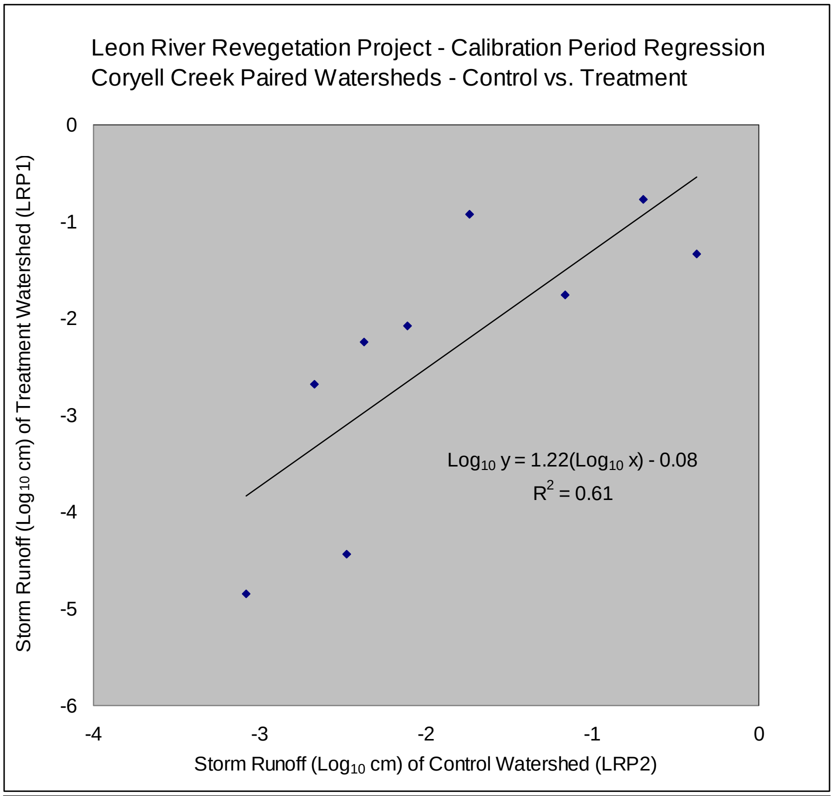
Objective: To develop a water quality / hydrology database and determine the effect of Ashe Juniper clearing Best Management Practices (BMPs) on stormwater runoff from paired sub-watersheds of the Leon River watershed.

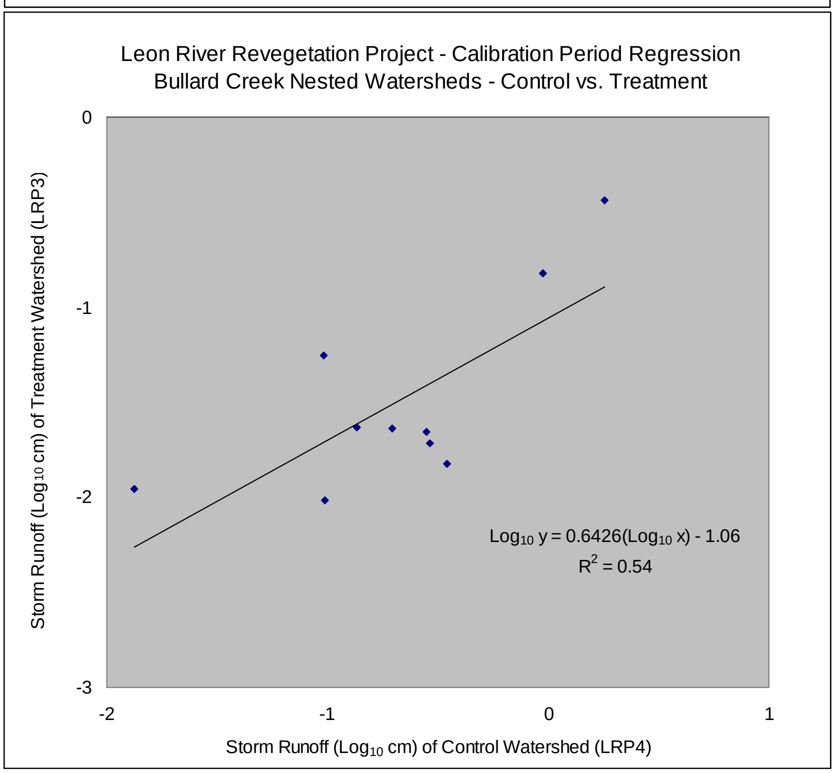
- BREC developed and maintained a Microsoft Access water quality data base containing all laboratory measured parameters (TSS and nutrients) collected from paired watershed runoff events. Storm precipitation and water discharge values were maintained in an ISCO FlowLink data base. The FlowLink database software allows BREC personnel to keep separate files for each monitoring station containing 5 minute interval values for precipitation, and stream level. Stream level data is converted to flow volumes with a stage / discharge relationship. These stage-discharge curves were calculated with survey data using FlowMaster software (See SubTask 2.2 and Appendix 2)

- Water samples were collected during storm water runoff events of sufficient size to immerse water sampler intake lines. During the previous reporting period (August 1, 2001 to February 1, 2003), nine paired runoff events were measured in the Coryell Creek watersheds and nine paired runoff events were measured in the Bullard Creek watersheds. Events large enough to trigger automated samplers and collect samples were analyzed for sediment concentrations (reported as Total Suspended Solids) when adequate funding was available for laboratory processing.

- Preliminary measurements indicated nutrient concentrations of sampled runoff were close to method detection limits (essentially zero). Therefore, nutrient loads were not measured for successive events.

- The original calibration regression coefficients were reported to have exhibited quantifiable relationships between treatment and control watersheds (Figures 3 and 4). While the linear fits appeared to be reasonable for natural systems (r^2 = 0.61 and 0.54, for Coryell and Bullard Creek watersheds respectively), a closer examination of data variation indicated that they were not sufficient to detect runoff differences due to the BMP of less than ~47% (using Equation 9 in EPA “Paired Watershed Study Design”). These relationships were expected to improve as more data were gathered from successive runoff events. This, however, was not the case.





Figures 3 and 4. Comparisons of storm discharge from control watersheds verses storm discharge from treatment watersheds in Coryell paired and Bullard Creek nested Watersheds during the calibration (pre BMP) period

- From February 1, 2003 through April 10, 2005, BREC continued to collect stormwater runoff data from paired and nested sub-watersheds of the Leon River watershed. All stormwater discharge (Q) and precipitation (P) data collected between project initiation and conclusion (August 1, 2001 to April 10, 2005) were re-evaluated on a per-event basis for the following analysis. Stormwater discharge volumes were re-calculated using five minute ISCO data intervals. This interval produces the best estimate of Q based on the stage-discharge rating curves previously established for each watershed. Only storm events with measurable Q from both paired watersheds were included in the analysis. A total of 12 paired observations pre BMP implementation and 11 paired observations post BMP implementation were collected in the Coryell Creek (CC) watersheds. A total of 13 paired observations pre BMP implementation and 20 paired observations post BMP implementation were collected in the Bullard Creek (BC) watersheds. The revised, five- minute data interval, paired observations of Q and P for CC and BC are shown in Tables 1 and 2. Histograms of paired Q observations for CC and BC watersheds are shown in Figures 5 and 6. Runoff, expressed in millimeters, was calculated for each paired event for statistical comparison. Runoff was determined by dividing the event discharge volume (Q) in cubic meters by the watershed area in square meters and converting to millimeters (LRP1 = 138.6 Acres, LRP2 = 64.6 Acres).

Table 1. Revised data summary for Coryell Creek paired watersheds (LRP1 & 2). Paired observations using five minute interval data for stormwater discharge volumes (Q) and cumulative precipitation (P), pre and post BMP establishment (clearing of Ashe Juniper on watershed slopes)

		LRP1 -Treatment Watershed		LRP2 -Control Watershed	
Event	Date	Q (m^3)	P (mm)	Q (m^3)	P (mm)
Pre BMP (Before Ashe Juniper clearing on watershed slopes)					
1	10/15/2001	41	107	2	N/A†
2	11/15/2001	248	100	2344	N/A
3	12/15/2001	84	54	364	N/A
4	4/8/2002	32	46	11	N/A
5	7/2/2002	39	54	39	N/A
5	7/5/2002	12	27	6	N/A
7	7/17/2002	1	47	9	N/A
8	10/8/2002	950	120	1116	N/A
9	12/8/2002	495	52	93	45
10	12/30/2002	172	23	7506	19
11	2/21/2003	328	50	61	47
12	3/2/2003	437	26	35	22

Table 1. Continued

Event	Date	LRP1 -Treatment Watershed Q (m^3)	P (mm)	LRP2 -Control Watershed Q (m^3)	P (mm)
Post BMP (After Ashe Juniper clearing on watershed slopes, LRP 1 only)					
13	6/5/2003	*607*	*91*	129	85
14	10/9/2003	*5968*	*176*	14200	166
15	1/16/2004	*934*	*75*	165	69
16	2/24/2004	*928*	*57*	752	52
17	3/4/2004	*495*	*23*	105	18
18	4/6/2004	*379*	*45*	604	38
19	4/24/04	*1816*	*77*	4673	72
20	5/1/2004	*271*	*18*	452	17
21	6/9/2004	*131*	*89*	152	91
22	6/28/2004	*1000*	*45*	106	38
23	11/17/2004	*2304*	*108*	5899	99

† Precipitation values for these dates at this location are not available.

Table 2. Revised data summary for Bullard Creek paired watersheds (LRP1 & 4). Paired observations using five minute interval data for stormwater discharge volumes (Q) and cumulative precipitation (P), pre and post BMP establishment (clearing of Ashe Juniper on watershed slopes)

Event	Date	LRP3 - Treatment Watershed Q (m^3)	P (mm)	LRP4 - Control Watershed Q (m^3)	P (mm)
Pre BMP (before Ashe Juniper clearing on watershed slopes)					
1	4/7/2002	2160	21	38417	N/A†
	5/28/2002	390	30	511	N/A
	6/17/2002	522	44	25260	N/A
2	6/30/2002	649	84	40175	N/A
3	7/3/2002	3424	26	185549	N/A
4	7/5/2002	9451	30	477609	N/A
5	7/13/2002	959	3	79016	N/A
6	10/10/2002	249	21	2465	1
7	10/22/2002	468	2	29614	3
8	12/8/2002	495	9	75639	15
9	12/23/2002	339	9	68414	25
10	1/12/2003	433	NA	95293	14
11	2/14/2003	592	18	164186	19
12	2/21/2003	3121	NA	472535	14
13	3/3/2003	5461	NA	460209	27

Table 2. Continued

Event	Date	LRP3 - Treatment Watershed Q (m^3)	LRP3 - Treatment Watershed P (mm)	LRP4 - Control Watershed Q (m^3)	LRP4 - Control Watershed P (mm)
Post BMP (after Ashe Juniper clearing on watershed slopes, LRP3 only)					
14	3/18/2003	*1610*	*NA*	52621	8
15	6/8/2003	*528*	*NA*	233909	16
16	10/10/2003	*3933*	*NA*	404087	100
17	4/24/2004	*748*	*57*	206381	45
18	6/1/2004	*44*	*34*	46150	32
19	6/4/2004	*8*	*19*	74956	18
20	6/28/2004	*2131*	*42*	373619	20
21	6/30/2004	*1698*	*19*	249004	18
22	8/19/2004	*611*	*49*	151482	20
23	9/6/2004	*936*	*52*	190293	40
25	10/4/2004	*72*	*14*	76980	8
26	10/31/2004	*279*	*NA*	82253	26
27	11/17/2004	*28914*	*NA*	1431774	82
28	1/27/2005	*329*	*21*	153616	12
29	2/1/2005	*1070*	*14*	401266	7
30	2/6/2005	*88*	*4*	114754	4
31	2/23/2005	*1794*	*30*	400081	18
32	2/24/2005	*854*	*7*	215911	3
33	2/26/2005	*2262*	*13*	429792	14
34	3/1/2005	*1105*	*10*	207238	10
35	3/5/2005	*942*	*8*	183152	7
36	3/26/2005	*409*	*15*	173650	8
37	4/10/2005	*52*	*18*	142007	16

† Precipitation values for these dates at this location are not available.

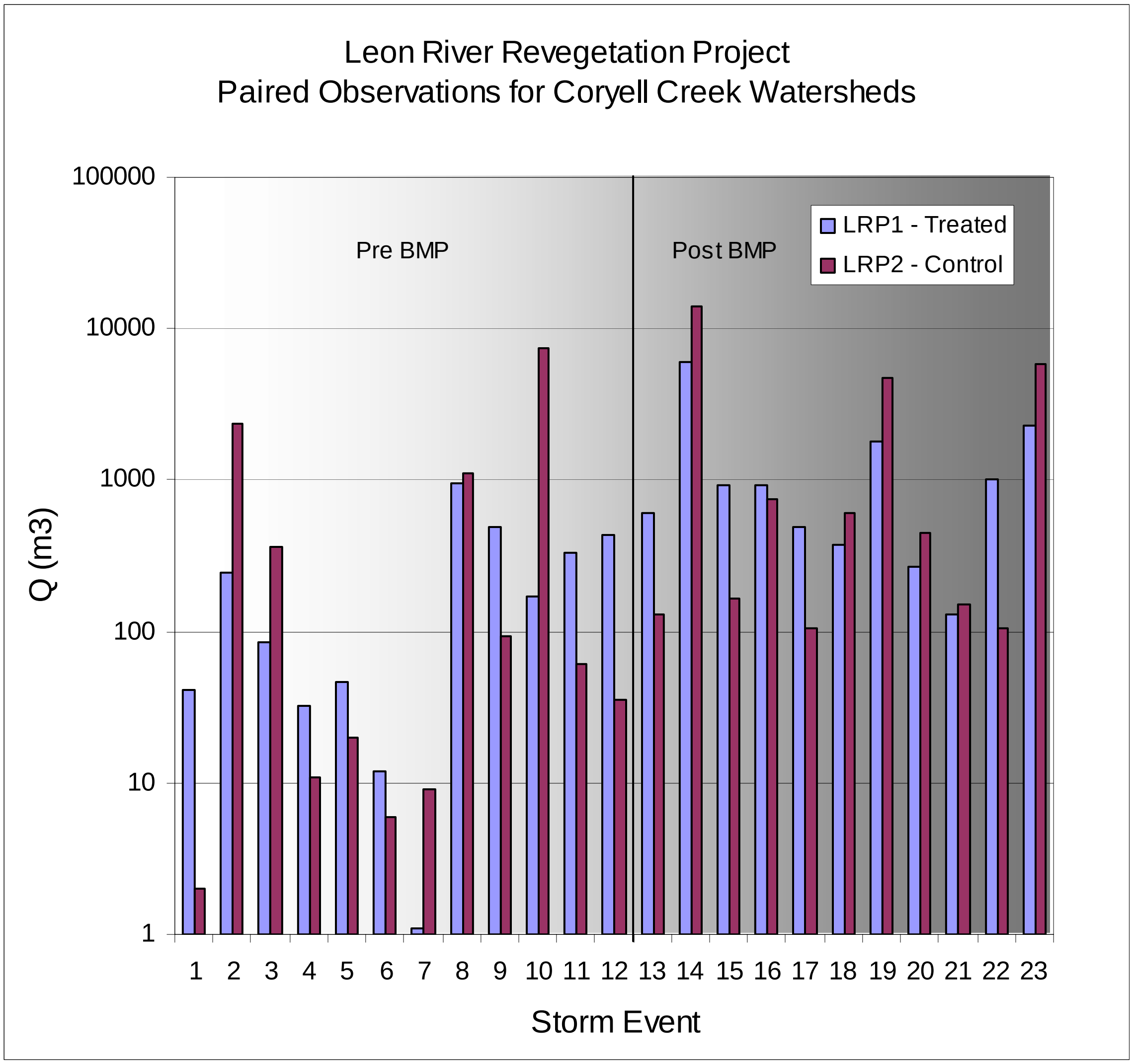


Figure 5. Histogram for Coryell Creek paired watersheds (LRP1 & 2). Five minute data interval based stormwater discharge volumes (Q) pre and post BMP establishment (clearing of Ashe Juniper), for individual storm events producing runoff on both watersheds. Note use of log scale.

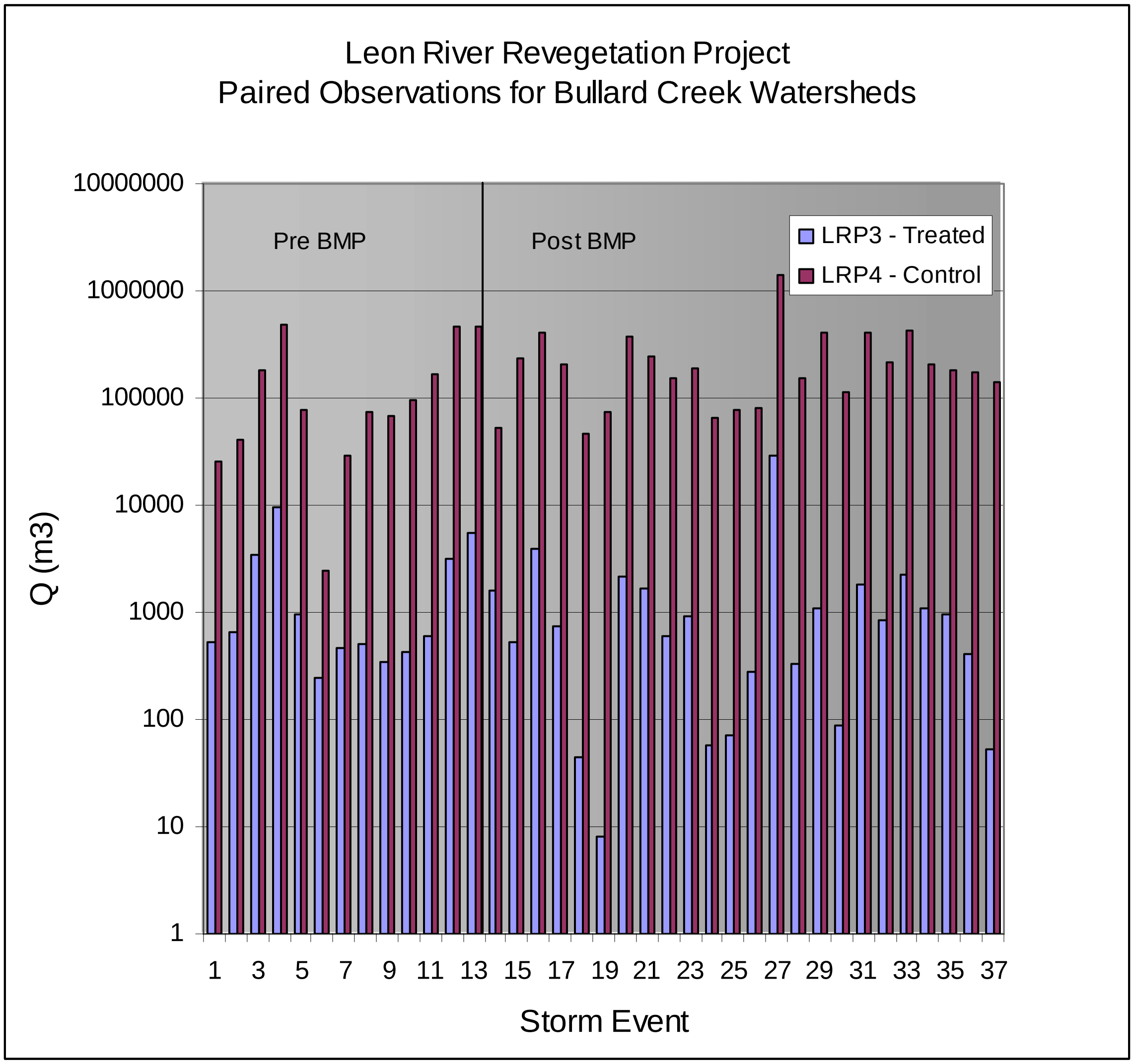


Figure 6. Histogram for Bullard Creek nested watersheds (LRP1 & 2). Five minute data interval based stormwater discharge volumes (Q) pre and post BMP establishment (clearing of Ashe Juniper), for individual storm events producing runoff on both watersheds. Note use of log scale.

- The relationships between cumulative daily precipitation amounts at the Coryell Creek (CC) paired watersheds and Bullard Creek (BC) nested watersheds were compared using scatter-plots. A strong visual correlation was observed at CC between the control and treated watersheds (Figure 7). The relationship was considerably weaker between BC nested watersheds (Figure 8). Differences are likely due to gauge proximity. The CC rain gauges were located within 1 km of each other while the BC rain gauges were separated by > 5 km.

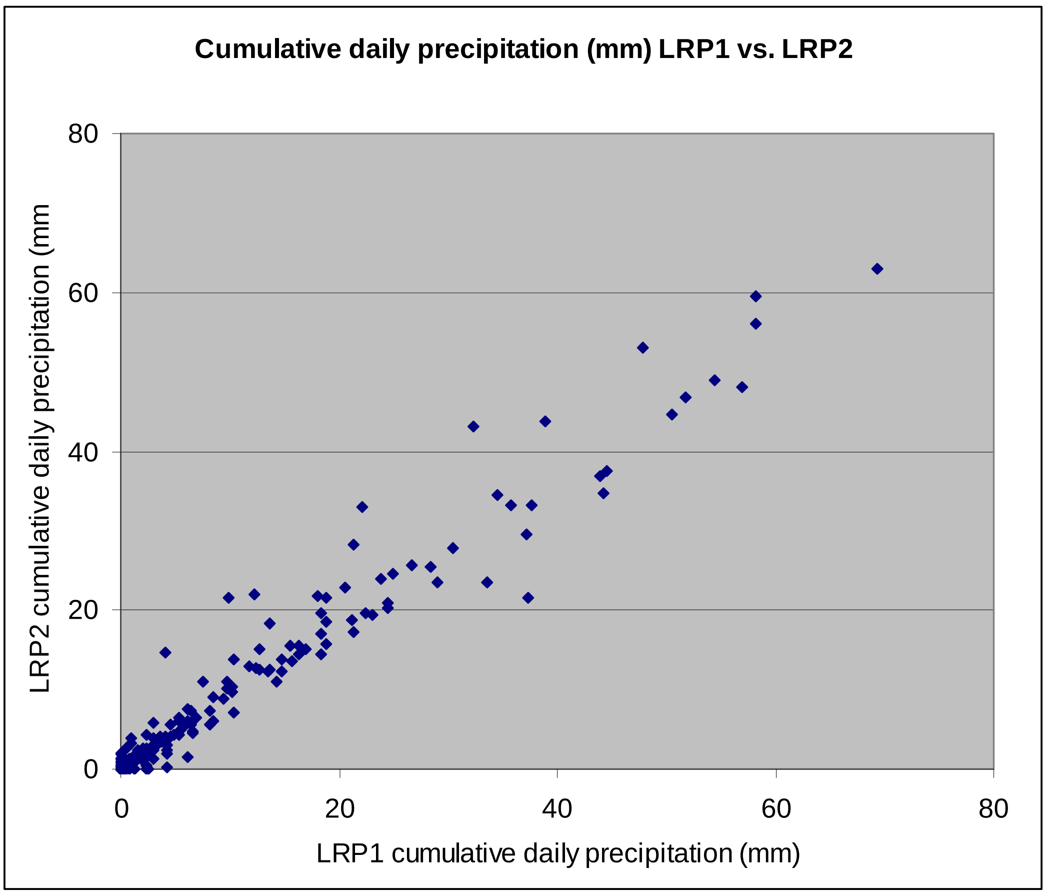


Figure 7. Relationship between cumulative daily precipitation values (mm) for Coryell Creek watersheds. Proximity of gauges influences correlation.

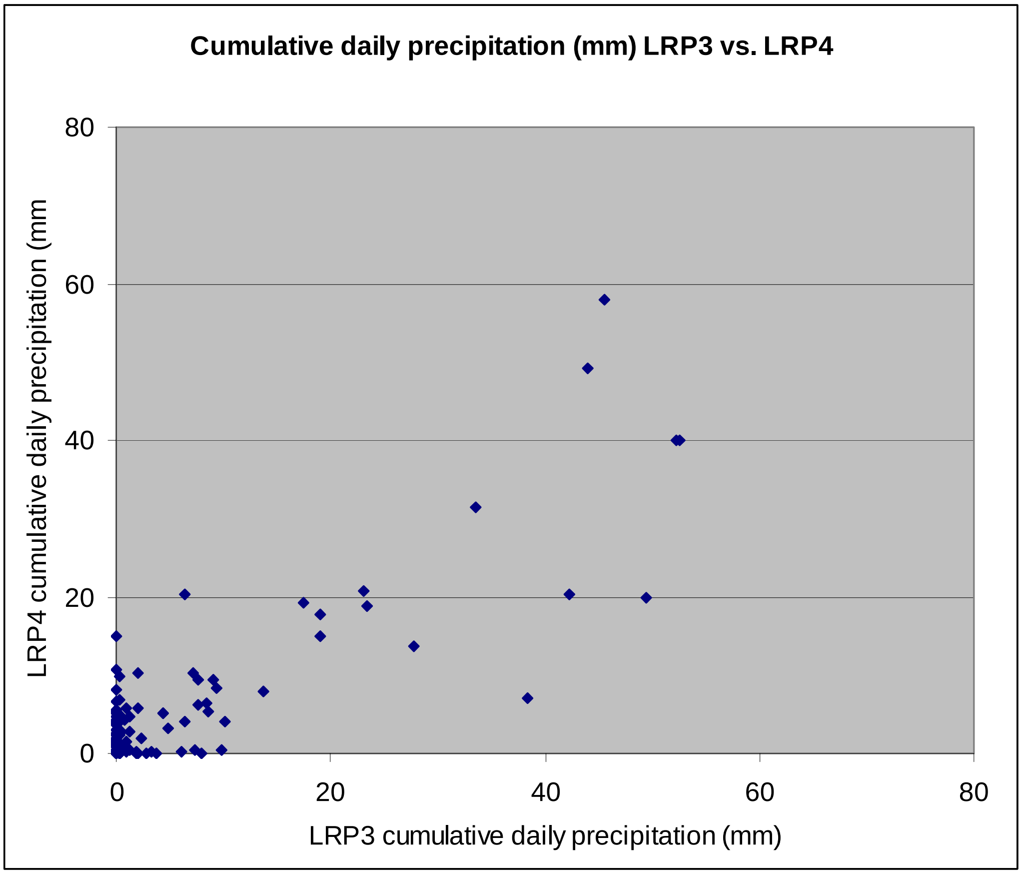


Figure 8. Relationship between cumulative daily precipitation values (mm) for Bullard Creek watersheds. Proximity of gauges influences correlation.

- Evaluation of BMP effect at Coryell Creek: Following the methods outlined in the "Paired Watershed Study Design", stormwater runoff (Q /Area, expressed in millimeters) data for the Coryell Creek paired watersheds were log-log transformed to approach a normal distribution before carrying out analysis of variance and regression analysis to determine if the watersheds responded together in a predictable manner. Simple linear regression models of runoff between control and treated watersheds were fitted to the pre and post BMP periods (Tables 3 and 4).

Table 3. ANOVA for Coryell Creek Paired Watersheds; regression of control watershed runoff vs. treatment watershed runoff for the calibration (Pre BMP) period.

Source	df	MS	F	p
Model	1	2.64	5.28	0.044
Error	10	0.50		
Total	11			

Table 4. ANOVA for Coryell Creek Paired Watersheds; regression of control watershed runoff vs. treatment watershed runoff for the treatment (Post BMP) period.

Source	df	MS	F	p
Model	1	3.27	10.98	0.009
Error	9	0.30		
Total	10			

The Pre BMP ANOVA indicates that the regression model adequately explains most of the variability in the paired runoff data ($F_{1, 10} = 5.28$, $p = 0.044$). The Post BMP ANOVA also explains most of the variability in the paired runoff data ($F_{1, 9} = 10.97$, $p = 0.009$) with an improved regression relationship. The regression coefficients of determination (r^2) were 0.35 and 0.55 for the pre and post BMP treatment periods respectively (Figure 9). Given the amount of pre BMP data collected, the ratio between the residual variance for the pre BMP regression and the smallest detectable difference due to the BMP was determined to be > 80% (from Equation 9 in EPA "Paired Watershed Study Design"). That is, the amount of variation in the pre BMP data would require a change of > 80% in runoff to statistically infer an effect due to the BMP. The 95% confidence bands about the pre BMP regression equation indicate the level of change necessary to have a significant treatment effect for any paired observation (i.e. how far away from the pre BMP regression does the post BMP data need to be to infer statistical significance?). The 95% confidence band is shown in Figure 9.

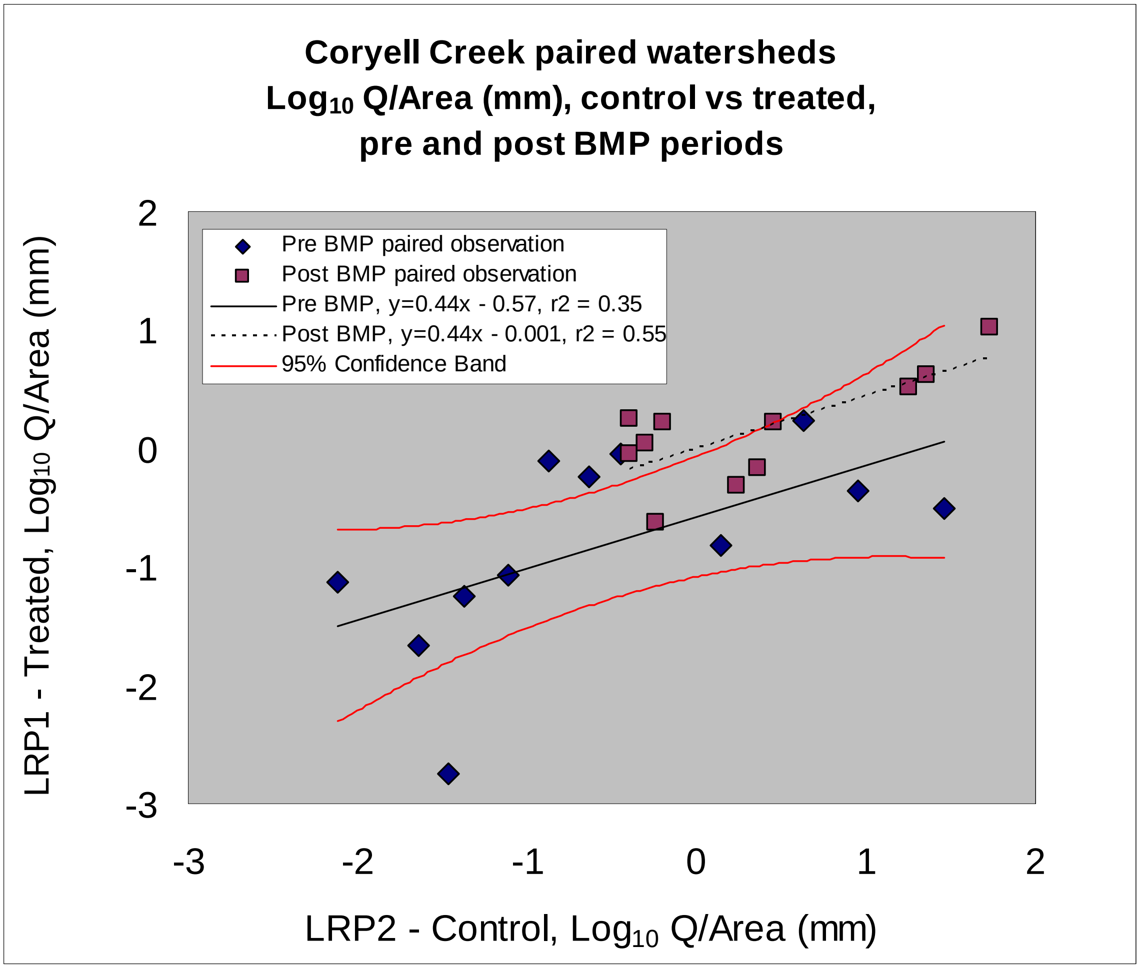


Figure 9. Coryell Creek paired watersheds; Log_{10} stormwater runoff (Q/Area, expressed in millimeters) with linear regressions and 95% confidence band for control (LRP2) verses treatment (LRP1) watersheds during pre and post BMP periods. Paired runoff observations are log-log transformed to approach normal distribution.

At the end of the treatment period the significance of the BMP effect was tested using analysis of covariance (ANCOVA). Simple linear regression models of runoff from control and treated watersheds were fitted to the combined and separate data from the pre and post BMP periods (Table 5).

Table 5. Analysis of covariance comparing pre and post BMP regressions.

Source	df	MS	F	p
Model	1	7.59	21.21	0.002
Error	21	0.36		
Total	22			
Overall	1	3.21	10.23	0.005
Intercept	1	1.54	4.92	0.039
Slope	1	0.00	0.00	0.979

The ANOVA for combined pre and post BMP data indicates that the regression model explains most of the variability in the paired runoff data ($F_{1, 21}$ = 21.21, p = 0.002). The ANCOVA for the regression coefficients of intercept were found to be significantly different between pre and post BMP periods ($F_{1, 1}$ = 4.92, p = 0.039). This is may be a result of natural weather patterns and suggests the runoff from the treated watershed was increased during the post treatment period. However, the ANCOVA for the regression coefficients of slope were not found to be significant ($F_{1, 1}$ = 0.00, p = 0.979) indicating no difference in the relationship for runoff between pre and post BMP periods for the two watersheds.

Several other data arrangements and manipulations were examined (Q, Q/P, % Q/P) to determine if stronger relationships could be established for statistical comparison. The results were similar. With no statistical differences between runoff from the control and treated watersheds for the two periods, no further analyses were made for measured water quality constituents (i.e. sediment or nutrient loads).

Simply stated, these results indicate the relationship between paired runoff events occurring on the control and treated Coryell Creek paired watersheds during the pre and post BMP implementation periods were not statistically different. Any BMP effects were overwhelmed by the random variability in the paired observations.

- Evaluation of BMP effect on stormwater discharge at Bullard Creek: The treated watershed of the BC pair was placed within the control watershed. This is a nested watershed design which violates the assumptions of a paired watershed statistical design. The paired watershed study design cannot be used to compare differences in runoff pre and post BMP implementation between these watersheds so no analysis was conducted.

Conclusions:

- Paired runoff observations from Coryell Creek did not show a statistically measurable effect on runoff when the BMP (clearing Ashe Juniper from slopes) was adopted. Using the procedures outlined in the EPA "Paired Watershed Study Design", the data collected from the Coryell Creek paired watersheds cannot be used to infer a BMP effect due to the high variation in paired runoff observations between the control and treatment watersheds. A sample size of 12 pairs from Pre BMP and 11 pairs Post BMP is insufficient to detect differences between Pre BMP and Post BMP runoff of less than 80%.

- Placing the treated watershed within the control watershed of the Bullard Creek pair violates the procedures outlined in the EPA "Paired Watershed Study Design" making statistical comparisons using this method impossible.

- A number of other factors may have contributed to these results including: natural variation in weather patterns, soil types and moisture conditions, vegetative cover, stormwater infiltration, and subsurface geology.

References:

Clausen, J. C. and J. Spooner. 1993. Paired watershed study design, United States Environmental Protection Agency publication number 841-F-93-009. EPA Office of Water, Washington D.C.

Dahlgren R. A., K. W. Tate, D. J. Lewis, E. R. Atwill, J. M. Harper, and B. H. Allen-Diaz, 2001. Watershed research examines rangeland management effects on water quality. California Agriculture. 55(6):64-71.

Schilling, K. E. and C. A. Thompson. 2000. Walnut Creek watershed monitoring project, Iowa: Monitoring water quality response to prairie restoration. Journal of the American Water Resources Association. 36(5):1101-1114.

Wilcox, B. P. 2002. Shrub control and streamflow on rangelands: A process based viewpoint. Journal of Range Management. 55(4):318-326.

Appendix 1

Cooperators and Stakeholders

Cooperators/Stakeholders:

Steve Manning,
Central Texas Cattleman's Association
Gatesville, TX

Mike McMurrey
Texas Department of Agriculture
Austin Texas

Ned Miester
Texas Farm Bureau

Kirby Brown
Texas Parks and Wildlife

David Langford
Texas Wildlife Association

David Wolfe
Environmental Defense

Jeff Weigle
Natures Conservatory of Texas

Homer Sanchez
Grazing Lands Conservation Initiative

Bob McCan
Texas and Southwestern Cattle Raisers

Appendix 2

Channel Surveys and
Stage / Discharge Curves

Leon River Revegetation Project

Primary device and open channel surveys - 20 June, 2002
Surveyed by June Wolfe, Pam Ellis
All measurements in feet

Coryell Creek Paired Watersheds

Station 1 - Cook

Measuring Device - Round culvert

Diameter	3.00
Length	22.50
Inflow elevation	7.42
Outflow elevation	7.84
Slope (%)	1.8667

Station 2 - Sutton

Measuring Device - Stream cross section

Station	Elevation	Corrected
1	4.98	99.77
7	5.00	99.75
10	5.25	99.50
13	5.72	99.03
16	6.68	98.07
21	9.42	95.33
22	9.85	94.90
23	10.32	94.43
24	11.22	93.53
25	11.25	93.50
26	11.15	93.60
27	11.00	93.75
28	10.85	93.90
29	10.75	94.00
30	10.70	94.05
31	10.60	94.15
32	10.10	94.65
33	9.52	95.23
34	9.10	95.65
35	8.25	96.50
36	7.80	96.95
37	7.28	97.47
38	6.70	98.05
39	6.68	98.07
40	5.75	99.00
41	5.30	99.45
45	4.75	100.00
Bubble Outlet	11.02	93.73
Upstream	10.60	94.15
Downstream	11.60	93.15
Run Distance	95.00	
Slope	1.0526	

Leon River Revegetation Project

Primary device and open channel surveys - 20 June, 2002
Surveyed by June Wolfe, Pam Ellis
All measurements in feet

Bullard Creek Paired Watersheds

Station 3 - Hall

Measuring Device - Stream cross section

Station	Elevation	Corrected
1	2.43	100.00
7	2.62	99.81
12	2.93	99.50
17	3.45	98.98
22	3.95	98.48
27	4.14	98.29
30	4.40	98.03
31	4.58	97.85
32	4.81	97.62
33	5.12	97.31
34	5.27	97.16
35	5.65	96.78
36	6.20	96.23
37	6.43	96.00
38	7.00	95.43
39	7.50	94.93
40	8.15	94.28
41	8.34	94.09
42	8.27	94.16
43	8.13	94.30
44	7.82	94.61
45	7.40	95.03
465	6.85	95.58
47	6.52	95.91
48	5.85	96.58
49	5.42	97.01
50	4.44	97.99
51	4.10	98.33
53	3.98	98.45
56	3.97	98.46
Bubble	7.90	94.53
Upstream	8.16	94.27
Downstream	8.40	94.03
Run Distanc	61	
Slope	0.3934	

Station 4 - TX HWY 183

Measuring Device - Rectangular culvert

Height	6.00
Width	18.00
Length	46.00
Bubble	16.23
Upstream	15.81
Downstream	16.65
Downstream*	16.85
Slope	1.8261
Slope*	0.913043

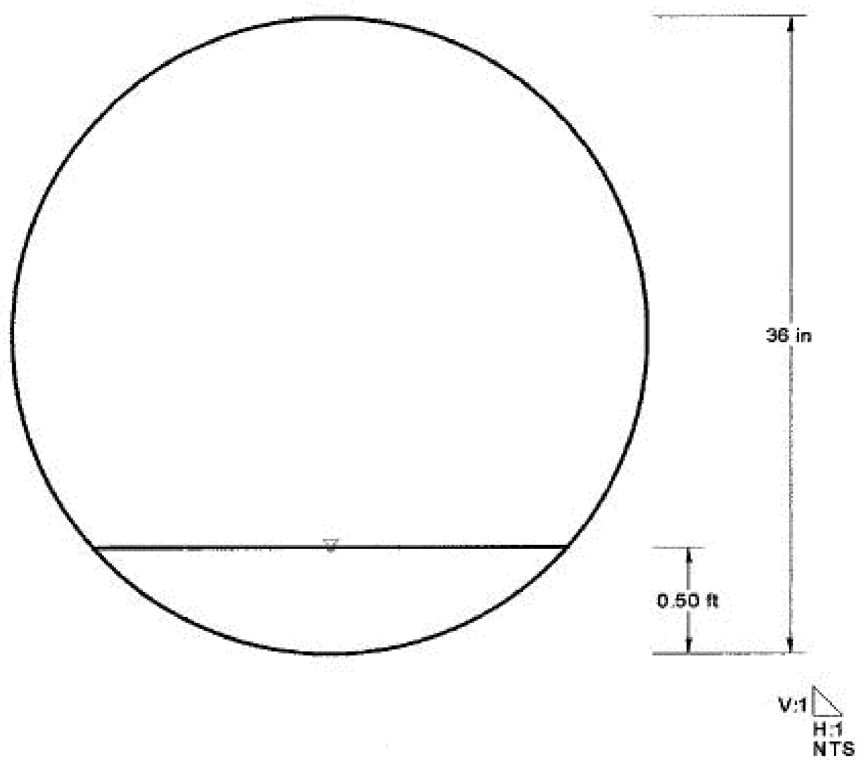
Downstream*
Water ponds below culvert at this location. This measurement reflects stream channel elevation about 100 feet below culvert.

Slope*
Assume bubble outlet is zero.

Cross Section
Cross Section for Circular Channel

Project Description	
Worksheet	Station 1 - Coo
Flow Element	Circular Chann
Method	Manning's Forr
Solve For	Discharge

Section Data		
Mannings Coeffic	0.013	
Slope	018667	ft/ft
Depth	0.50	ft
Diameter	36	in
Discharge	5.50	cfs

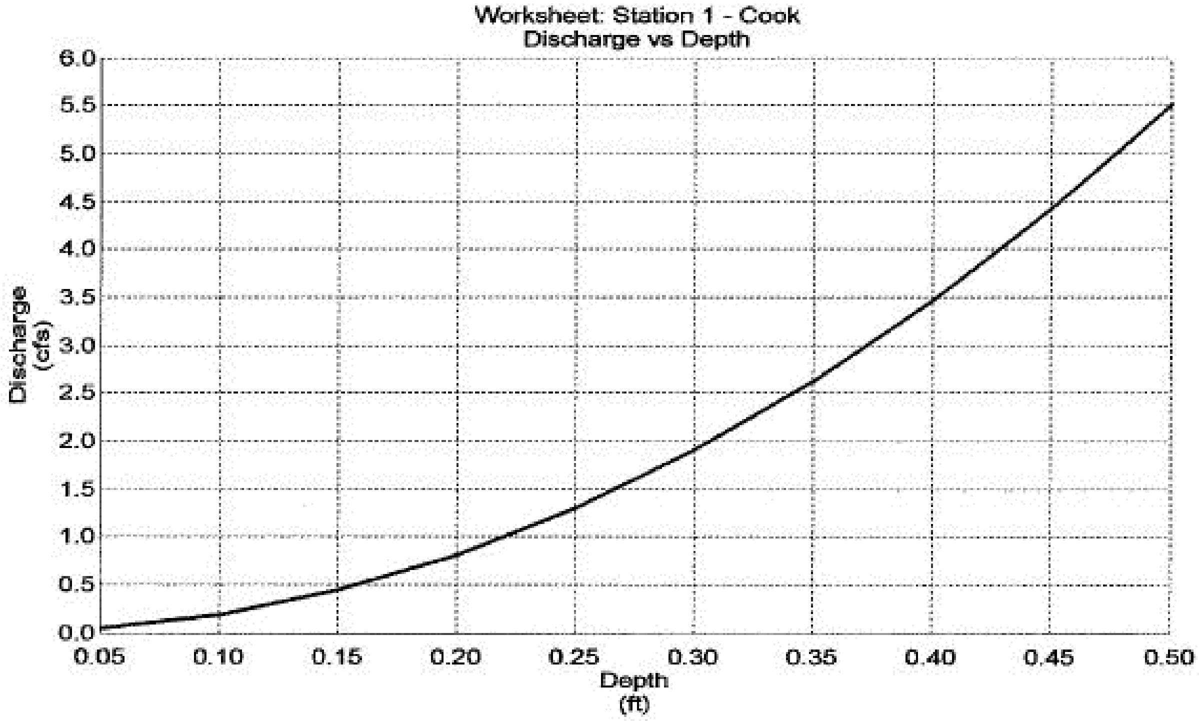


Curve
Plotted Curves for Circular Channel

Project Description	
Worksheet	Station 1 - Coo
Flow Element	Circular Chann
Method	Manning's Forr
Solve For	Discharge

Input Data		
Mannings Coeffic	0.013	
Slope	018667	ft/ft
Diameter	36	in

Attribute	Minimum	Maximum	Increment
Depth (ft)	0.00	0.50	0.05



Project Engineer: June Wolfe, III
c:\leon\surveys\leon river restoration project.fm2 Texas A&M Univ. / TAES / Blackland Research Center FlowMaster v6.0 [614b]
01/21/03 03:41:30 PM © Haestad Methods, Inc. 37 Brookside Road Waterbury, CT 06708 USA (203) 755-1666 Page 1 of 1

Table
Rating Table for Circular Channel

Project Description	
Worksheet	Station 1 - Coo
Flow Element	Circular Chann
Method	Manning's Forr
Solve For	Discharge

Input Data		
Mannings Coeffic	0.013	
Slope	018667	ft/ft
Diameter	36	in

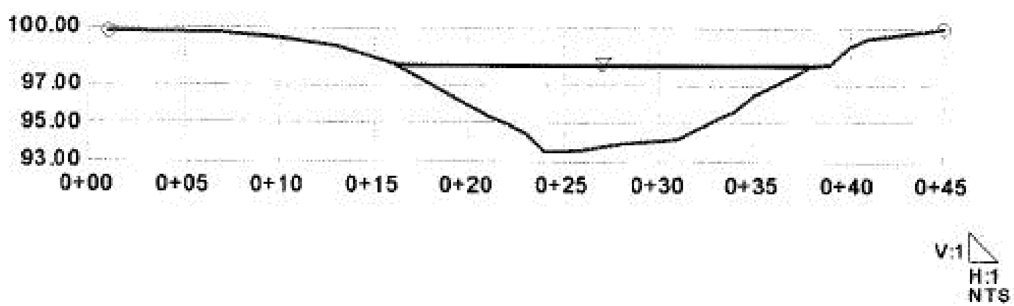
Attribute	Minimum	Maximum	Increment
Depth (ft)	0.00	0.50	0.05

Depth (ft)	Discharge (cfs)	Velocity (ft/s)	Flow Area (ft²)	Wetted Perimeter (ft)	Top Width (ft)
0.00	N/A	N/A	N/A	N/A	N/A
0.05	0.04	1.61	2.6e-2	0.78	0.77
0.10	0.18	2.54	0.1	1.10	1.08
0.15	0.44	3.31	0.1	1.35	1.31
0.20	0.81	3.99	0.2	1.57	1.50
0.25	1.30	4.60	0.3	1.76	1.66
0.30	1.90	5.17	0.4	1.93	1.80
0.35	2.63	5.70	0.5	2.09	1.93
0.40	3.47	6.19	0.6	2.24	2.04
0.45	4.43	6.66	0.7	2.39	2.14
0.50	5.50	7.11	0.8	2.52	2.24

Station 2 - Sutton Channel Cross Section
Cross Section for Irregular Channel

Project Description	
Worksheet	Station 2 - Suttc
Flow Element	Irregular Chann
Method	Manning's Forr
Solve For	Discharge

Section Data		
Mannings Coefficier	0.040	
Slope	0.010526	ft/ft
Water Surface Elev.	98.00	ft
Elevation Range	.50 to 100.00	
Discharge	415.07	cfs



Curve
Plotted Curves for Irregular Channel

Project Description	
Worksheet	Station 2 - Suttc
Flow Element	Irregular Chann
Method	Manning's Forr
Solve For	Discharge

Input Data		
Slope	010526	ft/ft

Options	
Current Roughness Methc	›ved Lotter's Method
Open Channel Weighting	›ved Lotter's Method
Closed Channel Weightinç	Horton's Method

Attribute	Minimum	Maximum	Increment
Water Surface Elevat	93.50	98.00	0.05

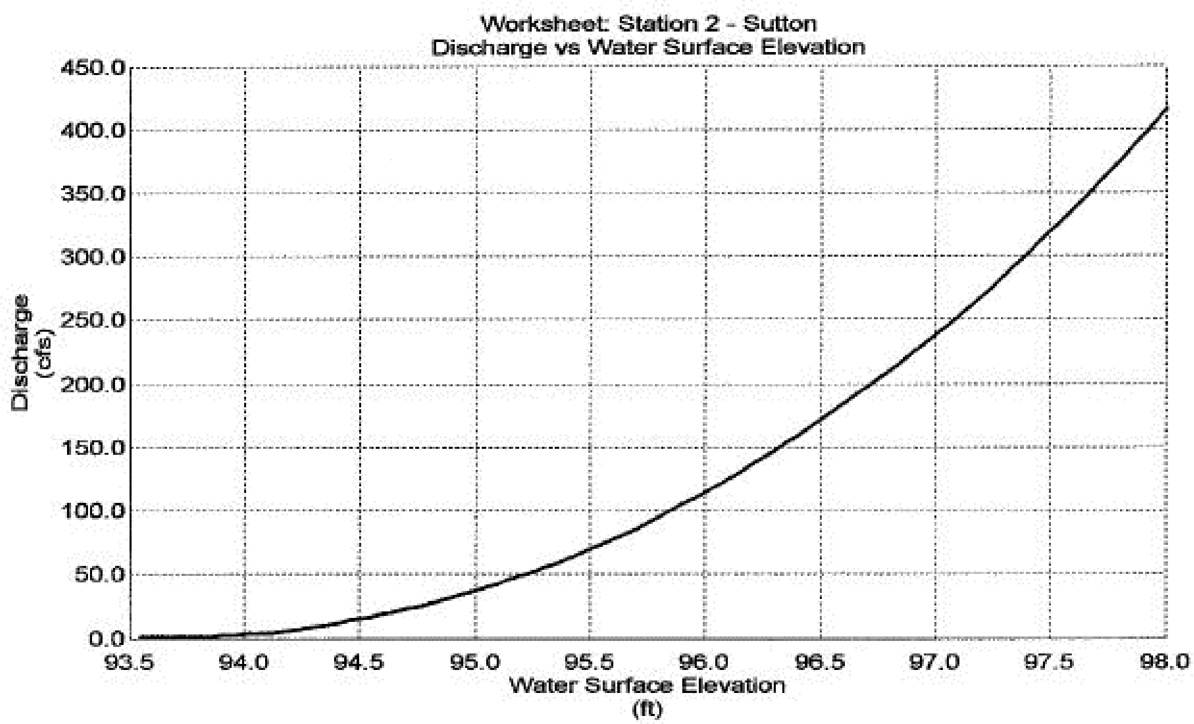


Table
Rating Table for Irregular Channel

Project Description	
Worksheet	Station 2 - Suttc
Flow Element	Irregular Chann
Method	Manning's Forn
Solve For	Discharge

Input Data		
Slope	010526	ft/ft

Options	
Current Roughness Methc	oved Lotter's Method
Open Channel Weighting	oved Lotter's Method
Closed Channel Weightinç	Horton's Method

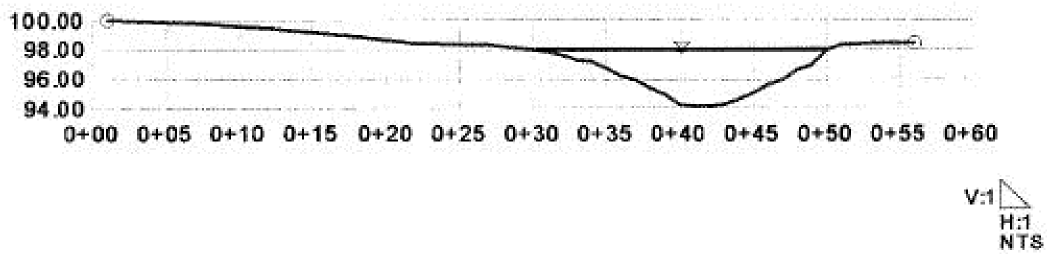
Attribute	Minimum	Maximum	Increment
Water Surface Elevat	93.50	94.50	0.05

Water Surface Elevation (ft)	Discharge (cfs)	Velocity (ft/s)	Flow Area (ft²)	Wetted Perimeter (ft)	Top Width (ft)
93.50	N/A	N/A	N/A	N/A	N/A
93.55	0.02	0.36	4.8e-2	1.53	1.52
93.60	0.09	0.62	0.1	2.11	2.08
93.65	0.21	0.82	0.3	2.52	2.47
93.70	0.38	0.98	0.4	2.93	2.86
93.75	0.60	1.13	0.5	3.35	3.24
93.80	0.89	1.25	0.7	3.76	3.63
93.85	1.23	1.37	0.9	4.17	4.02
93.90	1.65	1.48	1.1	4.58	4.41
93.95	2.09	1.56	1.3	5.16	4.97
94.00	2.62	1.63	1.6	5.74	5.52
94.05	3.12	1.63	1.9	6.81	6.58
94.10	3.89	1.73	2.3	7.39	7.13
94.15	4.77	1.82	2.6	7.97	7.69
94.20	5.91	1.96	3.0	8.15	7.84
94.25	7.15	2.10	3.4	8.34	8.00
94.30	8.49	2.23	3.8	8.53	8.16
94.35	9.93	2.35	4.2	8.71	8.31
94.40	11.47	2.47	4.6	8.90	8.47
94.45	13.08	2.58	5.1	9.10	8.64
94.50	14.77	2.68	5.5	9.33	8.85

Cross Section
Cross Section for Irregular Channel

Project Description	
Worksheet	Station 3 - Hall
Flow Element	Irregular Chan
Method	Manning's For
Solve For	Discharge

Section Data	
Mannings Coefficier	0.030
Slope	0.003934 ft/ft
Water Surface Elev	98.00 ft
Elevation Range	.09 to 100.00
Discharge	195.88 cfs



c:\leon\surveys\leon river restoration project.fm2 Texas A&M Univ. / TAES / Blackland Research Center
01/21/03 04:11:32 PM © Haestad Methods, Inc. 37 Brookside Road Waterbury, CT 06708 USA (203) 755-1666

Project Engineer: June Wolfe, III
FlowMaster v6.0 [614b]
Page 1 of 1

Curve
Plotted Curves for Irregular Channel

Project Description	
Worksheet	Station 3 - Hall
Flow Element	Irregular Chanr
Method	Manning's Forr
Solve For	Discharge

Input Data		
Slope	003934	ft/ft

Options	
Current Roughness Methc	ɔved Lotter's Method
Open Channel Weighting	ɔved Lotter's Method
Closed Channel Weighting	Horton's Method

Attribute	Minimum	Maximum	Increment
Water Surface Elevat	94.09	98.00	0.50

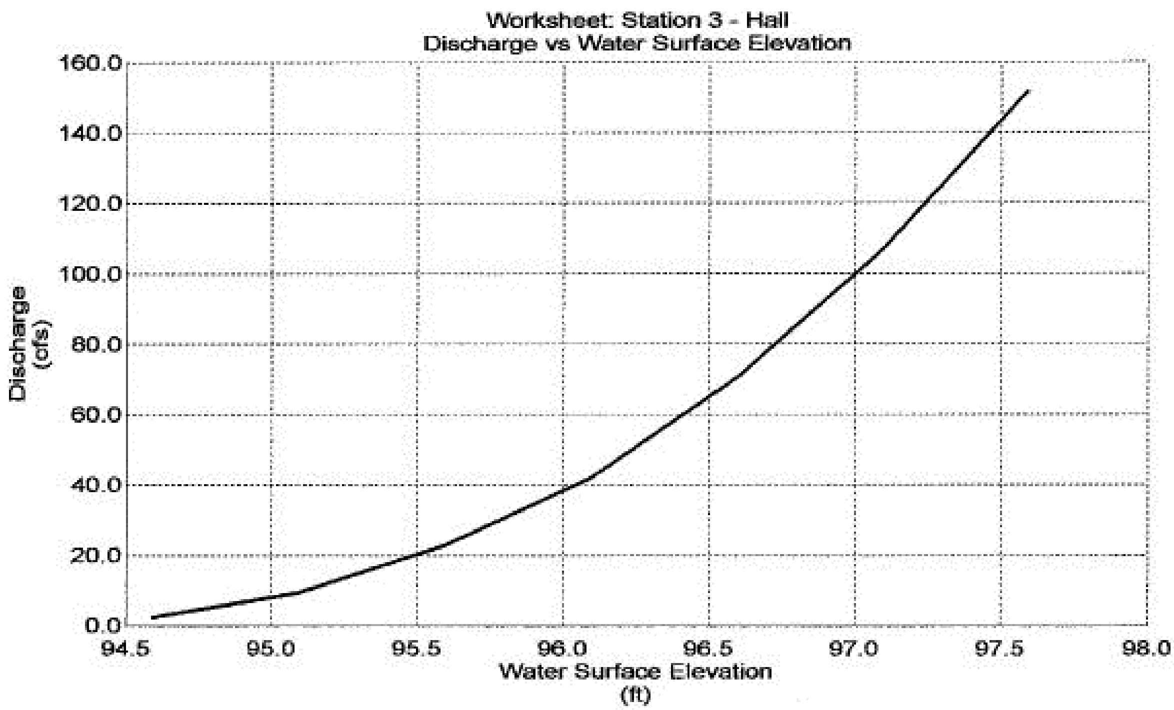


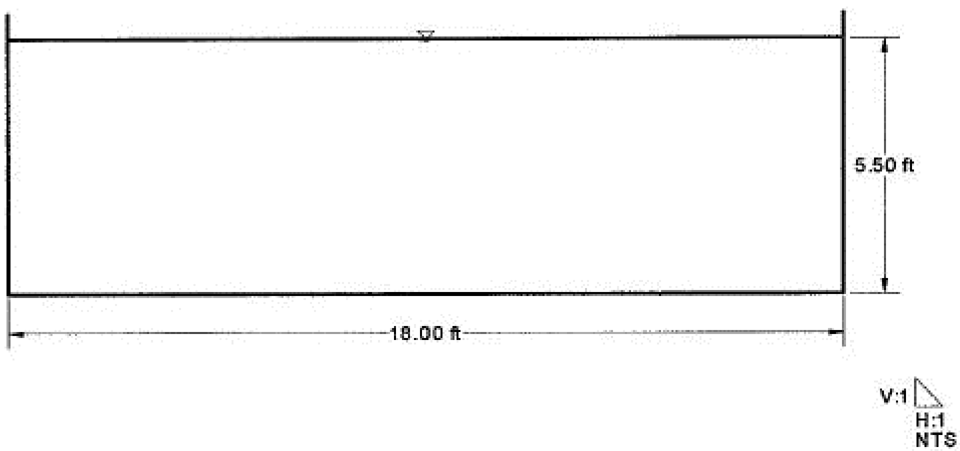
Table
Rating Table for Irregular Channel

Water Surface Elevation (ft)	Discharge (cfs)	Velocity (ft/s)	Flow Area (ft²)	Wetted Perimeter (ft)	Top Width (ft)
97.10	107.02	4.19	25.5	16.31	14.93
97.20	115.09	4.25	27.1	16.89	15.46
97.30	122.61	4.28	28.6	17.71	16.23
97.40	132.05	4.36	30.3	18.22	16.69
97.50	142.07	4.44	32.0	18.70	17.11
97.60	152.52	4.52	33.7	19.18	17.54
97.70	162.97	4.59	35.5	19.75	18.05
97.80	173.79	4.66	37.3	20.34	18.59
97.90	184.78	4.71	39.2	20.99	19.19
98.00	195.88	4.76	41.2	21.71	19.66

Station 4 - HWY 183 Culvert Cross Section
Cross Section for Rectangular Channel

Project Description	
Worksheet	Station 4 - TX HW\
Flow Element	Rectangular Chanr
Method	Manning's Formula
Solve For	Discharge

Section Data		
Mannings Coeffic	0.015	
Slope	009130	ft/ft
Depth	5.50	ft
Bottom Width	18.00	ft
Discharge	,124.54	cfs



Curve

Plotted Curves for Rectangular Channel

Project Description	
Worksheet	Station 4 - TX HW\
Flow Element	Rectangular Chanr
Method	Manning's Formula
Solve For	Discharge

Input Data		
Mannings Coeffic	0.015	
Slope	009130	ft/ft
Bottom Width	18.00	ft

Attribute	Minimum	Maximum	Increment
Depth (ft)	0.00	5.50	0.50

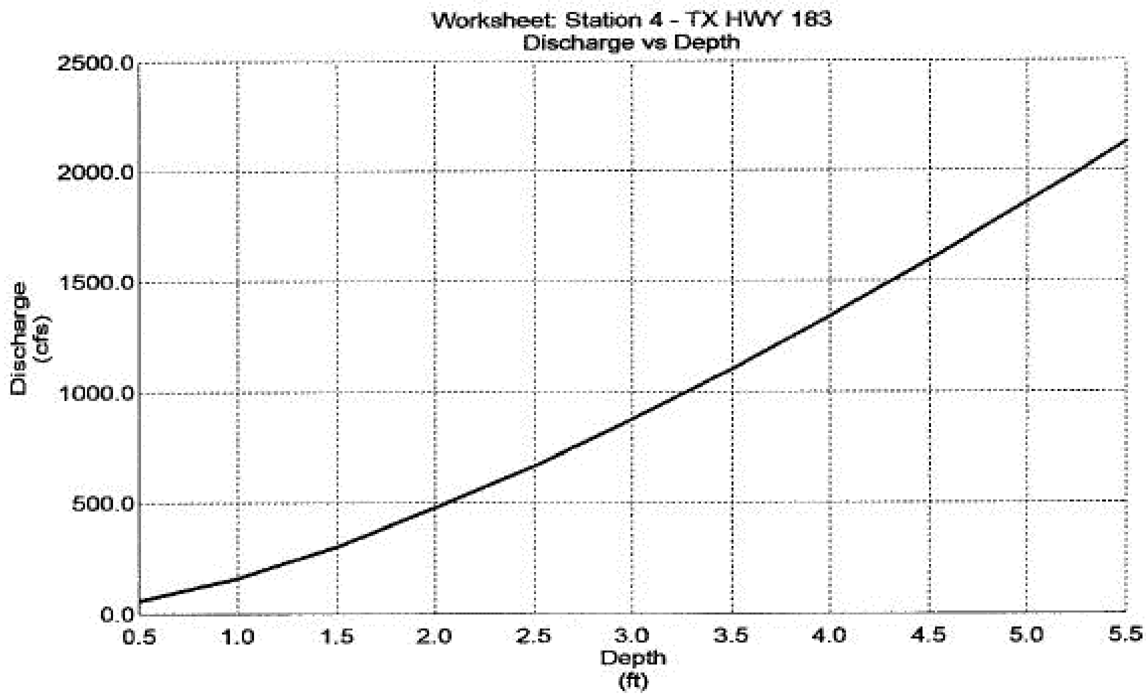


Table
Rating Table for Rectangular Channel

Project Description	
Worksheet	Station 4 - TX HWY
Flow Element	Rectangular Chanr
Method	Manning's Formula
Solve For	Discharge

Input Data		
Mannings Coeffic	0.015	
Slope	009130	ft/ft
Bottom Width	18.00	ft

Attribute	Minimum	Maximum	Increment
Depth (ft)	0.00	5.50	0.50

Depth (ft)	Discharge (cfs)	Velocity (ft/s)	Flow Area (ft^2)	Wetted Perimeter (ft)	Top Width (ft)
0.00	N/A	N/A	N/A	N/A	N/A
0.50	51.77	5.75	9.0	19.00	18.00
1.00	158.82	8.82	18.0	20.00	18.00
1.50	302.18	11.19	27.0	21.00	18.00
2.00	473.18	13.14	36.0	22.00	18.00
2.50	666.31	14.81	45.0	23.00	18.00
3.00	877.65	16.25	54.0	24.00	18.00
3.50	1,104.28	17.53	63.0	25.00	18.00
4.00	1,343.93	18.67	72.0	26.00	18.00
4.50	1,594.80	19.69	81.0	27.00	18.00
5.00	1,855.40	20.62	90.0	28.00	18.00
5.50	2,124.54	21.46	99.0	29.00	18.00

Appendix 3

Water Quality Data

LRP1 - Cook Ranch - Treated watershed – Total Suspended Solids (TSS)

Lab ID	Collect Date	ISCO Bottle	Process Date	TSS (mg/L)
3665	10/15/2001	01	10/17/2001	744
3708	11/15/2001	03	11/19/2001	32
3709	11/15/2001	06	11/19/2001	30
3710	11/15/2001	07	11/19/2001	44
3734	12/15/2001	01	12/18/2001	287
3735	12/15/2001	03	12/18/2001	255
3736	12/15/2001	07	12/18/2001	42
3863	7/2/2002	01	7/8/2002	458
3864	7/2/2002	02	7/8/2002	483
3865	7/2/2002	03	7/8/2002	251
3866	7/2/2002	04	7/8/2002	219
3867	7/2/2002	05	7/8/2002	151
3940	10/8/2002	01	10/17/2002	588
3941	10/8/2002	05	10/17/2002	738
3942	10/8/2002	09	10/17/2002	88
3970	12/8/2002	02	12/17/2002	31
3971	12/8/2002	04	12/17/2002	45
3972	12/8/2002	07	12/17/2002	35
3982	12/30/2002	01	1/6/2003	479
3983	12/30/2002	04	1/6/2003	170
3984	12/30/2002	08	1/6/2003	40
4048	6/5/2003	01	6/18/2003	2281
4049	6/5/2003	04	6/18/2003	679
4050	6/5/2003	09	6/18/2003	99
4069	6/15/2003	01	6/18/2003	2673
4070	6/15/2003	03	6/18/2003	1280
4071	6/15/2003	05	6/18/2003	605
4149	10/9/2003	01	10/29/2003	465
4150	10/9/2003	02	10/29/2003	555
4151	10/9/2003	10	10/29/2003	248
4152	10/9/2003	16	10/29/2003	31
4275	3/4/2004	01	3/25/2004	213
4276	3/4/2004	03	3/25/2004	204
4277	3/4/2004	07	3/25/2004	43
4330	4/6/2004	01	4/17/2004	3
4331	4/6/2004	04	4/17/2004	9
4332	4/6/2004	06	4/17/2004	8
4433	6/28/2004	01	7/5/2004	179
4434	6/28/2004	05	7/5/2004	178
4435	6/28/2004	09	7/5/2004	38
4630	11/17/2004	01	12/6/2004	55
4631	11/17/2004	04	12/6/2004	37
4632	11/17/2004	05	12/6/2004	22
4633	11/17/2004	16	12/6/2004	3
4634	11/17/2004	22	12/6/2004	20
4635	11/17/2004	24	12/6/2004	3

LRP2 - Sutton Ranch - Control watershed – Total Suspended Solids (TSS)

Lab ID	Sample Date	Sample Bottle	Process Date	TSS (mg/L)
3711	11/15/2001	06	11/19/2001	145
3712	11/15/2001	09	11/19/2001	345
3713	11/15/2001	11	11/19/2001	5
3737	12/15/2001	01	12/18/2001	54
3738	12/15/2001	05	12/18/2001	103
3739	12/15/2001	07	12/18/2001	7
3740	12/15/2001	16	12/18/2001	2
3817	4/8/2002	01	4/11/2002	93
3818	4/8/2002	02	4/11/2002	137
3819	4/8/2002	03	4/11/2002	51
3868	7/2/2002	01	7/8/2002	403
3869	7/2/2002	02	7/8/2002	64
3870	7/2/2002	03	7/8/2002	33
3871	7/2/2002	04	7/8/2002	7
3943	10/11/2002	01	10/17/2002	1328
3944	10/11/2002	02	10/17/2002	672
3945	10/11/2002	06	10/17/2002	26
3973	12/8/2002	01	12/17/2002	14
3974	12/8/2002	06	12/17/2002	17
3975	12/8/2002	10	12/17/2002	26
3985	12/30/2002	01	1/6/2003	127
3986	12/30/2002	02	1/6/2003	117
3987	12/30/2002	03	1/6/2003	117
4051	6/5/2003	01	6/18/2003	785
4052	6/5/2003	02	6/18/2003	207
4053	6/5/2003	03	6/18/2003	79
4153	6/5/2003	01	10/29/2003	473
4154	10/9/2003	06	10/29/2003	312
4155	10/9/2003	09	10/29/2003	21
4192	1/16/2004	01	1/23/2004	26
4193	1/16/2004	04	1/23/2004	12
4194	1/16/2004	06	1/23/2004	6
4238	2/24/2004	01	3/8/2004	19
4239	2/24/2004	05	3/8/2004	21
4240	2/24/2004	08	3/8/2004	24
4272	3/4/2004	12	3/25/2004	57
4273	3/4/2004	13	3/25/2004	50
4274	3/4/2004	17	3/25/2004	31
4327	3/15/2004	01	4/17/2004	15
4328	3/15/2004	02	4/17/2004	13
4329	3/15/2004	03	4/17/2004	16
4333	4/6/2004	23	4/17/2004	20
4334	4/6/2004	24	4/27/2004	9
4369	4/24/2004	01	5/3/2004	50
4370	4/24/2004	16	5/3/2004	45
4371	4/24/2004	20	5/3/2004	3

LRP2 (continued) - Sutton Ranch - Control watershed – Total Suspended Solids

Lab ID	Sample Date	Sample Bottle	Process Date	TSS (mg/L)
4389	5/1/2004	01	5/6/2004	74
4390	5/1/2004	02	5/6/2004	82
4391	5/1/2004	03	5/6/2004	75
4421	6/9/2004	01	7/5/2004	413
4422	6/9/2004	03	7/5/2004	227
4423	6/9/2004	05	7/5/2004	51
4436	6/28/2004	01	7/5/2004	939
4437	6/28/2004	02	7/5/2004	461
4438	6/28/2004	03	7/5/2004	215

LRP3 - Hunt Ranch - Treated watershed – Total Suspended Solids

Lab ID	Sample Date	Sample Bottle	Process Date	TSS (mg/L)
3731	12/8/2001	01	12/13/2001	383
3732	12/8/2001	03	12/13/2001	1399
3733	12/8/2001	05	12/13/2001	304
3742	12/16/2001	03	12/18/2001	998
3743	12/16/2001	08	12/18/2001	142
3741	12/19/2001	01	12/18/2001	260
3760	1/31/2002	02	2/25/2002	1174
3761	1/31/2002	03	2/25/2002	336
3768	2/5/2002	06	2/25/2002	98
3769	2/5/2002	10	2/25/2002	163
3770	2/5/2002	13	2/25/2002	18
3820	4/7/2002	01	4/11/2002	89
3821	4/7/2002	02	4/11/2002	76
3838	6/17/2002	01	6/18/2002	846
3901	7/3/2002	01	7/9/2002	153
3902	7/3/2002	02	7/9/2002	1176
3903	7/3/2002	07	7/9/2002	23
3904	7/5/2002	08	7/9/2002	318
3905	7/5/2002	09	7/9/2002	1243
3906	7/5/2002	11	7/9/2002	130
4156	10/10/2003	01	10/29/2003	360
4157	10/10/2003	02	10/29/2003	973
4158	10/10/2003	04	10/29/2003	119
4363	4/24/2004	01	4/27/2004	187
4364	4/24/2004	02	4/27/2004	264
4365	4/24/2004	03	4/27/2004	128
4430	6/25/2004	01	7/5/2004	293
4431	6/25/2004	02	7/5/2004	229
4432	6/25/2004	03	7/5/2004	966
4459	6/28/2004	01	7/5/2004	357
4460	6/28/2004	02	7/5/2004	403
4461	6/28/2004	03	7/5/2004	162
4465	6/30/2004	11	7/5/2004	83
4466	6/30/2004	12	7/5/2004	15
4467	6/30/2004	13	7/5/2004	12
4527	9/6/2004	01	9/15/2004	144
4528	9/6/2004	02	9/15/2004	412
4529	9/6/2004	03	9/15/2004	141
4636	11/17/2004	11	12/6/2004	93
4637	11/17/2004	12	12/6/2004	758
4638	11/17/2004	13	12/6/2004	66
4680	11/22/2004	01	12/20/2004	317
4681	11/22/2004	02	12/20/2004	307
4682	11/22/2004	03	12/20/2004	83

LRP4 - HWY 183 Crossing - Control watershed – Total Suspended Solids

Lab ID	Sample Date	Sample Bottle	Process Date	TSS (mg/L)
3907	7/3/2002	04	7/9/2002	179
3908	7/3/2002	05	7/9/2002	346
3909	7/3/2002	06	7/9/2002	606
3910	7/3/2002	10	7/9/2002	153
3872	7/5/2002	01	7/8/2002	430
3873	7/5/2002	02	7/8/2002	607
4159	10/10/2003	01	10/29/2003	560
4160	10/10/2003	03	10/29/2003	237
4161	10/10/2003	05	10/29/2003	206
4366	4/24/2004	01	4/27/2004	185
4367	4/24/2004	02	4/27/2004	156
4368	4/24/2004	03	4/27/2004	410
4462	6/28/2004	01	7/5/2004	98
4463	6/28/2004	04	7/5/2004	737
4464	6/30/2004	09	7/5/2004	60
4508	8/24/2004	01	8/26/2004	241
4509	8/24/2004	02	8/26/2004	508
4510	8/24/2004	03	8/26/2004	349
4530	9/6/2004	01	9/15/2004	67
4531	9/6/2004	02	9/15/2004	62
4532	9/6/2004	03	9/15/2004	56
4639	11/17/2004	12	12/6/2004	47
4640	11/17/2004	13	12/6/2004	353
4641	11/17/2004	14	12/6/2004	163
4683	11/22/2004	01	12/20/2004	57
4684	11/22/2004	02	12/20/2004	400
4685	11/22/2004	03	12/20/2004	228

Leon River Revegetation Project Water Quality Data - Dissolved Nutrients

Lab ID	Watershed	Collect Date	ISCO Bottle	Process Date	$N\text{-}NO_3$ (mg/L)	$P\text{-}PO_4$ (mg/L)
3665	LRP1 - Treated	10/15/2001	01	10/17/2001	0.12	0.00
3734	LRP1 - Treated	12/15/2001	01	12/18/2001	0.21	0.00
3735	LRP1 - Treated	12/15/2001	03	12/18/2001	0.03	0.00
3736	LRP1 - Treated	12/15/2001	07	12/18/2001	0.07	0.00
3863	LRP1 - Treated	7/2/2002	01	7/8/2002	0.00	0.00
3864	LRP1 - Treated	7/2/2002	02	7/8/2002	0.00	0.00
3865	LRP1 - Treated	7/2/2002	03	7/8/2002	0.00	0.00
3866	LRP1 - Treated	7/2/2002	04	7/8/2002	0.00	0.00
3867	LRP1 - Treated	7/2/2002	05	7/8/2002	0.00	0.00
3737	LRP2 - Control	12/15/2001	01	12/18/2001	0.11	0.05
3738	LRP2 - Control	12/15/2001	05	12/18/2001	0.56	0.01
3739	LRP2 - Control	12/15/2001	07	12/18/2001	0.51	0.00
3740	LRP2 - Control	12/15/2001	16	12/18/2001	0.42	0.00
3817	LRP2 - Control	4/7/2002	01	4/11/2002	0.37	0.07
3818	LRP2 - Control	4/7/2002	02	4/11/2002	0.41	0.07
3819	LRP2 - Control	4/7/2002	03	4/11/2002	0.54	0.07
3868	LRP2 - Control	7/2/2002	01	7/8/2002	0.00	0.06
3869	LRP2 - Control	7/2/2002	02	7/8/2002	0.00	0.07
3870	LRP2 - Control	7/2/2002	03	7/8/2002	0.00	0.08
3871	LRP2 - Control	7/2/2002	04	7/8/2002	0.00	0.07
3731	LRP3 - Treated	12/8/2001	01	12/13/2001	0.36	0.00
3732	LRP3 - Treated	12/8/2001	03	12/13/2001	0.24	0.03
3733	LRP3 - Treated	12/8/2001	05	12/13/2001	0.23	0.03
3742	LRP3 - Treated	12/16/2001	03	12/18/2001	0.12	0.00
3743	LRP3 - Treated	12/16/2001	08	12/18/2001	0.13	0.00
3741	LRP3 - Treated	12/19/2001	01	12/18/2001	0.25	0.00
3820	LRP3 - Treated	4/7/2002	01	4/11/2002	0.81	0.00
3821	LRP3 - Treated	4/7/2002	02	4/11/2002	0.82	0.00
3872	LRP4 - Control	7/5/2002	01	7/8/2002	0.41	0.00
3873	LRP4 - Control	7/5/2002	02	7/8/2002	0.00	0.00