Assessment of Preexisting and Post-Implementation Effects for the North Bosque River Watershed: Clean Water Act Section 319 Report

Project Report

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PR0602

August 2006

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Acknowledgments

This report presents the results of two concurrent projects entitled *Technical and Financial Assistance to Dairy Producers and Landowners of the North Bosque River Watershed within the Cross-Timbers Soil and Water Conservation District* and *Technical and Financial Assistance to Dairy Producers and Landowners of the North Bosque River Watershed within the Upper Leon Soil and Water Conservation District*. Financial support for these projects was provided under Section 319(h) of the Clean Water Act via the Texas State Soil and Water Conservation Board (TSSWCB) in cooperation with the United States Environmental Protection Agency, Region 6 as TSSWCB projects 01-13 and 01-14. Matching funds were provided by the State of Texas through the Texas Institute for Applied Environmental Research (TIAER) at Tarleton State University in Stephenville, Texas. Preliminary analyses of some of the data presented in this report are presented in the TIAER reports TR0410 by Bekele and McFarland (2004a) and TR0510 by McFarland et al. (2005) that were funded under the Composting Support Project in the Bosque River Watershed through the TSSWCB.

The authors would also like to acknowledge the dedicated work of the field personnel and laboratory chemists, particularly since monitoring nonpoint source pollution associated with storm events requires personnel to be on call seven days a week.

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TSSWCB 013&014

Abstract

This project provided assessment activities in the North Bosque River watershed to support the Texas State Soil and Water Conservation Board and local Soil and Water Conservation Districts in efforts to reduce agricultural nonpoint source pollution loadings. These assessment activities were in response to a total maximum daily load (TMDL) for soluble reactive phosphorus for segments 1226 (North Bosque River) and 1255 (Upper North Bosque River). Preexisting and post-implementation conditions were assessed to help target areas where agricultural producer assistance for improved management practices might best help reduce phosphorus loadings to the North Bosque River. Dairy waste application fields were indicated in the TMDL as the primary nonpoint source of soluble reactive phosphorus to the North Bosque River. To assess improvements in water quality, 19 monitoring sites were established in the upper third of the watershed, where most of the dairy operations are located. Although the focus of the monitoring was on contributions from dairy waste application fields, these sites represented a diversity of land uses within the watershed to allow a comparison between impacted and lesser impacted locations. These sampling sites represented fairly small watershed areas ranging from about 500 to 12,000 hectares. Relatively small watershed sizes were selected for monitoring to allow better targeting of land owners and because changes in land management were expected to become apparent more quickly in smaller than in larger watershed areas.

Although a focus of the project was on the updating and development of water quality management plan (WQMPs), for a variety of reasons, including litigation occurring between the City of Waco and the Dairy Industry, the adoption of WQMPs and comprehensive nutrient management plans (CNMPs) was very limited during the project. The primary practice that could be evaluated in association with water quality improvements during the post-implementation period of the TMDL was manure hauling via the Dairy Manure Export Support (DMES) project associated with Composted Manure Incentive Project. In evaluating the assessment data of storm water quality, the concentration of nutrients and total suspended solids were positively correlated with the amount of land associated with dairy waste application fields and negatively correlated to the amount of land associated with wood/range. This indicated that for the sites evaluated dairy waste application fields were most likely a dominant source of nonpoint source pollution and that watersheds with more wood/range generally had less land associated with dairy waste application fields, thus, less nutrient runoff. With regard to manure hauled in association with the manure composting program, seven watersheds with a range of dairying activity and participation in the manure haul-off program were evaluated “before” and “after” implementation of the program. At the three sites with the largest amount of manure haul-off on a cow per unit area basis, significant decreases were seen in phosphorus concentrations associated with storm events. Improvements for these three sites varied from about 16 to 25 percent over the four years of the program. While the monitoring data collected to date shows some improvement in water quality, monitoring is continuing under a separate project for at least the next two years for continuing assessment of improvements. It is anticipated that more nutrient

management practices will be implemented in the next two years and improvement in water quality will become even more apparent.

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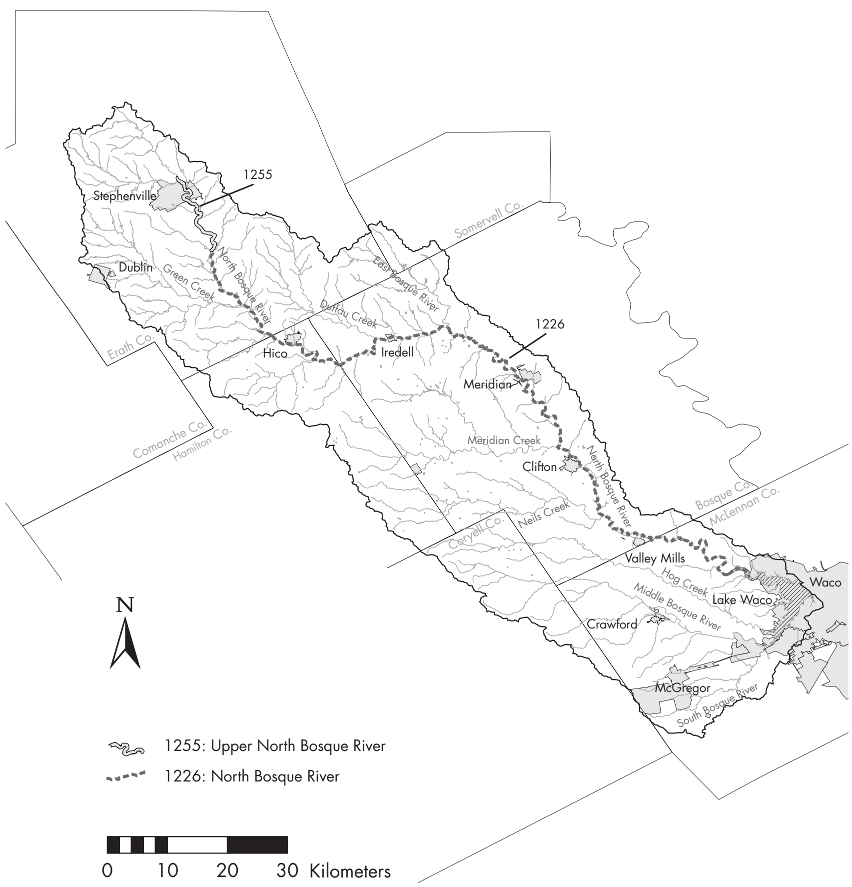
CHAPTER 1

Introduction

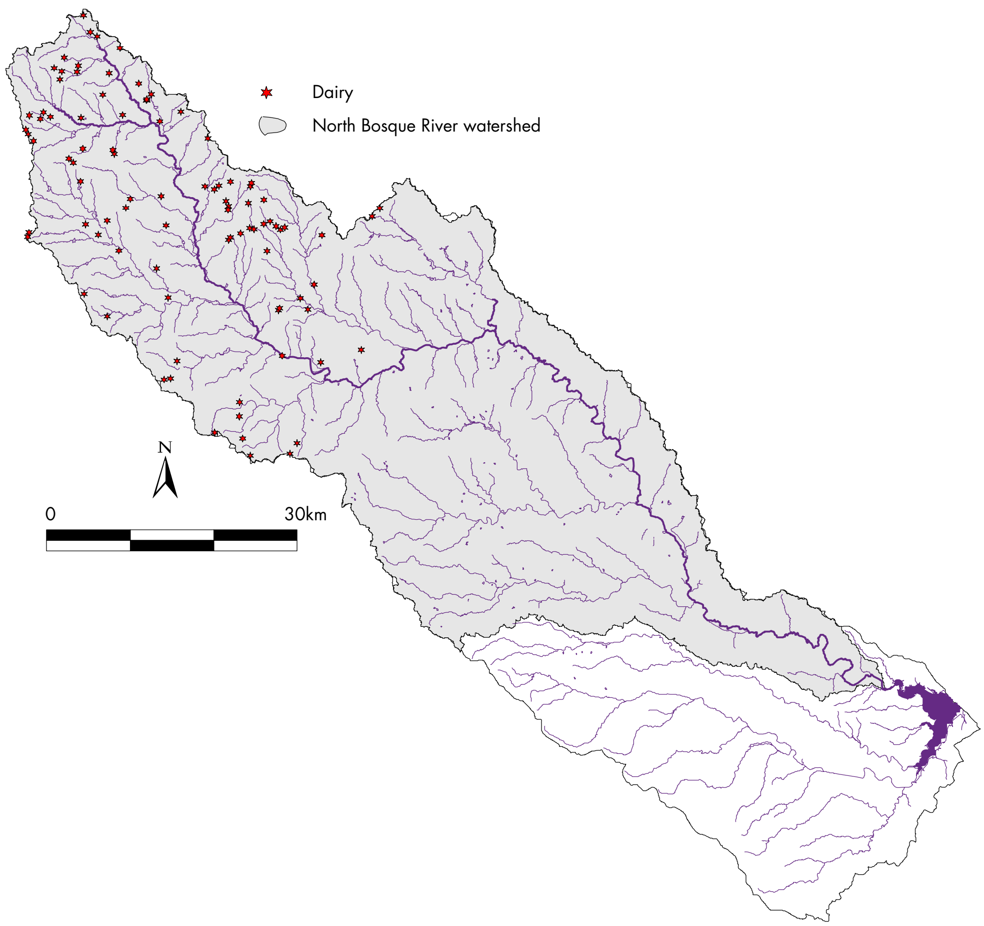
The basis for this project was to provide assessment activities in the North Bosque River watershed to support the Texas State Soil and Water Conservation Board (TSSWCB) and local Soil and Water Conservation Districts (SWCDs) in efforts to reduce agricultural nonpoint source (NPS) pollution loadings. In 2001, a total maximum daily load (TMDL) for soluble reactive phosphorus (SRP) was approved for segments 1226 (North Bosque River) and 1255 (Upper North Bosque River) of the North Bosque River (Figure 1; TNRCC, 2001). The North Bosque River is located within the Brazos River Basin in north-central Texas. The North Bosque River extends from Erath County, where its headwaters initiate just north of the city of Stephenville, to Waco, Texas where the river enters into Lake Waco.

Figure 1 Classified stream segments along the North Bosque River.



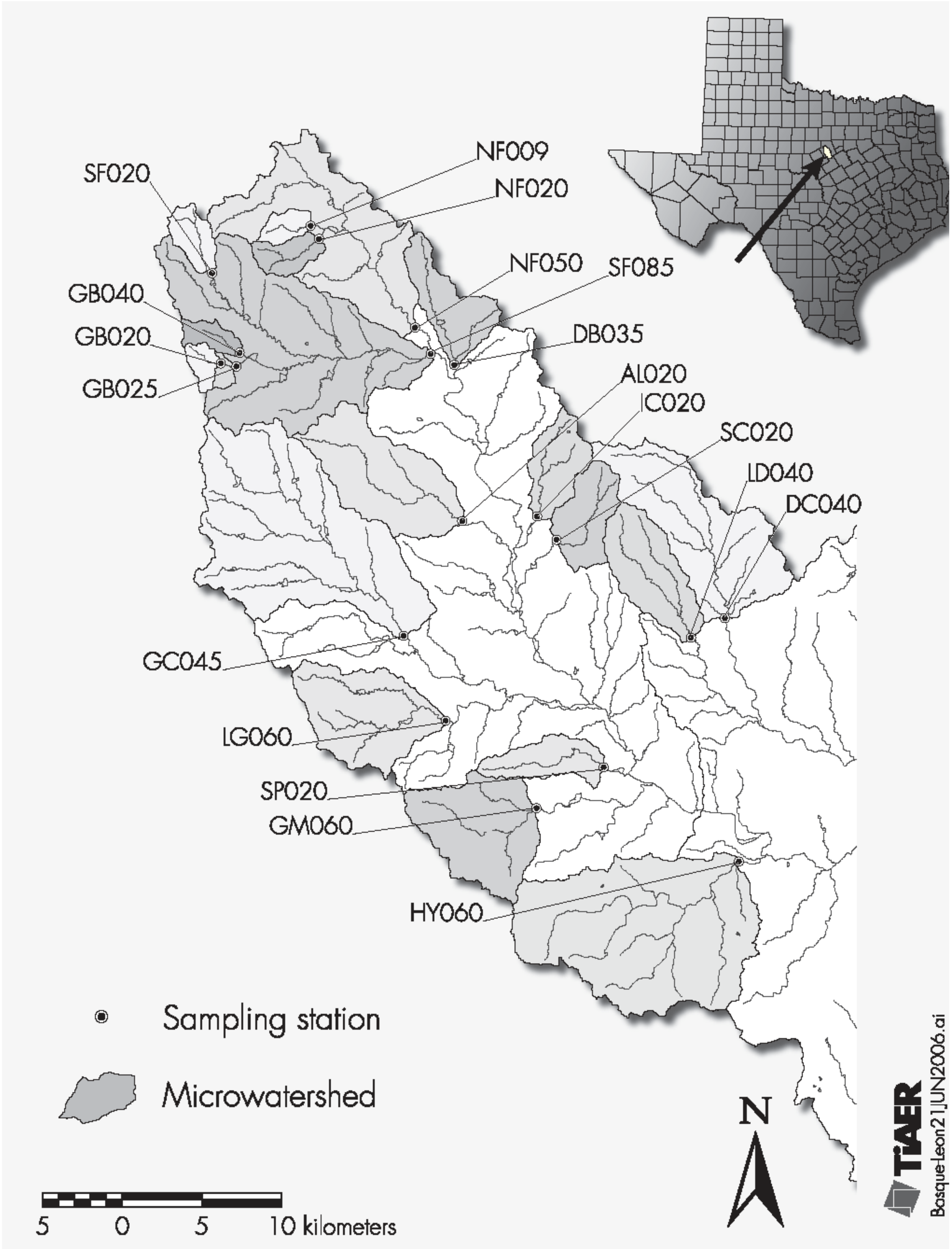
Within the TMDL, runoff from dairy waste application fields was identified as the most controllable nonpoint source contributing SRP to the North Bosque River. As of October 2004, 84 dairies were active in the North Bosque River watershed comprising about 38,000 total cows in confinement based on Texas Commission on Environmental Quality (TCEQ) inspection numbers. Most of these dairies are located within the upper third of the watershed (Figure 2).

Figure 2 Location of dairies within the North Bosque River watershed.



In order to better target and address potential agricultural sources of nonpoint source pollution, this project was incorporated into the TMDL Implementation Plan for the overall Watershed Action Plan (WAP) for the North Bosque River Basin (TCEQ and TSSWCB, 2002). Both routine grab and storm monitoring was conducted at 19 microwatershed sites (Figure 3). A microwatershed approach was used with regard to water quality monitoring to help target areas where agricultural producer assistance for best management practice (BMP) implementation might best help reduce phosphorus loadings to the North Bosque River. As indicated in the North Bosque River TMDL Implementation Plan, monitoring at the microwatershed level should enable more precise identification of areas with waste management problems or inadequacies and better target efforts for improvements.

Figure 3 Location of sampling sites showing delineation of microwatersheds.

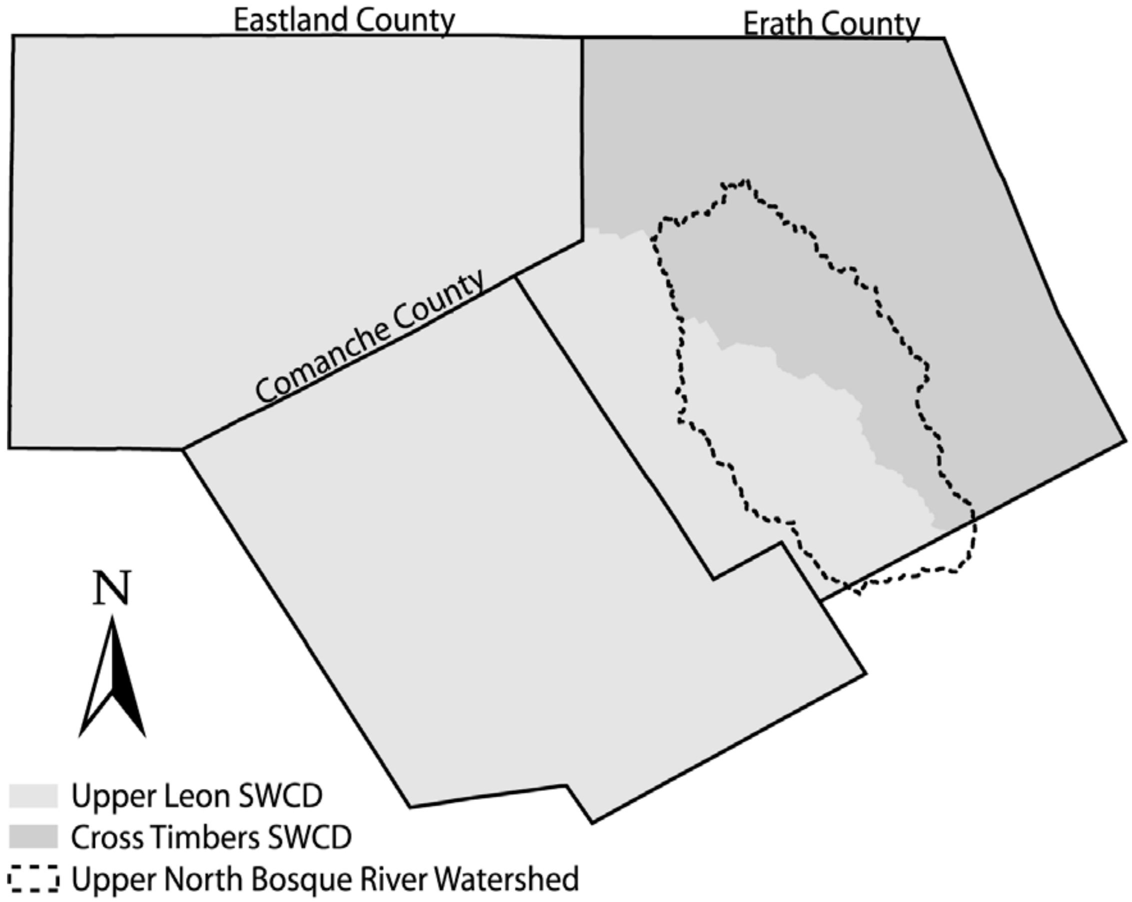


As the lead agency for the State of Texas for the abatement of agricultural NPS pollution, the TSSWCB works closely with local SWCDs to reduce NPS pollution. The TSSWCB addresses the prevention or abatement of NPS pollution from various agricultural activities through the Water Quality Management Plan (WQMP) Program. A certified WQMP is a site-specific plan that includes appropriate land-treatment practices, production practices, technologies and combinations thereof, and an implementation schedule. The TSSWCB is also involved with the development and certification of comprehensive nutrient management plans (CNMPs). A CNMP is a resource management plan containing a grouping of conservation practices and management activities, which when combined help ensure that both agricultural production and water quality goals are achieved with regard to nutrient and organic by-products. The WQMP and CNMP programs are administered by the TSSWCB and provide agricultural producers in priority areas, such as the North Bosque River watershed, an opportunity to comply with state water quality laws through traditional voluntary incentive-based programs. The TSSWCB oversees and is responsible for the cost-share component of the program, while local SWCDs are required to provide or arrange for technical assistance to applicants to implement BMPs through certified WQMPs.

As part of this project, three technicians were hired; two by the Cross Timbers SWCD and one by the Upper Leon SWCD. These two SWCDs include most of the upper third of the North Bosque River watershed where most of the dairy operations are located (Figure 4). Hiring of these technicians allowed TSSWCB to work cooperatively with the Cross Timbers and Upper Leon SWCDs in the North Bosque River watershed to provide technical and financial assistance to dairy producers and third party landowners. Assistance was aimed toward developing and implementing certified WQMPs for the purposes of reducing NPS nutrient losses from agricultural operations that land-apply animal waste. District technicians solicited landowners to develop WQMPs for waste application fields (WAFs) and update existing certified WQMPs to make them consistent with TMDL Implementation Plan and the current standards in the United States Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS) technical guidance.

To help focus the efforts of these technicians and allow for more direct monitoring of potential water quality improvements associated with the implementation of WQMPs, microwatersheds within the North Bosque River watershed were delineated and targeted for project participation from landowners and operators (Figure 3). The assistance portion of the project operated through March 2005, while the monitoring portion of the project continued through March 2006. Assistance activities conducted by the technicians are outlined in Appendix A. This assistance program lead to the updating of 22 WQMPs in the Upper Leon and 9 WQMPs in the Cross Timbers SWCDs. The most frequent management practices noted involved pasture planting, brush removal (chemical and mechanical), fencing, and water development via ponds and wells. While these WQMPs were not generally specific to dairy operations, these practices should help improve nutrient management in the watershed through better land use and improved flexibility in water management for crop and animal production.

Figure 4 Boundaries of Cross Timbers and Upper Leon Soil and Water Conservation Districts in reference to the upper portion of the North Bosque River watershed.



A further goal of the project was to work with local landowners in microwatershed producer councils to help educate landowners about local water quality issues in an effort to support the adoption of WQMPs and CNMPs. The TSSWCB and the SWCDs planned to facilitate meetings of landowners and operators within each project microwatershed as microwatershed producer councils (MWPCs) for educational purposes. Due to a variety of reasons, including litigation occurring between the City of Waco and the Dairy Industry, the facilitation of MWPCs and the adoption of WQMPs and CNMPs in the North Bosque River watershed has been quite slow. As of January 2005, only three CNMPs had received certification from TSSWCB (TCEQ, 2005) and no MWPC meetings had been held. Because of deadline extensions, delays have occurred in the issuance of individual permits for dairies in the North Bosque River watershed beyond the timeline of this project, so in March 2005, money associated with the educational portion of the project was transferred to extend the monitoring through March 2006. This transfer was done because it was judged that the political and social environment was not conducive to successful educational activities and that extension of the monitoring would be more valuable.

While the development and implementation of WQMPs and CNMPs is still important, evaluating their impact with regard to water quality improvements will have to be assessed at a later date after more plans have been approved. It is anticipated that over the next year or two, management planning activities will become more apparent in the watershed. Extended monitoring for two more years has already been approved to help track improvements in relation to these activities as a separate Clean Water Act 319(h) assessment project. The monitoring data collected to date could not be used to evaluate the original project objective of assessing changes in water quality that occur with the implementation of WQMPs and CNMPs, because of the limited implementation of WQMPs and CNMPs. The data, however, can be used to assess pre-implementation plan water quality conditions and improvements associated with the manure haul-off and composting projects, another component of the TMDL Implementation Plan.

In late 2000 TSSWCB developed the Dairy Manure Export Support (DMES) project as a way to export dairy manure from the North Bosque River watershed (TSSWCB, 2005). TIAER is working with TSSWCB as a project management partner for the DMES project. The DMES project provides incentives to haulers to transport manure from dairies to composting facilities and works in conjunction with the Composted Manure Incentive Project (CMIP) under TCEQ. Through CMIP, TCEQ is responsible for providing technical assistance to composters and ensuring that manure is properly processed and contained at composting facilities (TCEQ, 2005). Only manure hauled to composting facilities participating in CMIP is eligible for DMES hauling reimbursement. In turn, the compost can then be hauled to other watersheds as a beneficial soil amendment. Individual composting facilities are developing markets for compost as a beneficial amendment for gardening and turfgrass production. CMIP is also providing rebates to Texas State agencies, such as the Texas Department of Transportation (TxDOT), which use manure compost received through the DMES project. TxDOT is using dairy manure compost for roadside revegetation throughout the state. Jointly these two projects, DMES and CMIP, comprise a comprehensive manure-composting program for the North Bosque River watershed with the goal of reducing nutrient loading from conventional land application practices to streams through the relocation of manure outside the watershed. Preliminary evaluations indicate decreases in stream soluble phosphorus concentrations during storm events in association with implementation of the manure hauling and composting project (McFarland et al., 2005).

Within this report, routine grab and storm samples collected post-TMDL implementation were assessed to help target areas for focusing efforts by the TSSWCB and SWCDs for NPS management practices. A comparison of pre-implementation versus post-implementation effects with regard to the manure haul-off and composting program is presented using a “before” and “after” approach to evaluate changes in water quality.

CHAPTER 2

Site Information

Land Use and Sampling History

Nineteen sampling sites were evaluated within the North Bosque River watershed (Figure 3). The sites monitored are all located in the upper third of the watershed to focus on nonpoint contributions from dairy waste application fields. Although the focus was on contributions from dairy waste application fields, these sites were chosen to represent the diversity of land uses within the watershed ranging from primarily wood and rangeland, such as the land area above sites SF020 and SP020, to highly impacted microwatersheds, such as GB025 and NF020, to allow comparison between different land uses (Table 1).

Table 1 Estimated land use and drainage area above sampling sites.

Site	Wood & Range (%)	Pasture (%)	Cropland (%)	Dairy Waste App. Fields (%)	Urban (%)	Other (%)	Total Area (Hectares)	Estimated Dairy Cows
AL020	57.6	23.0	7.4	11.4	0.7	0.0	4,720	1878
DB035	46.2	24.1	12.8	14.0	2.3	0.6	2,130	526
DC040	72.5	4.8	7.1	14.9	0.6	0.0	6,250	2257
GB020	40.6	17.7	0.6	40.6	0.6	0.0	440	2722
GB025	29.5	13.5	0.6	55.9	0.5	0.0	660	2722[a]
GB040	21.1	42.8	4.9	30.2	0.7	0.1	540	1977
GC045	61.5	22.2	8.4	6.4	0.9	0.5	11,900	4797
GM060	78.1	13.3	2.8	5.7	0.1	0.0	4,410	1932
HY060	71.7	12.9	12.3	2.9	0.1	0.1	11,800	3458
IC020	64.9	16.8	6.1	11.8	0.3	0.0	1,740	1579
LD040	59.3	5.4	5.5	29.6	0.1	0.1	2,960	4329
LG060	66.2	16.7	9.4	7.1	0.1	0.5	4,260	2742
NF009	58.4	27.2	11.4	2.7	0.2	0.0	520	0
NF020[b]	29.7	14.2	3.3	52.6	0.1	0.1	800	1488
NF050	45.6	34.1	8.3	11.2	0.3	0.6	8,370	1617
SC020	68.7	9.4	1.4	20.0	0.1	0.4	1,900	285
SF020	96.1	2.7	1.0	0.0	0.0	0.2	848	0
SF085	50.6	26.5	5.6	14.3	2.2	0.7	12,900	2350
SP020	82.6	12.0	5.2	0.0	0.1	0.1	1,560	0

a. The same dairy operations are associated with the area above GB020 and GB025, although more of the waste application field area is associated with GB025.
b. About 8 hectares (20 acres) or about 1 percent of the drainage area above site NF020 is permitted for septic disposal.

All sampling sites are labeled using a five character alphanumeric code. The first two letters specify the tributary or river (AL for Alarm Creek) on which the site is located, while the last three digits indicate the relative location of the site. Lower numeric values indicate sites nearer the headwaters, while larger numeric values indicate sites further downstream. A monitoring history for each site is outlined in Table 2.

Although the monitoring history at several of the sites goes back to the early 1990s, the monitoring was not always continuous and gaps are noted in the monitoring history that impact how the data should be evaluated.

General land-use/land-cover descriptions are based on Landsat Thematic Mapper imagery classification provided by the USDA-NRCS, Temple State Office as a geographic information system (GIS) data layer (Table 1). The land-use/land-cover data were developed from a 1992 overflight of Erath County and a 1996 overflight of Erath, Bosque, Coryell, Hamilton, and McLennan Counties. Extensive ground verification occurred from January through April 1998 to update land use changes. Information on dairy waste application fields within the watershed was obtained from dairy permits and dairy waste management plans on record with the TCEQ as of May 2000.

The sizes of the drainage area above sampling sites (Table 1) were delineated using 30-meter digital elevation models created from United States Geological Survey 1:24,000 topographic maps. Drainage areas for sampling sites were calculated using the AVSWAT 2000 extension in ArcView (DiLuzio et al., 2000). Of note, the drainage area values presented in Table 1 may differ some from those in TIAER reports prior to January 2002 because of changes in the GIS system and the calculation method used to determine these areas.

Table 2 Sampling history for monitoring sites in the North Bosque River watershed.

Site	TCEQ ID	Watershed and General Location	Sample Type [a]	Date of First Grab Sample	Date of First Automatic Storm Sample
AL020	17604	Alarm Creek at FM 914	C	14-May-01	05-Sep-01
DB035	17603	Dry Branch near FM 8	C	02-Apr-02	05-Feb-02
DC040	17607	Duffau Creek at FM 2481	C	16-Apr-01	07-May-01
GB020	17214	Unnamed tributary to Goose Branch between CR 541 and CR 297	C	11-May-95	05-May-95
GB025	17213	Unnamed tributary to Goose Branch near end of CR 297	C	12-Feb-97	19-May-97
GB040	17215	Goose Branch downstream of FM 8	C	12-Feb-97	06-Feb-97
GC045	17609	Green Creek upstream of SH 6	C	16-Apr-01	26-May01
GM060	17610	Gilmore Creek at bend of CR 293	C	05-Feb-01	31-Aug-01
HY060	17611	Honey Creek at FM 1602	C	16-Apr-01	04-May-01
IC020	17235	Indian Creek downstream of US 281	C	08-Jun-94	18-Oct-93 [b]
LD040	17608	Little Duffau Creek at FM 1824	C	14-May-01	31-Aug-01
LG060	17606	Little Green Creek at FM 914	C	14-May-01	14-Jul-01
NF009	17223	Unnamed tributary of Scarborough Creek at CR 423	C	18-Apr-91	16-May-92 [c]
NF020	17222	North Fork North Bosque River Scarborough Creek at CR 423	C	30-Oct-91	19-May-92
NF050	17413	North Fork of North Bosque River at SH 108	C	04-Apr-91 [d]	07-Jun-91 [d]
SC020	17240	Sims Creek upstream of US 281	C	21-Sep-94	17-Jan-95 [b]
SF020	17218	South Fork North Bosque River 1km upstream FM 219	C	01-Jun-93[e]	16-May-92[e]
SF085	17602	South Fork of North Bosque River at SH 108	C	30-Apr-01	26-May-01
SP020	17242	Spring Creek at CR 271	C	08-Jun-94	20-Oct-93 [b]

a. G = grab sampling site, S=storm sampling site, C=combined grab and storm sampling site.
b. Storm sampling suspended 03-Mar-98 to 03-May-2001 at IC020 and SP020 and 03-Mar-98 to 12-May-2001 at SC020.
c. Automated sampler at NF009 was offline from 25-Mar-98 through 12-Jun-98.
d. Storm sampling at NF050 suspended from 09-Feb-97 to 04-May-01 and grab sampling suspended 06-May-97 through April 2001. In April 2001, grab sampling was reinitiated, but no samples were collected until April 2002 due to dry conditions.
e. Sampling at SF020 was discontinued in Dec. 2002 at the request of the landowner.

Because monitoring directly associated with this project did not start until fairly recently (spring 2002), historical or non-direct data associated with other monitoring projects conducted by TIAER were used to help supplement this project. TIAER has collected data from project sites beginning as early as 1992 under a variety of quality assurance project plans (QAPPs). These QAPPs include the following:

- Data collected by TIAER in the Upper North Bosque River Watershed under the United States Environmental Protection Agency (USEPA) sponsored Livestock and the Environment: A National Pilot Project (NPP). The QAPP is the TIAER document entitled Quality Assurance Project Plan for the National Pilot Project (1993), which encompasses data collected from June 1, 1992 through August 31, 1995. Data that may be used from this project includes water quality, rainfall, and water level (streamflow) information.
- Data collected by the Brazos River Authority (BRA) and TIAER, as a subcontractor, under the TCEQ Clean Rivers Program. The QAPP is the BRA document entitled Quality Assurance Project Plan for the Bosque River Watershed Pilot Project (BRA, 1995) which encompasses data collected from October 1, 1995 through May 31, 1996. Data that may be used from this project includes water quality, rainfall, and water level (streamflow) information.
- Data collected by TIAER under the USDA Lake Waco-Bosque River Initiative. The QAPPs are TIAER documents entitled Quality Assurance Project Plan for the Lake Waco-Bosque River Initiative (1996, 1997-99, 1999-2000, 2000-2003, and 2003 - 2005), which encompass data collected from September 1, 1996 through September 1, 2005. Data that may be used from this project includes water quality, rainfall, and water level (streamflow) information.

Site Descriptions

Specific site descriptions are provided below by creek.

Alarm Creek

Site AL020 AL020 is an automated sampling site located on Alarm Creek at Farm to Market (FM) 914, 7.2 kilometers (4.5 miles) south of Stephenville. The dominant land uses above AL020 are wood and range, with a fair amount of land associated with improved pasture and dairy operations. Alarm Creek has been monitored on a biweekly basis since May 2001.

Dry Branch

Site DB035 DB035 is an automated sampling site located on Dry Branch near FM 8, about 0.8 kilometers (0.5 miles) upstream of the confluence with the North Bosque River. The dominant land uses above DB035 are wood and range, with a fair amount of land associated with improved pasture, dairy operations, and cropland. A number of dairies are located in the drainage area of DB035. Routine and storm sampling at DB035 was initiated in 2002.

Duffau Creek

Site DC040 DC040 is an automated sampling site, located on Duffau Creek, at FM 2481, immediately northeast of Duffau, Texas in Erath County. An automated sampler was installed at the site in May 2001. The majority of land in the DC040 drainage area is classified as wood and range, with some land used as dairy waste application fields. A number of dairies are located in the drainage area of DC040.

Goose Branch

Sites GB020, GB025, and GB040 GB020, GB025, and GB040 are automated sampling sites located in the Goose Branch microwatershed of the South Fork of the North Bosque River, northwest of Stephenville. Dairying is the predominant land use in the Goose Branch microwatershed. Much of the remaining land area is covered by native range and woodland. GB020 is located on an unnamed road off of Erath County Road (CR) 297, and GB025 and GB040 are located on private property away from roads. Sites GB025 and GB040 are located on separate forks of Goose Branch, both of which discharge into the same PL-566 reservoir. GB020 is located about 1.6 kilometers (1 mile) upstream from GB025. The same dairy operations are associated with both GB020 and GB025, although more dairy waste application fields are associated with GB025. Although somewhat duplicative in effort, both GB020 and GB025 were included in the monitoring program at landowner request.

Green Creek

Site GC045 Site GC045 is an automated site, located on Green Creek, 0.6 km (0.4 miles) upstream of State Highway (SH) 6, 3.3 km (2.0 miles) northwest of Alexander, Texas. The majority of the land above GC045 is designated as wood or range with some permanent pasture. A number of dairies are located in the drainage area of GC045. Routine and storm sampling was initiated at GC045 in 2001.

Gilmer Creek

Site GM060 GM060 is an automated sampling site located on Gilmer Creek, at the bend of Erath CR 293, approximately 330 meters (0.2 miles) downstream of the confluence with Wolf Prong Creek, north northeast of Carleton. Land uses above GM060 are predominantly wood or range with some permanent pasture, cropland, and dairy operations.

Honey Creek

Site HY060 HY060 is an automated sampling site located on Honey Creek, at FM 1602 approximately 4.7 kilometers (2.9 miles) southeast of Hico, in Hamilton County. The majority of the land above HY060 is designated as wood or range with some permanent pasture and cropland. A few dairy operations are located in this drainage.

Indian Creek

Site IC020 IC020 is located near U.S. Highway 281, on Indian Creek, which discharges into the upper North Bosque River between Stephenville and Hico. Automated sampling was suspended from March 3, 1998 to May 3, 2001. Routine biweekly grab sampling continued throughout the monitoring period. The majority of the land use above IC020 is characterized as wood or range, although a number of dairies are also located in this drainage area.

Little Duffau Creek

Site LD040 LD040 is an automated sampling site, located on Little Duffau Creek, at FM 1824, 2 km (1.2 miles) west of Duffau, Texas in Erath County. The land use above LD040 is predominantly wood or range, although about 30 percent of the drainage basin is associated with dairy operations. Routine and storm sampling were initiated at LD040 in 2001.

Little Green Creek

Site LG060 LG060 is an automated sampling site, located on Little Green Creek, at FM 914, 3.2 kilometers (2.0 miles) south of Alexander, Texas. The land use above LG060 is characterized as mostly woodland or range with some improved pasture and cropland. A few dairy operations are located within this drainage basin. Routine and storm sampling were initiated at LG060 in 2001.

North Fork

Sites NF009, NF020 and NF050 These automated sites are located on or on tributaries to the North Fork of the North Bosque River. The North Fork joins the South Fork just north of Stephenville to form the North Bosque River. Sites NF009 and NF020 are located on separate tributaries flowing into the same PL-566 reservoir. Site NF020 is located on Scarborough Creek at CR 423. Site NF009 is located on an unnamed tributary of Scarborough Creek on CR 423. The dominant land use above NF020 is dairy farming, while most of the land above NF009 is characterized as range and forage fields. Although these two sites are quite near one another, their hydrology can be different. Site NF050, an automated sampling site, is located on the North Fork of the North Bosque River, at SH 108, approximately 1.6 km (1.0 mile) northwest of Stephenville. The dominant land use above NF050 is designated as woodland or range and permanent pasture.

Sims Creek

Site SC020 Site SC020 is located near U.S. Highway 281 on Sims Creek. Sims Creek is just south of Indian Creek within the upper portion of the North Bosque River watershed. Automated storm sampling at SC020 was suspended from March 3, 1998 to May 12, 2001. Routine grab sampling continued during this period when storm sampling was suspended. The majority of the land area above SC020 is considered nonintensive agriculture, with most of the land area characterized as wood or range, although a fair amount of land is also associated with dairy operations.

South Fork

Site SF020 and SF085 Site SF020 is an automated sampling site, located on private property, on an unnamed branch of the South Fork of the North Bosque River. Almost all of the land above SF020 is characterized as wood or range, making this drainage basin one of the least impacted within the watershed. Sampling at SF020 was discontinued in December 2002 at the request of the landowner. Site SF085 is an automated sampling site located on the South Fork of the North Bosque River, at SH 108, 250 m (820 feet) upstream of the confluence with the North Fork of the North Bosque River, north of Stephenville. The land use above SF085 is mostly woodland or range with the remaining permanent pasture and dairy farming.

Spring Creek

Site SP020 Site SP020 is located near CR 271, on Spring Creek, which discharges into the North Bosque River above Hico. Automated sampling was suspended from March 3, 1998 to May 3, 2001, although routine grab sampling was continued. Site SP020 is considered one of the least impacted sites within the watershed with most of its land designated as wood or range.

CHAPTER 3

Methods

Storm Sampling

Storm sampling was accomplished by placing an automated sampler at each site, which consisted of an Isco 4230 or 3230 bubbler type flow meter in conjunction with an Isco 3700 sampler. Each flow meter recorded water level at five-minute intervals by measuring the pressure required to force an air bubble through a 3 mm (0.125 inch) polypropylene tube. The automated sampler would begin sampling when a water level rise of approximately 4 cm (0.12 ft) occurred. Once activated the sampler would retrieve one-liter sequential samples. The typical sampling sequence for most sites was:

- An initial sample
- Three samples taken at one-hour intervals
- Four samples taken at two-hour intervals
- All remaining samples taken at six-hour intervals

For a few of the sites with larger watershed areas (HY060, NF050, and SF085) the sampling sequence was slightly modified to allow for a more extended hydrograph. The sampling sequence at these sites was as follows:

- An initial sample
- One sample taken at a one-hour interval
- One sample taken at a two-hour interval
- One sample taken at a three-hour interval
- One sample taken at a four hour interval
- One sample taken at a six-hour interval
- All remaining samples taken at eight-hour intervals

Samples from individual storm events by site were composited using a flow-weighting strategy. The flow-weighting strategy used stage data recorded during a storm, the rating curve developed for each site, and a TIAER-developed computer program. During sample collection, the stage data were uploaded from data loggers to portable computers, then downloaded at TIAER headquarters for use with the computer program. The program read the stage level associated with the time interval for each sample collected at the site, correlated the stage to flow using the site's rating curve, and calculated the amount of flow associated with each water sample taken during the storm event. For a group of bottles, the program would then designate the amount of sample to be taken from each bottle to compose a one-liter composite based on the relative volume of flow associated with each bottle within the group. This flow-weighting strategy allows a reduction in sample load without compromising the intended use of the data in determining storm loadings of waterborne constituents and storm-event mean concentrations.

Stage-discharge relationships were developed for most sites from manual wading-type flow measurements taken at various water level conditions following USGS methods (Buchanan and Somers, 1969). Stage-discharge relationships for stages that permitted safe wading were extrapolated using the cross-sectional area and a least-squares relationship of average stream velocity to the log of water level. At sites LD040 and LG060, the samplers and flow meters were located within a road culvert. For LD040 and LG060, mathematical fluid mechanics equations were used to estimate flow from culvert flow equations. If a site had storm samples prior to development of a rating curve, a relative discharge based on standard hydrologic relationships was calculated as the wetted cross-sectional area of the stream site times the square root of water level for flow-weighting of samples.

If for some reason (i.e., equipment failure), the automated sampler failed to collect samples, a storm grab sample was collected for analysis. If samples could not be flow-weighted because stage data were missing or could not be electronically downloaded at the time samples were retrieved, storm samples were analyzed separately as sequential samples.

Grab Sampling

Routine grab sampling at all sites was performed on a biweekly basis when flow was present. Samples were not collected at sites that were dry or pooled. Samples were collected at a depth of about 0.25 to 0.5 ft (0.08 to 0.15 meters). All filtration and preservation, other than temperature reduction by placing samples in coolers with ice, was performed in the laboratory until October 2003. Beginning in October 2003, sampling procedures were changed to allow filtration and acid preservation to occur in the field for grab samples as indicated by TCEQ sample collection methods (TCEQ, 2003).

Routine samples for nutrients and TSS were collected in a one-liter plastic bottle. Starting in October 2003, aliquots for analytes requiring filtration and/or acidification were taken from this bottle after it had been agitated thoroughly to ensure total mixing of sediments. Samples that require field filtration were filtered through a 0.45 -micron filter using a 50 CC or larger syringe. An aliquot for NO_2-N+NO_3-N and NH_3-N was filtered and transferred to an acidified 60-mL plastic bottle, labeled, capped, and shaken to disperse the acid in the sample. A fresh filter was then used to obtain an aliquot for PO_4-P analysis with the syringe, which was then labeled and iced for submittal to the lab. An aliquot for TP and TKN analysis was poured from the liter bottle into a labeled and acidified 250-mL plastic bottle, which was capped and shaken to disperse the acid. The remaining sample (about 500 mL) was submitted to the lab for TSS analysis. Of note, if samples were too turbid to reasonably allow field filtration with the syringe, a comment was added to the change of custody form and aliquots associated with constituents requiring filtration were kept in the one-liter bottle for filtration and acidification by the lab.

In addition to the nutrient and TSS constituents that were also analyzed for storm samples, routine grab samples were analyzed for fecal coliform and/or *Escherichia coli* bacteria. Samples for bacteria analysis were collected in sterile plastic 250-mL bottles that had been autoclaved and sealed with autoclave tape.

While routine grab samples for lab analysis were being collected, measurements were taken and recorded *in-situ* for water temperature, dissolved oxygen, pH, and specific conductance (conductivity) using a YSI multiprobe instrument.

Constituent and Analysis Methods

Ammonia-nitrogen (NH_3-N), nitrite-nitrogen plus nitrate-nitrogen (NO_2-N+NO_3-N), total Kjeldahl nitrogen (TKN), PO_4-P or SRP, total-P (total P), and total suspended solids (TSS) were evaluated for both the routine grab and storm samples (Table 3). In addition, fecal coliform (FC) and/or *Escherichia coli* (*E. coli*) were analyzed with grab samples. From April 2002 through March 2004, both FC and *E. coli* were analyzed with grab samples using plating techniques. Both FC and *E. coli* were analyzed, because TCEQ was in the process of changing the water quality criteria for bacteria from FC to *E. coli* (TNRCC, 2000). In April 2004, FC was discontinued, and the analysis method for *E. coli* was changed to the IDEXX Colilert method.

Table 3 Constituents and methods of analysis for water quality samples.

Constituent	Abbreviation	Units	Analysis Method[a]	Description
Ammonia-nitrogen	NH_3-N	mg/L	EPA 350.1	Inorganic form of nitrogen that is readily soluble and available for plant uptake. Elevated levels are toxic to many fish species.
Nitrite-nitrogen + nitrate-nitrogen	NO_2-N+NO_3-N	mg/L	EPA 353.2	Inorganic form of nitrogen that is readily soluble and available for plant uptake. Considered the end product in the conversion of N from the ammonia form to nitrite then to nitrate under aerobic conditions.
Total Kjeldahl nitrogen	TKN	mg/L	EPA 351.2 modified[b]	Organic and ammonia forms of nitrogen are included in TKN.
Orthophosphate-phosphorus	PO_4-P or SRP	mg/L	EPA 365.2	Inorganic form of phosphorus that is readily soluble and available for plant uptake. Soluble reactive phosphorus (SRP) is another name for this constituent.
Total phosphorus	Total-P	mg/L	EPA 365.4 modified[b]	Represents both organic and inorganic forms of phosphorus.
Total suspended solids	TSS	mg/L	EPA 160.2	Measures the solid materials, such as clays, silts, sand, and organic matter, suspended in the water column.
Fecal coliform	FC	colonies / 100 mL	SM 9222D	Indicator of public health hazards from infectious microorganisms
Escherichia coli	*E. coli*	colonies/100 mL or MPN (most probable number)	SM 9222G or SM 9223-B[c]	Indicator of public health hazards from infectious microorganisms

a. EPA refers to *Methods for Chemical Analysis of Water and Wastes* (USEPA, 1983). SM refers to the *Standard Methods for the Examination of Water and Wastewaters*, 18th edition (APHA, 1992).
b. Modification of TKN and TP methods involved using copper sulfate as the catalyst instead of mercuric oxide.
c. Analysis of *E. coli* was changed from SM 9222G to SM 9223-B in April 2004.

Laboratory method detection limits (MDLs) or left censored data below which the laboratory was unable to differentiate from zero were entered into the database as one-half the MDL following recommendations by Gilliom and Helsel (1986) and Ward et al. (1988). A comment field indicating the MDL at the time of the sample was analyzed for each value below the MDL was also added. In TIAER's laboratory, MDLs are updated about once every six months.

Statistical Evaluation Methods

To evaluate existing conditions at microwatershed sites, basic summary statistics including mean, median, and standard deviation were calculated for both routine grab samples and event mean concentrations (EMCs) of storm events. Event mean concentrations for storm events were calculated for each storm event by accumulating the mass via rectangular integration using a midpoint rule to associate concentration with streamflow (Stein, 1977). The instantaneous 5-minute stage readings were used as the minimum measurement interval to indicate flow in cubic feet per second (cfs) and multiplied by 300 seconds to obtain flow for each 5-minute interval. The flow associated with each 5-minute interval was multiplied by the associated water quality concentration and summed across the event to calculate the total constituent loadings. Total constituent loadings were divided by total storm volume to calculate EMCs.

These basic statistics were based on data collected between January 2001 through December 2005 and represent a time period after initiation of the TMDL Implementation Plan. To compare water quality between sites, an analysis of variance (ANOVA) was performed on each constituent. If significant differences were indicated at $\alpha = 0.05$ by the ANOVA, a test of least significant differences (LSD) was applied as a multiple comparison test to distinguish specific differences between sites (Ott, 1984). The purpose of these comparisons was to give a general idea of relative water quality between sites and indicate areas that might be of interest to TSSWCB for targeting nonpoint source management efforts.

For routine grab data, the number of samples collected per site varied considerably due to the intermittent nature of these small stream sites. For example, at site GB025 only two samples were collected between January 2001 and December 2005, while at site DC040, 113 samples were collected (Table 4). For comparisons of routine grab data sites GB020, GB025, and SF020 were excluded as having too few samples for a meaningful comparison. After excluding sites GB020, GB025, and SF020, only sampling periods when 75 percent or more of the sites were flowing were evaluated to provide a more representative time period for comparison between sites.

Storm events showed less variability in the number of events between sites with generally 30 to 60 events per site (Table 4). Of note, SF085 had 113 events monitored. It is suspected that the paved surfaces associated with nearby urban areas contributed to the frequency of events at SF085. For ANOVA and LSD comparisons, all storm event data were used, although data from site SF020 were excluded, because monitoring at this site was discontinued in December 2002.

Table 4 Number of routine grab samples and storm events monitored by sampling site between January 2001 and December 2005.

Site	Number of Routine Grab Samples	Number of Storm Events Monitored
AL020	60	53
DB035	40	61
DC040	113	62
GB020	5	32
GB025	2	47
GB040	49	56
GC045	58	47
GM060	80	51
HY060	72	54
IC020	45	53
LD040	29	35
LG060	49	30
NF009	52	41
NF020	24	57
NF050	36	49
SC020	72	49
SF020[a]	6	25
SF085	94	103
SP020	84	61

a. Sampling at SF020 was discontinued in Dec. 2002.

Prior to performing ANOVA, constituent data sets were evaluated to determine if the assumptions of normality and equal variances were met. The Shapiro-Wilk statistic was used to test for normality (SAS, 1992), while the Hartley's test was used to test for equal variances (Ott, 1984). For nutrient, TSS, and bacteria data represented by routine grab samples and nutrient and TSS data represented by EMCs, a natural log transformation allowed a better fit to the assumptions of normality and equal variances. In some cases even when transformed, the assumptions for normality and equal variances were still not met at $\alpha = 0.05$. In these cases when the assumptions were still not met, but the transformed data were indicated to more closely meet these assumptions than the untransformed data, the transformed data were used in the ANOVA. These deviations from the assumptions of normality and equal variances were considered to have a minimal impact of the validity of the ANOVA test, because of the inherent robustness of ANOVA to violations in these assumptions (Spooner, 1994). For all nutrient and TSS constituents, a natural-log transformation was implemented prior to evaluating the data using ANOVA.

For field parameters, pH, DO, and water temperature data met the assumptions for normality and equal variances without the need for considering data transformations. Of note, pH data are already on a log scale as the log of the hydrogen ion concentration. A natural-log transformation was applied to conductivity data to better fit the assumption of equal variances.

To evaluate the impact of land use on water quality, a correlation analysis was also conducted of median water quality concentrations with the percent land use by category within each microwatershed as provided in Table 1. The correlation analysis was conducted using the PROC CORR function of the SAS analysis system (SAS, 2000).

For comparison before and after the implementation of the manure composting program, long-term data that were suitable for trend analysis were available from seven of the monitoring sites (GB025, GB040, IC020, NF020, SF020, and SP020). The manure composting program represents a component of the TMDL Implementation Plan that has had notable participation and focuses specifically on abatement of nonpoint source pollution from dairy operations. Event mean concentrations (EMCs) before and after initiation of the manure composting program were analyzed using both parametric and nonparametric statistical tests. In preparing data sets for analysis, values below the MDL can cause problems with statistical evaluation, especially when detection limits change. To minimize problems associated with varying MDLs over time, the maximum MDL was identified for each site by constituent. For consistency, all values in the database below half the maximum MDL were set equal to half the maximum MDL.

Preliminary analyses of the data at sites NF020, GB025, GB040, and IC020, indicated that certain runoff events may have been impacted by effluent discharges from dairy retention control structures rather than solely from nonpoint source runoff. In most cases this could not be verified; but to isolate the impact of the manure composting program, it was important that potential contributions from sources other than nonpoint source runoff be removed. Consequently, a separate data set was constructed deleting data points suspected to be impacted by effluent discharges. Data points were deleted if they had uncharacteristically high NH_3-N concentrations (> 5.0 mg/ L), because wastewater effluent from dairies is typically associated with high ammonia values. Some differences were observed in the results between the full and reduced data sets (Bekele and McFarland, 2004a); therefore, only results from the reduced data set modified to remove the potential impact from effluent discharges are presented.

Step trend procedures were used for trend analysis, because there were gaps in the data record at some sites breaking the data into two distinct time periods and because there was a known event (the initiation of the manure composting program) that was expected to result in a change in water quality (Helsel and Hirsch, 1992). Data collected prior to initiation of the composting program in November 2000 was designated as the “before” period while data collected after November 2000 was designated as the “after” period. The data were analyzed as a “before/after” monitoring design (Grabow et al., 1999; Smith, 2002; Spooner et al., 1985) using analysis of covariance (ANCOVA) and the nonparametric Wilcoxon rank sum (WRS) procedures (SAS, 2000).

In the ANCOVA, average streamflow for each event was used as the covariate. The ANCOVA consists of multiple steps determining the statistical significance: 1) of the regression equations relating streamflow and concentration from the two monitoring periods; 2) of the equality of these regression slopes; and 3) of the difference between the intercepts of the regressions from the two monitoring periods (Littell et al., 1996; NRCS, 1997). ANCOVA was performed on the natural log-transformed data to satisfy the assumptions of the homogeneity of variance and the homogeneity of regression

(Littell et al., 1996). Results from ANCOVA were considered streamflow adjusted because ANCOVA allows obtaining estimates of differences among treatment level means (for the before and after periods) that would occur if all the concentrations have the same streamflow (Keppel, 1991).

In the WRS analysis, data were flow adjusted prior to analysis using locally weighted regression and smoothing scatterplots (LOWESS) with a smoothing coefficient of 0.5 (Helsel and Hirsh, 1992; Bekele and McFarland, 2004b), except site SC020. At site SC020 the flow-concentration relationship changed over time due to suspected damming of the stream upstream of the sampling site. The residuals from LOWESS regression were then used in the WRS test. This test is based on the assumption that if the regressions represent the variability due to streamflow, a difference in the regression residuals could be attributed directly to a difference due to the manure composting program (Helsel and Hirsh, 1992).

Both parametric and nonparametric procedures were implemented because at one site (SC020) the assumptions associated with the ANCOVA could not be fully met. In addition, the application of both parametric and nonparametric methods on the same data set is considered useful because it provides assurance in the interpretation of results (NRCS, 1997). A step trend confirmed by both analyses was considered more meaningful than one indicated by only one test. All statistical significance was evaluated at an $\alpha = 0.10$ probability level.

CHAPTER 4

Results and Discussion

Water Quality Comparisons between Sites

Routine Grab Data

Basic statistics for routine grab data are presented in Appendix B for data collected between January 2001 and December 2005. Geometric or mean values from routine grab data when at least 75 percent of sites were flowing are presented in Figures 5-9 to allow a general comparison of water quality between sites. These comparisons of routine grab data exclude data from sites GB020, GB025, and SF020, because too few samples were collected at these sites to allow meaningful comparisons (see Table 4). Basic statistics for sites GB020, GB025, and SF020 are included in Appendix B for reference. The purpose of these comparisons is to give a general idea of relative water quality and indicate areas in the watershed that might be of interest to TSSWCB for targeting nonpoint source management efforts. In Figures 5-9, different letters above bars indicate significantly different mean or geometric mean values at $\alpha = 0.05$.

Of the 16 sites compared, the highest geometric mean NH_3-N and NO_2-N+NO_3-N concentrations from routine grab samples occurred at GB040 (Figures 5a and b). The highest geometric mean TKN concentrations occurred at NF020 followed by GB040 (Figure 5c). The lowest geometric mean nitrogen concentrations consistently occurred at SP020 for all three forms of nitrogen measured. Sites GM060 and DC040 were also consistently ranked in the lowest quartile of sites for geometric mean nitrogen concentrations.

For NH_3-N and NO_2-N+NO_3-N, there appeared to be a fair amount of overlap in similarity of geometric mean concentrations except at very low and high concentrations. For NH_3-N, geometric mean concentrations were below 0.10 mg/L at all sites but GB040. For NO_2-N+NO_3-N, geometric mean concentrations were below 2 mg/L at all sites but GC045 and GB040. For TKN, sites appeared to fall in more distinctive groupings with a clear split between sites Al020 and NF009 indicating sites with geometric mean TKN concentrations above and below about 1.2 mg/L.

For phosphorus constituents, sites HY060 and SP020 had the lowest and sites GB040 and NF020 had the highest geometric mean PO_4-P and total-P concentrations (Figures 6a and b). For both PO_4-P and total-P there was a clear split in the grouping of similar sites between LG060 and AL020. The geometric mean at LG060 was 0.031 mg/L PO_4-P and 0.11 mg/L total-P and at AL020 0.073 mg/L PO_4-P and 0.17 mg/L total-P.

Figure 5 Geometric mean nitrogen concentrations for routine grab samples at sites for a) NH_3-N, b) NO_2-N + NO_3-N, and c) TKN collected between January 2001 and December 2005. Data limited to sampling periods when 75 percent or more of sites were flowing. Different letters indicate significantly different mean values at α=0.05 based on a test of LSD.

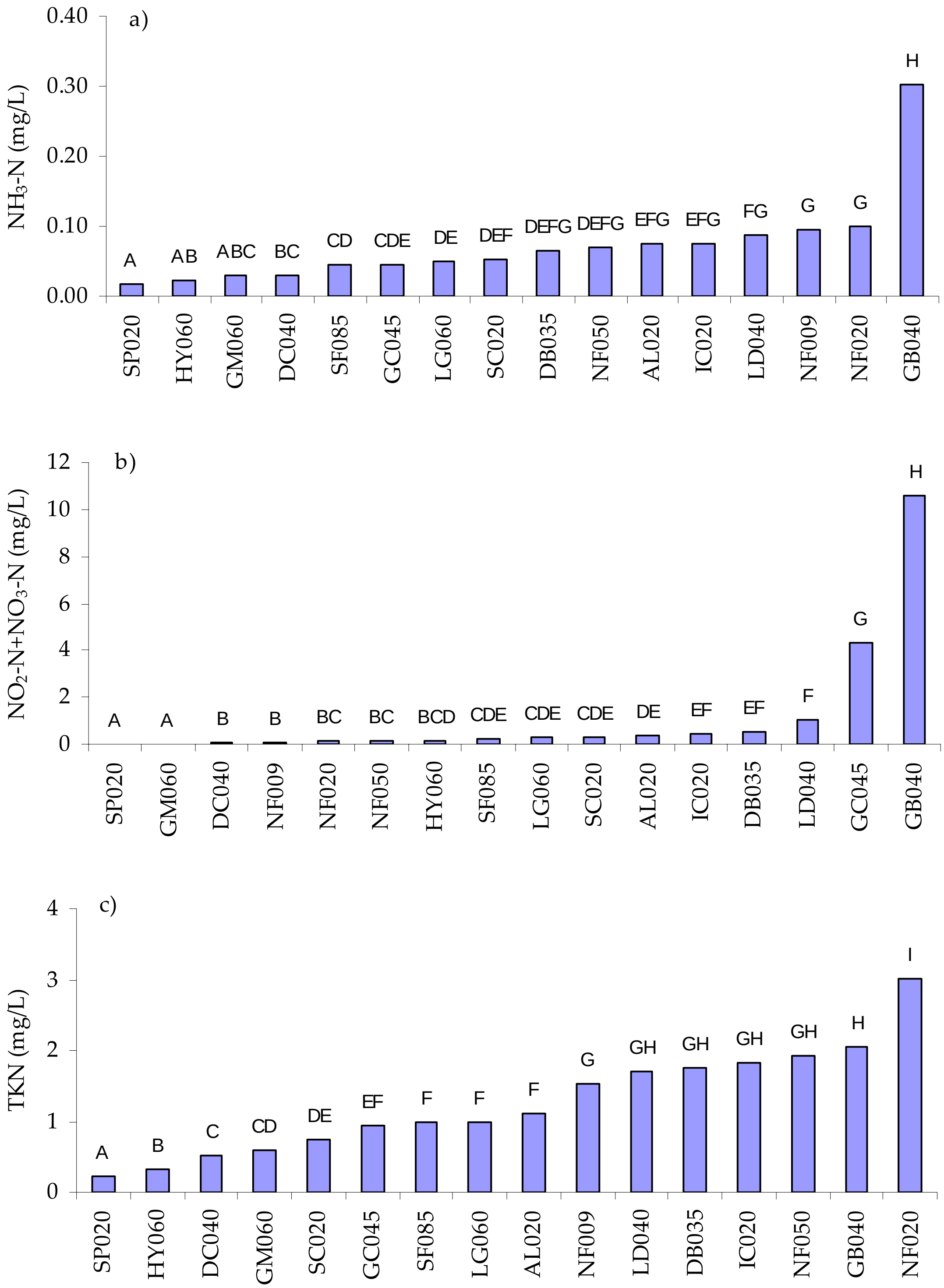
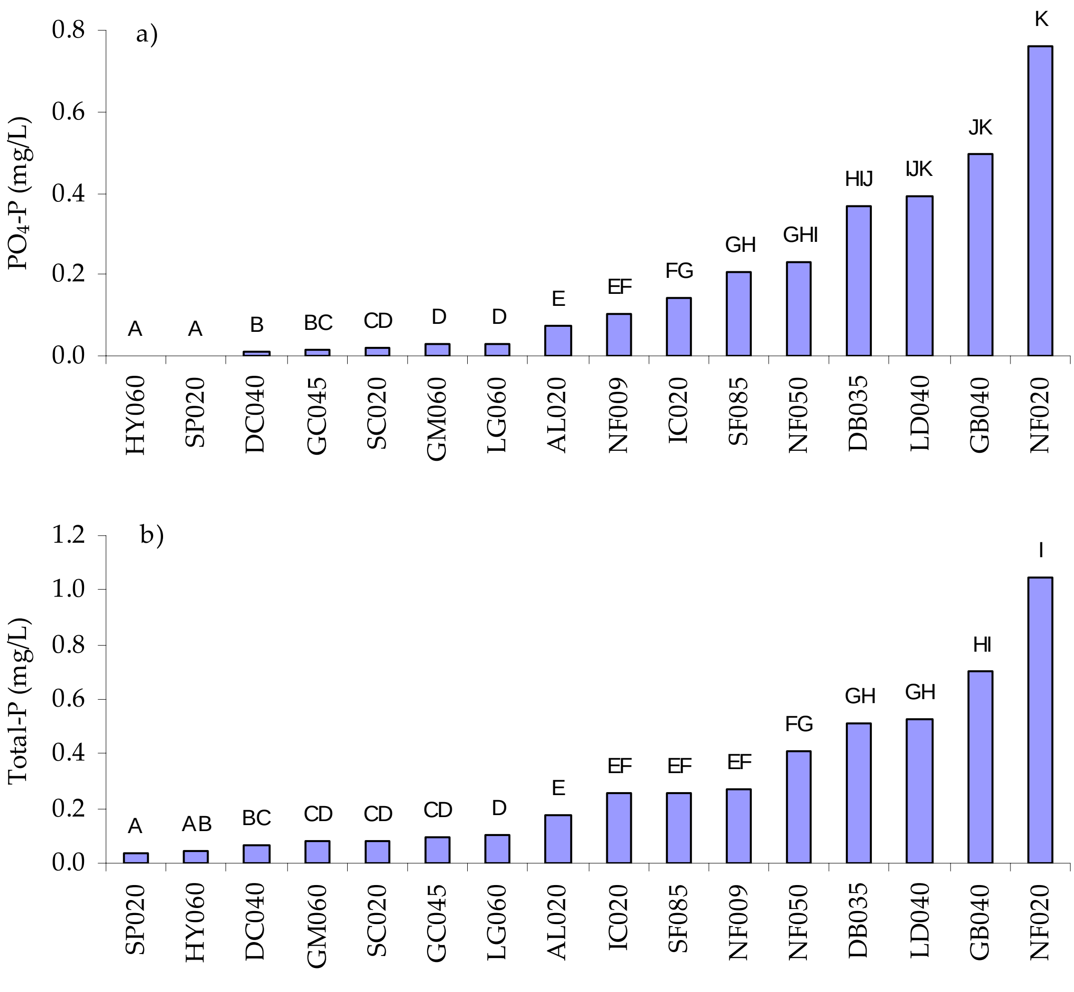


Figure 6 Median phosphorus concentrations for routine grab samples at sampling sites for a) PO_4-P and b) total-P collected between January 2001 and December 2005. Data limited to sampling periods when 75 percent or more of sites were flowing. Different letters indicate significantly different mean values at α=0.05 based on a test of LSD.



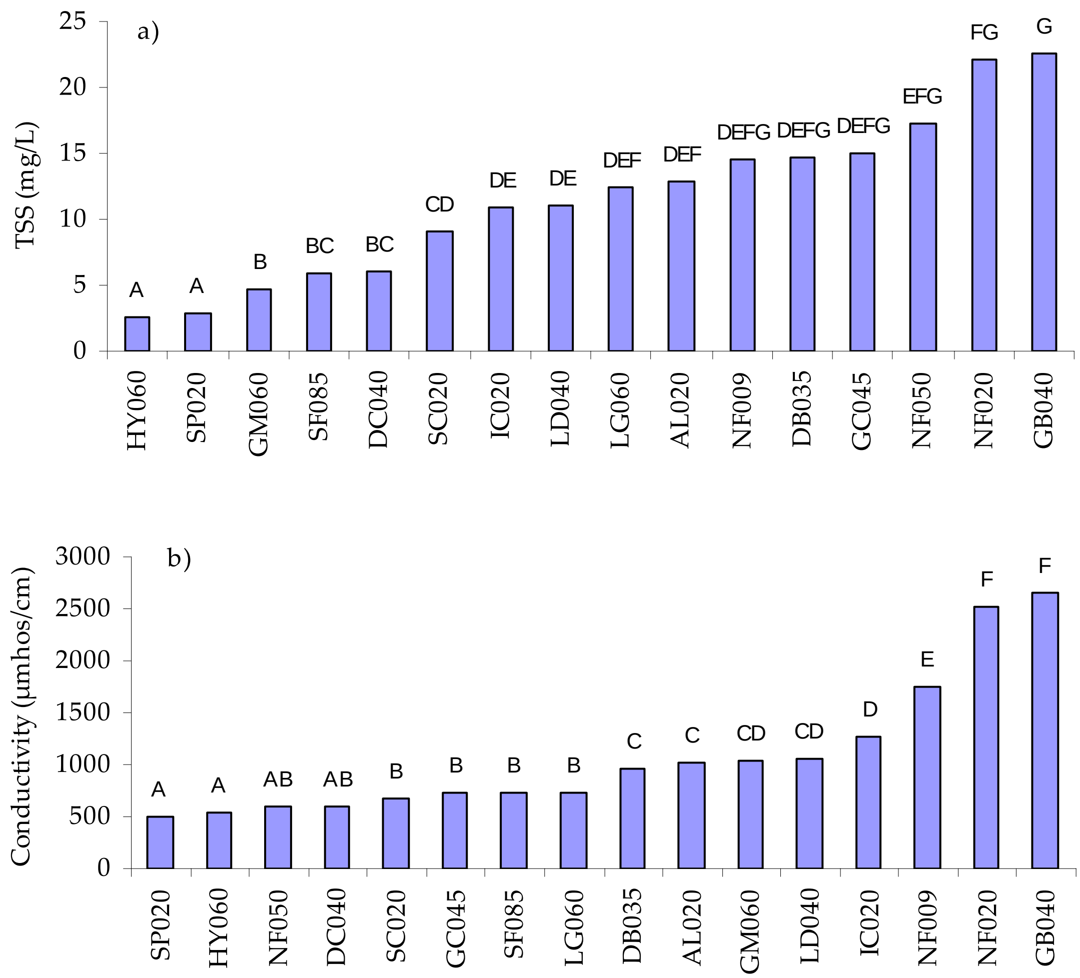
A general ordering of the sites from highest to lowest nutrient concentrations was determined based on an average of the ranking of the geometric mean for NO_2-N+NO_3-N, TKN, PO_4-P and total-P. Ammonia-N was not included in this general ranking, because NH_3-N is part of TKN.

NF020>GB040>LD040>DB035>NF050>IC020>NF009>SF085>AL020>LG060>GC045
>SC020>GM060>DC060>HY060>SP020

This ranking is not an assessment of water quality but is provided to help identify stations with higher nutrient concentrations where assistance with nutrient control practices might be targeted.

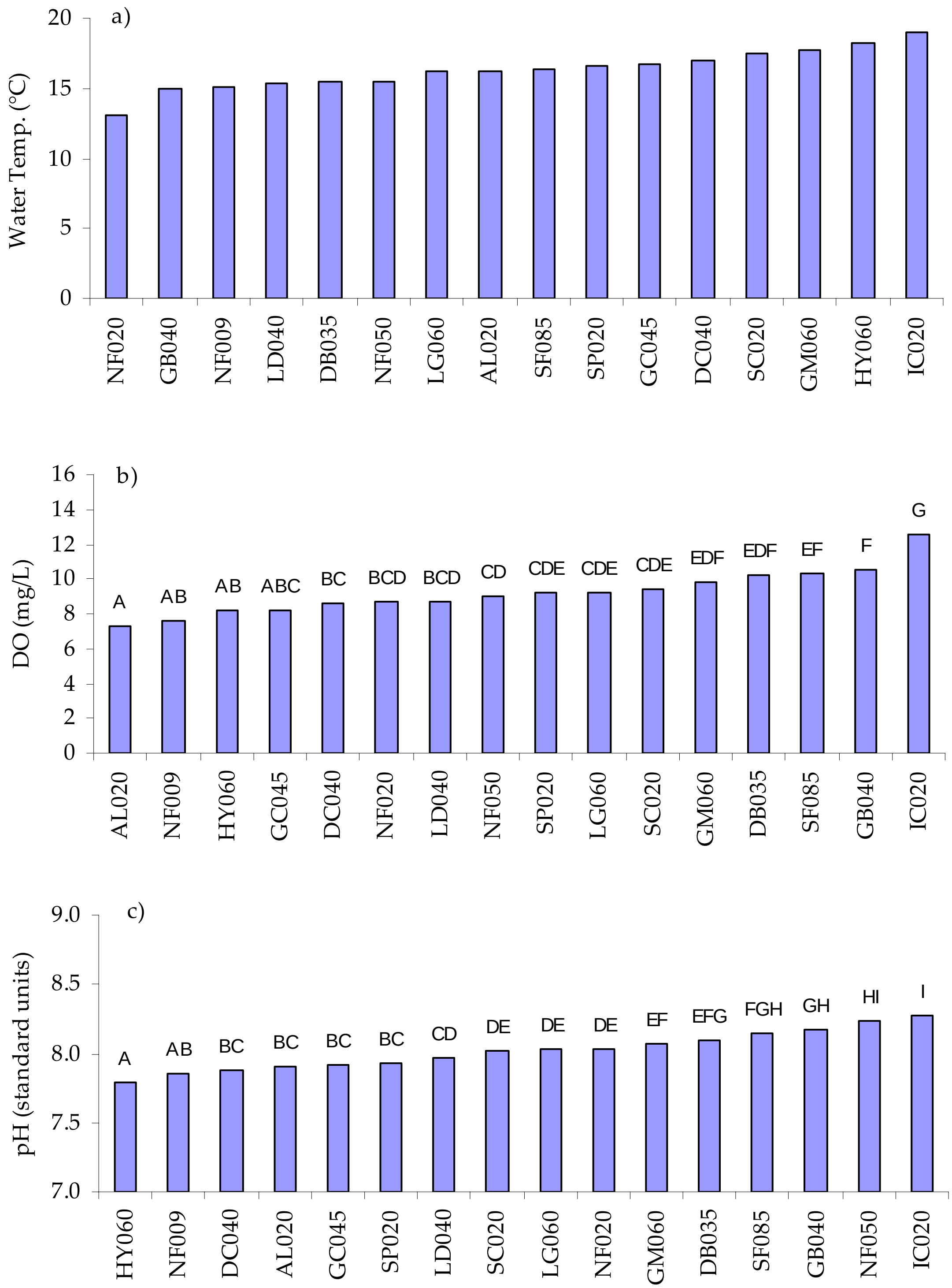
Geometric mean concentrations for TSS and conductivity for routine grab samples showed trends similar to those found for the nutrient constituents with sites SP020 and HY060 having some of the lowest concentrations, while NF020 and GB040 had some of the highest concentrations (Figure 7a and b). For conductivity, site NF050 was a bit of an anomaly in that this site was grouped with the lowest conductivity values, but for most other constituents, site NF050 was grouped at the higher end of the concentration range in comparisons between sites.

Figure 7 Geometric mean a) TSS concentrations and b) conductivity values for grab samples at sampling sites collected between January 2001 and December 2005. Data limited to sampling periods when 75 percent or more of sites were flowing. Different letters indicate significantly different mean values at α=0.05 based on a test of LSD.



Water temperature did not indicate significant differences between sites based on the ANOVA (Figure 8a). Mean water temperatures for the periods evaluated ranged from 13.1ºC at NF020 to 19.0ºC at IC020. Variation in water temperature between sites was expected to some degree due to the differences in shading associated with vegetative canopy cover at the various sites. For example, site NF020 is located within a densely vegetated riparian area, while IC020 is located in the middle of a pasture with no overhanging vegetation.

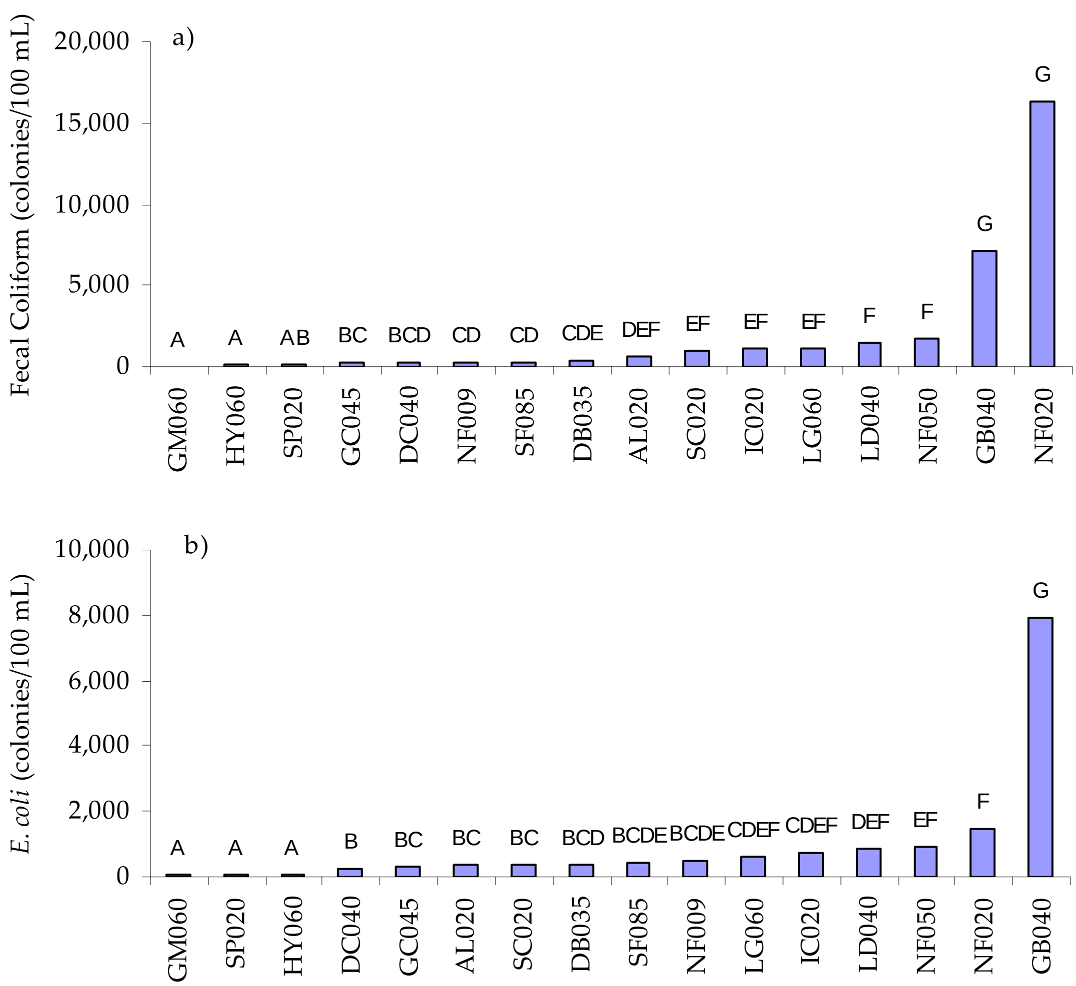
Figure 8 Mean a) water temperature, b) dissolved oxygen, and c) pH for grab samples at sampling sites collected between January 2001 and December 2005. Data limited to sampling periods when 75 percent or more of sites were flowing. Different letters indicate significantly different mean values at α=0.05 based on a test of LSD.



While site differences were noted for mean DO and pH values (Figure 8b and c), these differences were fairly minor and geometric mean values were well within expected limits for aquatic life use. All DO concentrations were well above 5 mg/L, a common screening level used by TCEQ for instantaneous DO measurements (TNRCC, 2000). Mean pH values also were well within the general range of 6.5 to 9.0 considered for most aquatic life uses (TNRCC, 2000). Of note, aquatic life use evaluations for DO should be based on 24-hr measurements rather than instantaneous measurements, because DO often follows a diurnal cycle with the lowest values often occurring in the early morning prior to the resumption of photosynthetic processes under the presence of sunlight. The measurements presented were generally taken mid-morning between 9am and noon and do not represent diurnal trends in DO.

Similar to nutrients, the highest bacteria concentrations for fecal coliform and *E. coli* in grabs samples was indicated at site GB040 and NF020 and the lowest concentrations were indicated at sites GM060, HY060, and SP020 (Figure 9a and b).

Figure 9 Geometric mean a) fecal coliform and b) *E. coli* concentrations for grab samples at sampling sites collected between January 2001 and December 2005. Data limited to sampling periods when 75 percent or more of sites were flowing. Different letters indicate significantly different mean values at α=0.05 based on a test of LSD.



Overall the geometric or arithmetic mean concentrations for grab samples were reflective of the major land uses in the drainage area above each site (Table 1). Microwatersheds comprising a large percent of dairy waste application fields consistently had some of the highest nutrient, TSS, and bacteria concentrations, while microwatersheds comprised primarily of wood/range generally had the some of the lowest nutrient, TSS, and bacteria concentrations.

Storm Event Data

Basic statistics for storm events were based on event mean concentrations associated with each event rather than individual samples (Appendix C). With regard to geometric mean concentrations for nutrients and TSS, generally storm concentrations were higher than concentrations from routine grab samples, although some exceptions occurred for specific sites and constituent combinations.

The highest geometric mean storm concentrations for NH_3-N and TKN were indicated at sites GB020, GB025, and GB040 with concentrations greater than 0.3 mg/L for NH_3-N and greater than 6 mg/L for TKN (Figure 10a and c). The highest geometric mean storm concentrations for NO_2-N+NO_3-N occurred at sites GB020, GB040, and GC045 with concentrations greater than 2.4 mg/L (Figure 10b). The lowest concentrations for nitrogen constituents consistently occurred at SP020.

For PO_4-P and total-P, the highest geometric mean storm concentrations were at GB020 followed by GB025, and then GB040 and NF020 (Figure 11a and b). Geometric mean concentrations of PO_4-P exceeded 1 mg/L at sites GB020 and GB025, while for total-P, geometric mean storm concentrations at sites NF020, GB040, GB025, and GB020 all exceeded 1 mg/L. The lowest geometric mean PO_4-P and total-P concentrations occurred at sites HY060 and SP020 with geometric mean PO_4-P concentrations less than 0.01 mg/L and total-P concentrations less than 0.1 mg/L.

Geometric mean TSS concentrations for storm events followed a slightly different pattern from PO_4-P and total-P in that site GB020 had fairly low storm concentrations rather than some of the highest concentrations (Figure 11c). In general it would be expected that TSS concentrations would be closely associated with total-P concentrations as a measure of particulate matter moved during storm events. In comparing the ratio of PO_4-P to particulate P in total-P, nearly 70 percent of the total-P measured at GB020 during storm event was associated with PO_4-P or soluble P (Figure 12).

A general ordering of the sites from highest to lowest nutrient concentrations based on an average of the ranking of the geometric mean for NO_2-N+NO_3-N, TKN, PO_4-P and total-P indicated the following:

GB020>GB025>GB040>NF020>IC020>LD040>DB035>NF050>NF009>LG060>AL020
>SF085>GC045>SC020>GM060>DC060>HY060>SP020

This ranking was fairly similar to the ranking indicated for routine grab samples for the high and low end of the scale, although some switching of the ordering of sites occurs in between.

Figure 10 Geometric mean nitrogen concentrations for storm events by site for a) NH_3-N, b) NO_2-N + NO_3-N, and c) TKN monitored between January 2001 and December 2005. Different letters indicate significantly different mean values at α=0.05 based on a test of LSD.

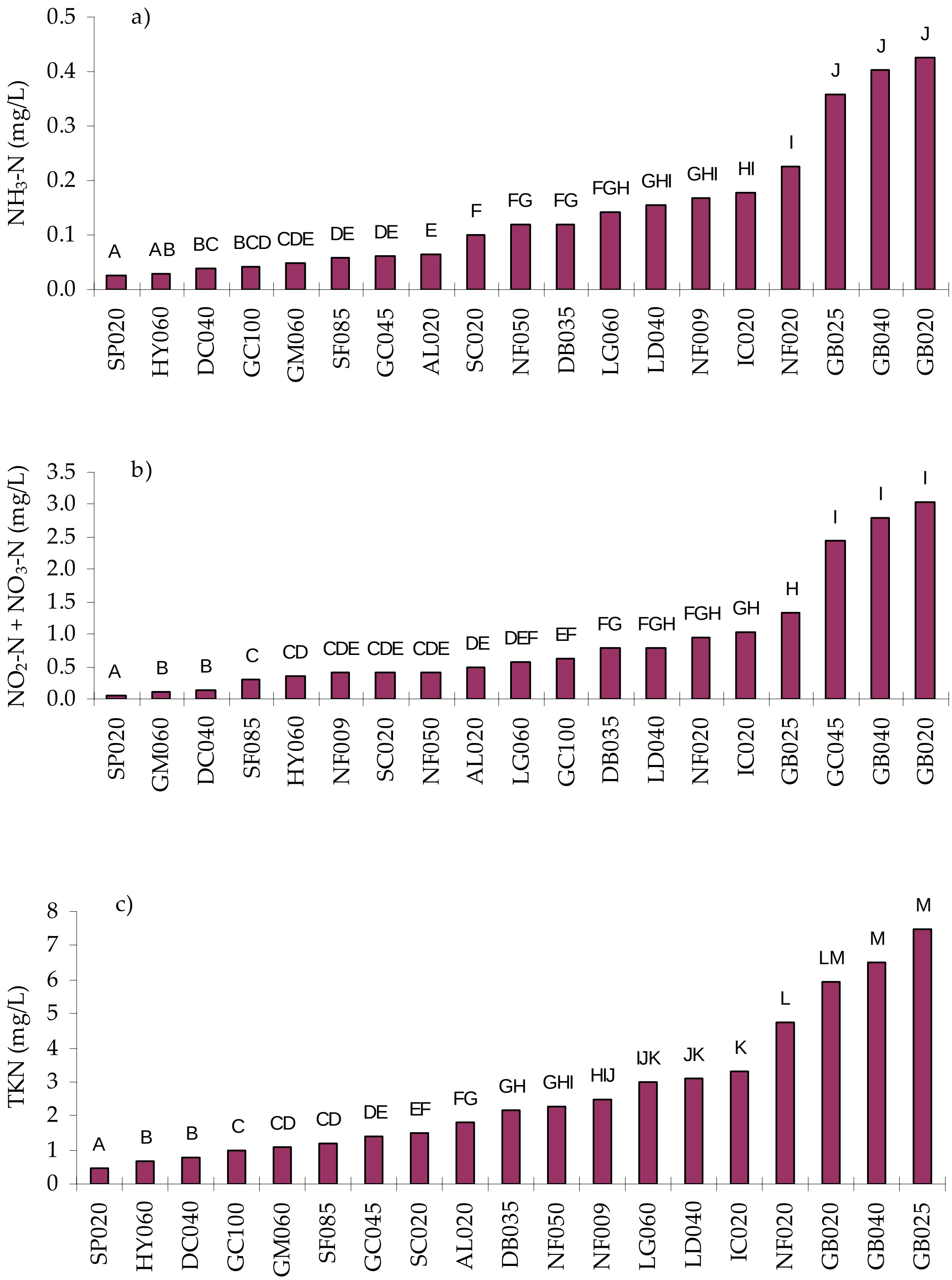


Figure 11 Geometric mean phosphorus and TSS concentrations for storm events by site for a) PO_4-P, b) total-P and c) TSS monitored between January 2001 and December 2005. Different letters indicate significantly different mean values at α=0.05 based on a test of LSD.

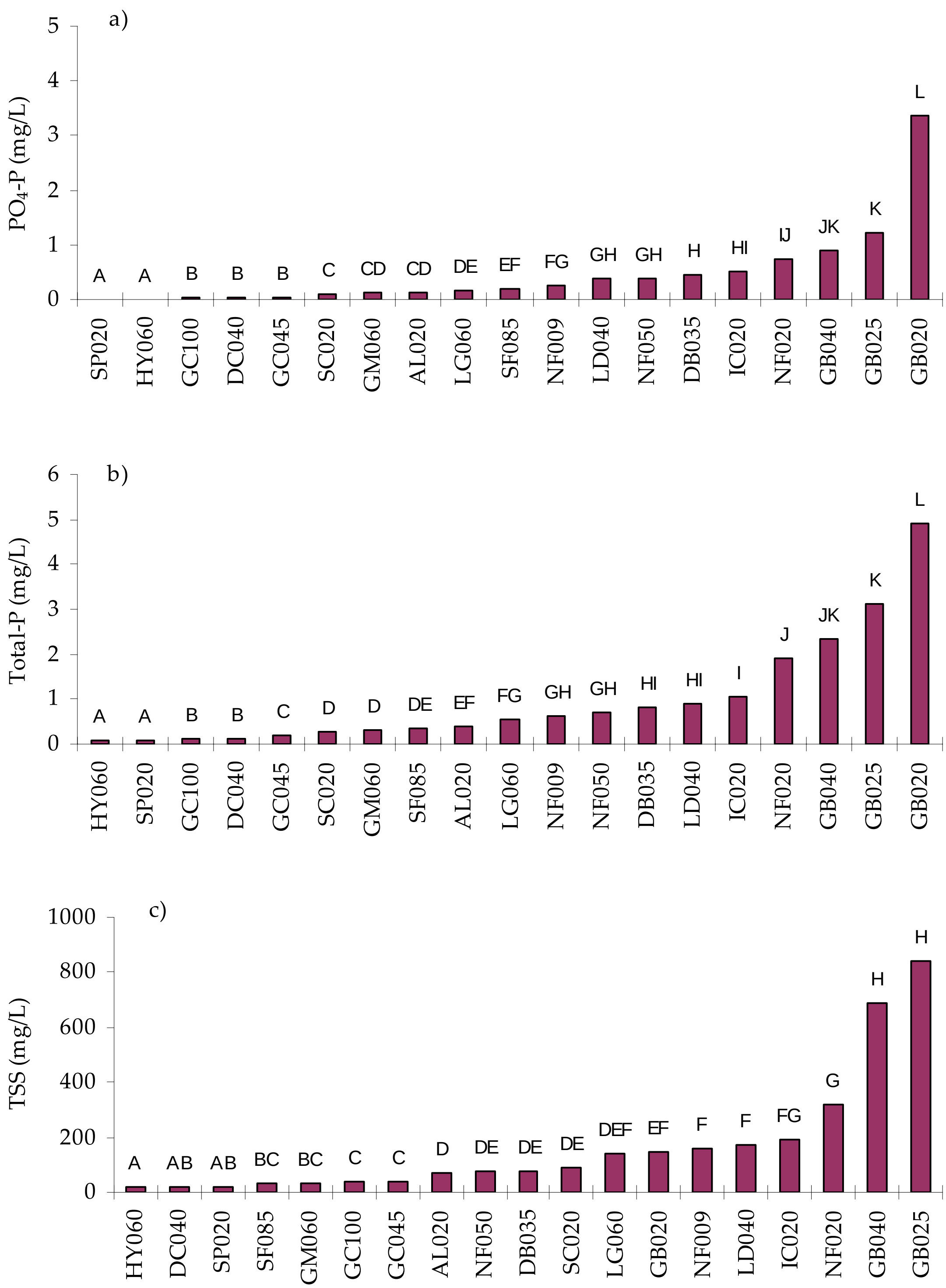
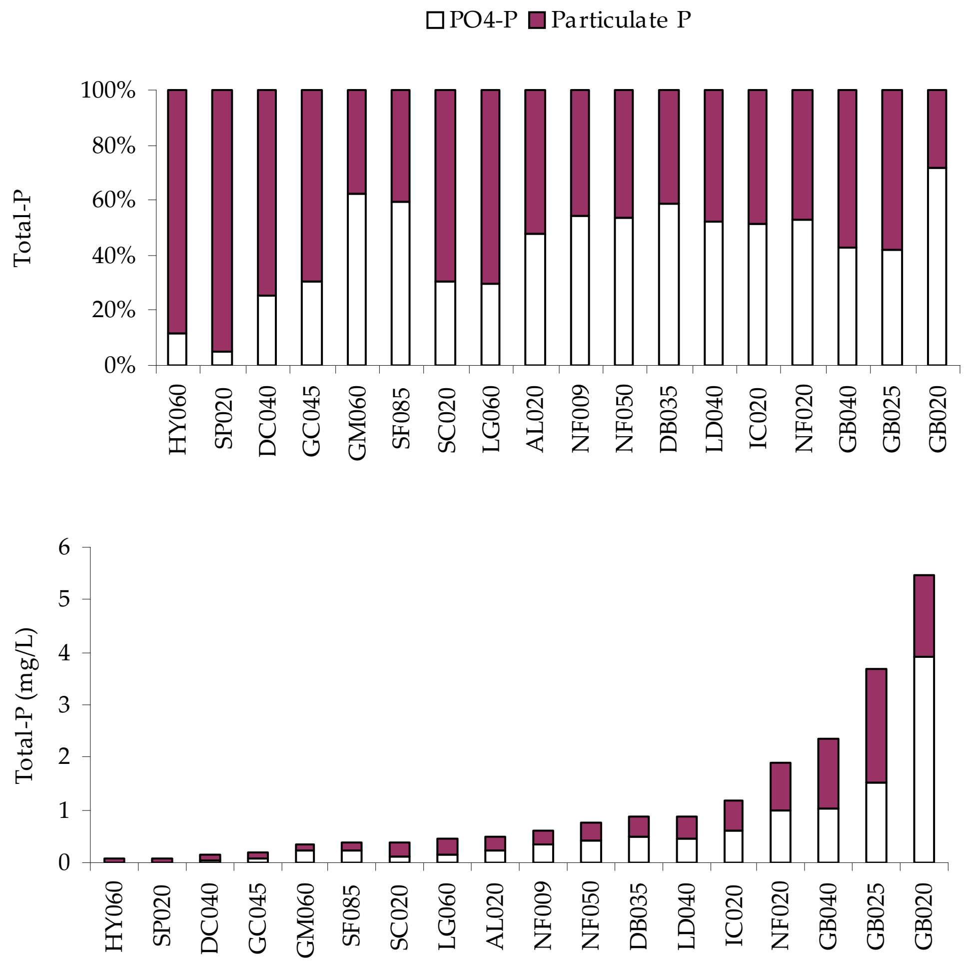


Figure 12 Proportions of PO_4-P and particulate P comprising total P from storm events monitored between January 2001 and December 2005.



As with grab samples, higher geometric mean storm concentrations for nutrients and TSS appeared to be most often associated with microwatersheds with a large proportion indicated for dairy waste application, while lower storm concentrations were generally associated with microwatershed representing predominately wood/ range (Table 1).

Land-Use Associations with Water Quality

To evaluate the association of water quality concentrations with land use, correlation analysis was performed using median concentrations from storm events and land-use characteristics for the drainage area above sampling sites. Results from the correlation analysis showed that the percent dairy waste application fields in the drainage area above sampling sites generally had significant positive correlation coefficients (α = 0.01) for each constituent (Table 5). Significant negative correlation coefficients were generally associated with the percent wood/range in the drainage area above a sampling site. Several other correlations indicated significance at $\alpha = 0.05$; however, these less significant correlations had fairly small correlation coefficients, generally less than 0.60 or an R^2 of 0.36 indicating that less than 36 percent of the variability in water quality could be explained by a single land use.

Table 5 Correlation of land characteristics with event mean concentrations from storm events. 'r' equals the correlation coefficient, while 'p' equals the p-value relating to the level of significance of the correlation. Bolded values represent significant correlations at α=0.01.

		NH_3-N (mg/L)	NO_2-N + NO_3-N (mg/L)	TKN (mg/L)	PO_4-P (mg/L)	Total-P (mg/L)	TSS (mg/L)
Waste Appl. Fields (%)	r	**0.71**	0.50	**0.83**	**0.67**	**0.78**	**0.74**
	p	**0.0007**	0.0303	**<0.0001**	**0.0018**	**<0.0001**	**0.0003**
Wood Range (%)	r	**-0.77**	**-0.62**	**-0.84**	-0.57	**-0.69**	**-0.75**
	p	**0.0001**	**0.0045**	**<0.0001**	0.0107	**0.0011**	**0.0002**
Pasture (%)	r	0.35	0.37	0.28	0.08	0.12	0.24
	p	0.1397	0.1138	0.2539	0.7393	0.6286	0.3158
Cropland (%)	r	-0.48	-0.32	-0.49	-0.52	-0.57	-0.41
	p	0.0395	0.1883	0.0341	0.0212	0.0101	0.0838
Total Area (ha)	r	-0.51	-0.17	-0.49	-0.39	-0.44	-0.44
	p	0.0242	0.4806	0.0338	0.0994	0.0575	0.0618

Regression equations for the percent wood/range and dairy waste application fields in mircowatersheds with water quality indicated slopes of similar magnitudes but in opposite directions (Table 6). For example, TKN indicated a slope of +0.097 for waste application fields and a slope of -0.095 for wood/range (Table 6). For the sites evaluated, microwatersheds with a large portion of land associated with wood/range generally had less land area associated with dairy waste application.

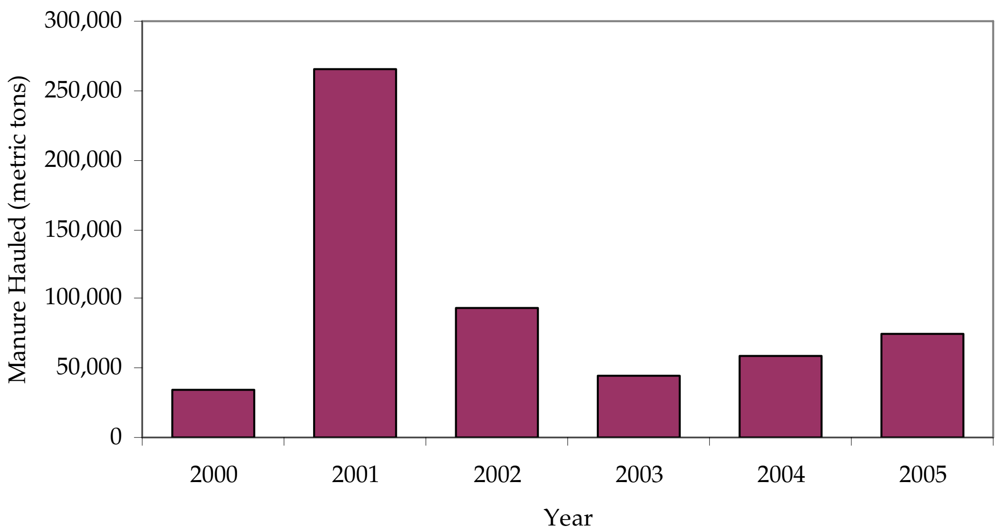
Table 6 Regression equations comparing median event mean concentrations with land use percentages of dairy waste application fields and wood/range in each microwatershed.

Constituent (y) in mg/L	Land Use (x) in percent	Regression Equation	R^2	p-value
NH_3-N	Waste Appl. Fields	y = 0.05 + 0.005x	0.50	0.0007
	Wood Range	y = 0.42 - 0.005x	0.60	0.0001
NO_2-N+NO_3-N	Waste Appl. Fields	y = 0.51 + 0.025x	0.25	0.0303
	Wood Range	y = 2.63 - 0.030x	0.39	0.0045
TKN	Waste Appl. Fields	y = 0.86 + 0.097x	0.69	<0.0001
	Wood Range	y = 7.92 - 0.095x	0.71	<0.0001
PO_4-P	Waste Appl. Fields	y = -0.08 + 0.036x	0.47	0.0011
	Wood Range	y = 2.27 - 0.030x	0.33	0.0107
Total P	Waste Appl. Fields	y = -0.10 + 0.066x	0.61	<0.0001
	Wood Range	y = 4.24 - 0.056x	0.47	0.0011
TSS	Waste Appl. Fields	y = -3.58 + 8.96x	0.55	0.0003
	Wood Range	y = 652 - 8.79x	0.57	0.0002

Manure Hauled to Composting Facilities

While existing water quality conditions still indicate a strong association of nonpoint source nutrient contributions from dairy waste application fields, that contribution is expected to have decreased over time due to the manure composting program. With the initiation of the manure composting program, approximately 570,000 metric tons of dairy manure was hauled-off to composting facilities from within the North Bosque River watershed (NBRW) between November 2000 and December 2005. The greatest manure haul-off occurred in 2001 with a notable drop in 2003 (Figure 13). The amount of manure hauled-off in 2000 represents only two months, November and December. The amount of manure hauled-off in 2001 was about five times the manure hauled in 2004. The relatively large delivery of manure to composting facilities in 2001 was in part related to stockpiling of manure on dairies in anticipation of the project. As a result, manure hauled in 2001 was greater than the total manure generated that year.

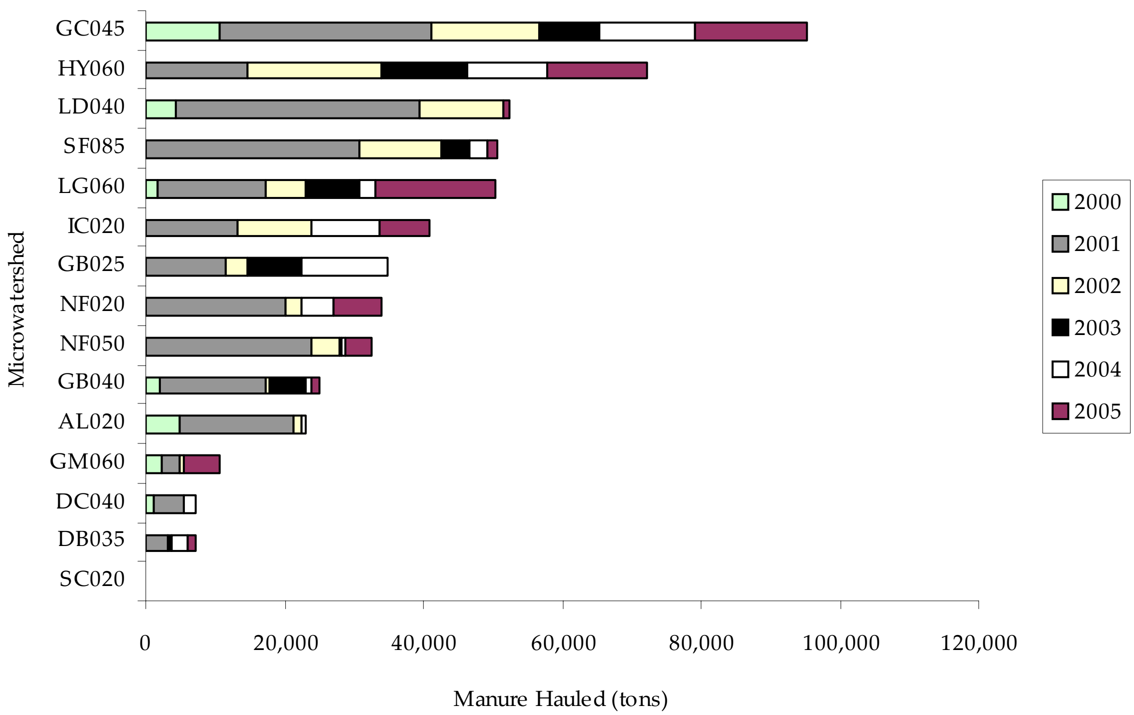
Figure 13 Manure hauled-off from the North Bosque River watershed to composting facilities between November 2000 and December 2005.



The specific reasons for the decrease in manure hauled in 2003 as compared to 2002 and lower levels continuing in 2004 and 2005 are unknown, although it is speculated that other programs may be competing for manure (TIAER, 2003).

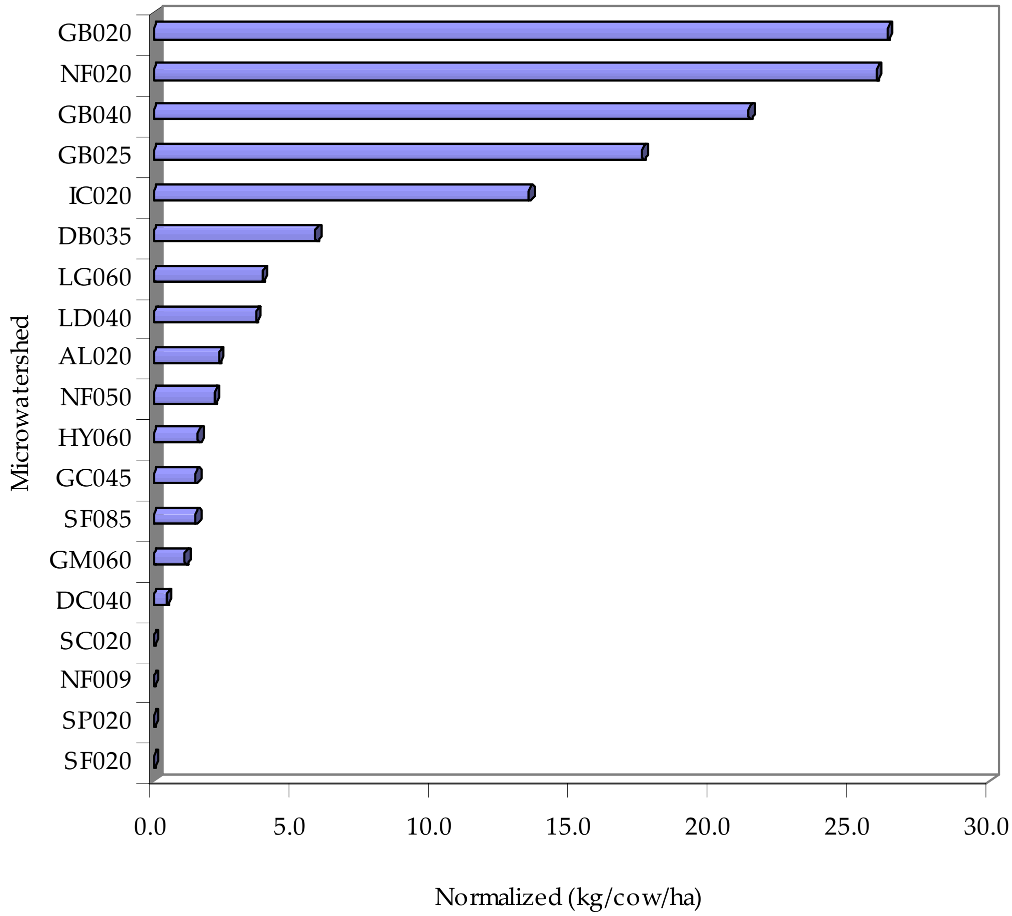
Manure hauled by year was also evaluated by microwatershed (Figure 14). The most manure hauled occurred in the GC045 drainage area on Greens Creek and from above the HY060 drainage area on Honey Creek. The GC045 and HY060 microwatersheds represent two of the larger watershed areas of the sites evaluated (Table 1), so not only the total amount hauled needs to be taken into account, but also the drainage area and the number of dairy cows to more accurately assess the potential impact of the manure composting program on stream water quality.

Figure 14 Manure hauled-off to composting facilities from within microwatersheds above sampling sites within the North Bosque watershed between November 2000 and December 2005. Note: GB020 not shown, because values are the same as for GB025.



In order to relate the amount of manure exported from microwatersheds above sampling sites to changes in water quality, the amount of manure hauled-off was normalized by estimated cow numbers and drainage area (Figure 15). The most manure hauled per cow and unit drainage area occurred in microwatersheds above sites GB020, NF020, and GB040. Of note, the same dairy operations were associated with GB020 and GB025, but the drainage area above GB025 is much larger. Both GB020 and GB025 were included in the monitoring program due to landowner requests, although the drainage area of GB025 includes more of the runoff associated with the waste application fields for these dairy operations. It was expected that the sampling sites with the greatest manure export per cow and unit drainage area would show the greatest improvement in water quality, especially with respect to PO_4-P. Although there are three dairies in the watershed above site SC020 and a few waste application fields in the drainage above sites NF009 and SF020, none of these dairies had manure hauled to composting facilities. The drainage area above site SP020 contains no dairy operations, and, thus, had no manure haul-off.

Figure 15 Manure hauled normalized by drainage area and cow number for microwatersheds above sampling sites.



Water Quality Before/After Results

To look at changes before and after implementation of the manure composting program, seven sites (GB025, GB040, IC020, NF020, SC020, SF020, and SP020) with long-term storm data were evaluated. Summary statistics of the flow adjusted and natural log (ln) transformed data are presented in Table 7 that have been back transformed into the original units. Because the standard deviation of log transformed data is not symmetrical about the mean when back transformed, an upper and lower bound is presented representing the mean plus and minus one standard error. Of note for site SC020, median values from the untransformed data are presented, because the flow-concentration relationship changed between the "before" and "after" periods making flow-adjustment inappropriate. These statistics can be used to generally compare water quality at a site between the two periods. Step trend analyses on the flow adjusted and natural log transformed data are presented in Table 8 that indicate statistically significant differences.

Table 7 Storm event summary statistics for microwatershed sampling sites.
Before and after refer to storm events monitored "before" and "after" the initiation of the manure composting program. Data were flow-adjusted and transformed using a natural log transformation and then back transformed into original units.

Site	Attribute	Number of Events		Mean[a]		Lower Standard Error Bound		Upper Standard Error Bound	
		Before	After	Before	After	Before	After	Before	After
GB025	PO_4-P (mg/L)	36	49	1.26	1.02	1.14	0.93	1.40	1.11
	Total P (mg/L)	36	49	3.23	3.07	2.98	2.87	3.50	3.29
	TSS (mg/L)	35	49	975	930	767	762	1240	1136
	NO_2-N+NO_3-N (mg/L)	36	49	1.10	1.19	0.95	1.06	1.26	1.34
	NH_3-N (mg/L)	36	49	0.28	0.34	0.24	0.29	0.33	0.39
	TKN (mg/L)	36	49	7.79	7.95	7.06	7.31	8.61	8.65
GB040	PO_4-P (mg/L)	28	58	1.12	0.85	1.01	0.79	1.24	0.91
	Total P (mg/L)	28	58	2.55	2.23	2.26	2.06	2.87	2.43
	TSS (mg/L)	28	58	541	635	421	533	696	756
	NO_2-N+NO_3-N (mg/L)	28	58	3.31	2.84	2.64	2.42	4.17	3.33
	NH_3-N (mg/L)	28	58	0.63	0.40	0.54	0.35	0.75	0.44
	TKN (mg/L)	28	58	7.42	6.27	6.55	5.75	8.41	6.85
IC020	PO_4-P (mg/L)	60	53	0.53	0.57	0.48	0.52	0.58	0.63
	Total P (mg/L)	60	53	0.92	1.18	0.85	1.10	0.99	1.28
	TSS (mg/L)	60	53	116	244	102	213	131	279
	NO_2-N+NO_3-N (mg/L)	60	53	0.63	1.29	0.55	1.13	0.71	1.47
	NH_3-N (mg/L)	60	53	0.10	0.19	0.09	0.17	0.11	0.21
	TKN (mg/L)	60	53	2.66	3.59	2.50	3.36	2.82	3.83
NF020	PO_4-P (mg/L)	81	55	0.81	0.68	0.74	0.61	0.88	0.76
	Total P (mg/L)	81	55	1.87	1.88	1.76	1.74	1.99	2.02
	TSS (mg/L)	81	55	595	383	515	321	689	457
	NO_2-N+NO_3-N (mg/L)	81	55	1.08	1.03	1.00	0.94	1.16	1.12
	NH_3-N (mg/L)	81	55	0.25	0.23	0.22	0.20	0.28	0.27
	TKN (mg/L)	80	55	4.72	4.86	4.43	4.50	5.03	5.25
SC020	PO_4-P (mg/L)	52	49	0.14	0.11	na[b]	na	na	na
	Total P (mg/L)	52	49	0.34	0.36	na	na	na	na
	TSS (mg/L)	52	49	64	90	na	na	na	na
	NO_2-N+NO_3-N (mg/L)	52	49	0.39	0.41	na	na	na	na
	NH_3-N (mg/L)	52	49	0.10	0.10	na	na	na	na
	TKN (mg/L)	52	49	1.37	1.55	na	na	na	na
SF020	PO_4-P (mg/L)	95	27	0.03	0.03	0.03	0.02	0.03	0.03
	Total P (mg/L)	95	27	0.19	0.21	0.18	0.19	0.20	0.24
	TSS (mg/L)	95	27	100	197	87	151	116	259
	NO_2-N+NO_3-N (mg/L)	95	27	0.15	0.35	0.13	0.28	0.16	0.42
	NH_3-N (mg/L)	95	27	0.11	0.09	0.10	0.08	0.12	0.11
	TKN (mg/L)	95	27	1.27	1.58	1.21	1.43	1.34	1.75
SP020	PO_4-P (mg/L)	61	61	0.02	0.01	0.02	0.01	0.02	0.02
	Total P (mg/L)	61	61	0.11	0.12	0.10	0.11	0.11	0.13
	TSS (mg/L)	61	61	18	29	15	24	21	35
	NO_2-N+NO_3-N (mg/L)	61	61	0.06	0.06	0.05	0.06	0.06	0.07
	NH_3-N (mg/L)	61	61	0.07	0.03	0.06	0.03	0.07	0.03
	TKN (mg/L)	61	61	0.52	0.60	0.48	0.56	0.56	0.65

a. Median rather than mean values are presented for SC020 that were not adjusted for flow, because the flow-concentration relationship for site SC020 changed between the "before" and "after" monitoring periods. The data for SC020 were also not natural log transformed, because the "before" and "after" analysis was evaluated on median values using the Wilcoxon nonparametric test.

b. na indicates not available. A standard error bound is not presented for SC020, because a standard error on a median is very difficult to accurately compute for non-normal distributions.

Comparing EMCs within a monitoring period, the summary statistics were generally reflective of the major land uses in the drainage area above each site (Table 1). Sampling sites with drainage areas containing a large percentage of land area comprised of dairy waste application fields, such as GB025 and NF020, consistently showed the highest PO_4-P and total P concentrations. Whereas sampling sites with few or no dairies in their drainage area, such as sites SP020 and SF020, indicated the lowest PO_4-P and total P EMCs. The general pattern shown for PO_4-P and total P concentrations also occurred for TKN and to a lesser degree for NH_3-N, NO_2-N+NO_3-N, and TSS (Table 7). Although site GB040 has a moderately high percentage of dairy waste application fields in its drainage area (30 percent), this sites was notes with some of the highest average NO_2-N+NO_3-N and TSS concentrations. Site GB040 does have a history of cows watering from the creek. The direct impact from cows watering in the creek near GB040 is probably a factor in the relatively high NO_2-N+NO_3-N and TSS concentrations found at this site.

In comparing changes in EMCs between the "before" and "after" manure-composting periods, the data were log transformed and flow-adjusted as part of the analysis. Statistically significant reductions in PO_4-P concentrations were observed at site GB040 for both the ANCOVA and WRS results (Table 8). This reduction was estimated to be 25 percent of the "before" concentration (Table 9). At sites GB025 and NF020, reductions in PO_4-P were significant based only on the WRS test. All three sites (GB025, GB040, and NF020) are highly impacted by dairy operations (Table 1), and these operations have had a relatively high level of participation in the manure composting program.

Table 8 P-values from analysis of covariance (ANCOVA) and Wilcoxon Rank Sum (WRS) comparing event mean concentrations "before" and "after" the start of the manure haul-off program. Arrows indicate significant increases and decreases (alpha=0.1) in storm water quality from "before" to "after" implementation of the manure composting program.

Site	Analysis	PO_4-P	Total P	TSS	NO_2-N +NO_3-N	NH_3-N	TKN
GB025	ANCOVA	0.1275	0.6442	0.8840	0.6668	0.4132	0.8831
	WRS	0.0994(↓)	0.4103	0.3283	0.1763	0.1107	0.4452
GB040	ANCOVA	0.0270(↓)	0.3782	0.6060	0.5809	0.0246(↓)	0.2788
	WRS	0.0029(↓)	0.0457(↓)	0.3490	0.2401	0.0298(↓)	0.0245(↓)
IC020	ANCOVA	0.5998	0.0252(↑)	0.0002(↑)	0.0003(↑)	0.0008(↑)	0.0015(↑)
	WRS	0.2110	0.0033(↑)	0.0010(↑)	0.0004(↑)	0.0008(↑)	0.0006(↑)
NF020	ANCOVA	0.2283	0.9898	0.0554(↓)	0.6556	0.7333	0.7764
	WRS	0.0504(↓)	0.1056	0.0223(↓)	0.2295	0.2418	0.2173
SC020	ANCOVA	na[a]	na	na	na	na	na
	WRS[b]	0.4473	0.2841	0.0504(↑)	0.2626	0.4810	0.0343(↑)
SF020	ANCOVA	0.7746	0.3307	0.0308(↑)	0.0001(↑)	0.4015	0.0555(↑)
	WRS	0.1362	0.1530	0.0586(↑)	0.0007(↑)	0.1348	0.1231
SP020	ANCOVA	0.0226(↓)	0.3047	0.0684(↑)	0.4214	<0.0001(↓)	0.1780
	WRS	0.0073(↓)	0.2746	0.0294(↑)	0.1493	<0.0001(↓)	0.2661

a. na indicates not applicable due to changes in the flow-concentration relationship at SC020 between the "before" and "after" periods violating assumptions for the ANCOVA procedure.
b. EMCs at SC020 were not flow-adjusted prior to conducting the analysis, because the flow-concentration relationship had changed between the "before" and "after" periods due to the construction of a small dam upstream of the site.

In comparison, significant reductions in PO_4-P were also indicated at site SP020, a least impacted stream site (Table 8). It is suspected that improvements in laboratory precision for PO_4-P played a role in the detection of significant decreases in the low storm PO_4-P concentrations at SP020, although other factors, such as differences in weather and land management patterns between the two time periods cannot be ruled out. Regardless of the cause, the small absolute decrease at SP020 cannot fully explain the much larger absolute decreases noted at sites GB025 and GB040 (Table 9). Because somewhat different timeframes were evaluated for each site (Table 2), care should be taken in comparing absolute changes for the "before" and "after" periods at a site between sites. Also, the relative change at a site was dependent on the absolute value of the "before" and "after" measurements, so the absolute values should be taken into consideration in evaluating these relative changes.

Table 9 Estimated change in flow adjusted PO_4-P concentrations "before" and "after" implementation of the manure composting program.

Site	PO_4-P (mg/L)[a]		Absolute Change (mg/L)	Relative Change (%)[b]
	Before	After		
GB025	1.26	1.02	-0.24	-19.0
GB040	1.12	0.845	-0.28	-24.6
IC020	0.529	0.571	0.042	+7.9
NF020	0.805	0.677	-0.128	-15.9
SC020[c]	0.135	0.111	-0.024	-17.8
SF020	0.030	0.029	-0.001	-3.3
SP020	0.020	0.014	-0.006	-30.0

a. Back transformed from natural log into original linear scale as $PO_4\text{-}P_{(Before)} = e_{before}$ and $PO_4\text{-}P_{(After)} = e_{after}$, where "before" and "after" represent EMCs adjusted for the covariate flow (on natural log scale) from the ANCOVA and 'e' is the base of the natural logarithm.

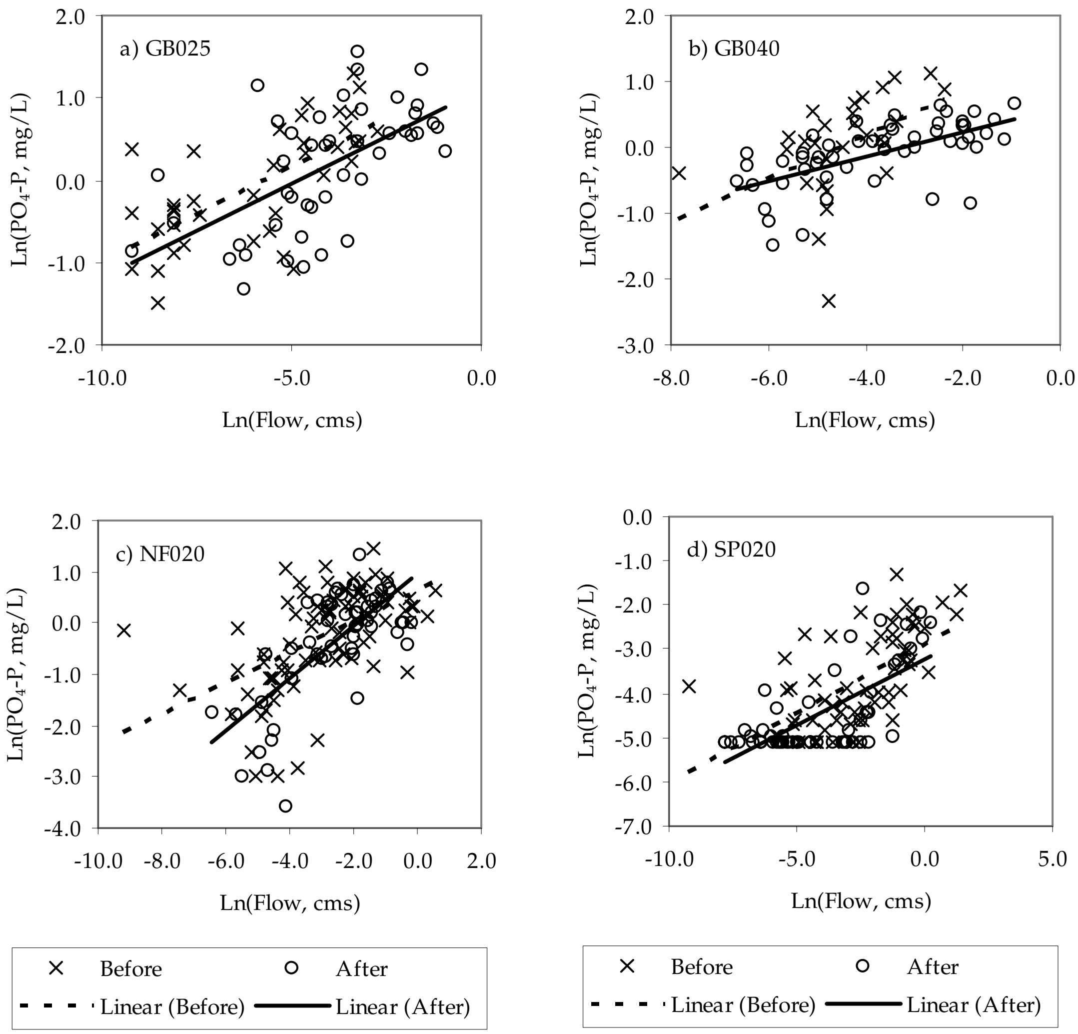
b. Percent change on a linear scale was calculated as $([PO_4\text{-}P_{after} - PO_4\text{-}P_{before}]/PO_4\text{-}P_{before})*100$

c. Percent change for SC020 is presented for flow unadjusted median values rather than flow-adjusted values, because the flow-concentration relationship changed over the analysis period.

At the other sites monitored, no statistical differences in the mean or median PO_4-P concentrations between the before and after periods were indicated. Of note only the nonparametric Wilcoxon rank sum test was used for data from site SC020, since the flow-concentration relationship significantly changed during the study period for this site violating an assumption of the ANCOVA procedure. Also, EMCs at SC020 were not flow adjusted prior to using the WRS procedure, because of this change in the flow-concentration relationship.

At GB025, significant differences in PO_4-P were not indicated between the two periods based on ANCOVA, although a slight downward trend was indicated from the WRS test (Table 8). The flow-PO_4-P relationship at site GB025 stayed fairly consistent during the "before" and "after" periods, although the "after" regression line had a lower intercept than the "before" regression line indicating the potential for minor, albeit not statistically significant, changes in PO_4-P concentrations (Figure 16a). The flow-PO_4-P concentration relationship for GB040 (Figure 16b) showed that the reduction in PO_4-P concentration during the manure composting program was greater under higher than lower flow conditions. However, the opposite was seen at NF020 with a larger decrease in PO_4-P concentrations under lower than higher flow conditions (Figure 16c). These regressions may partly explain why the statistical significance for a reduction in PO_4-P concentration at NF020 was apparent only with the WRS test and not the ANCOVA (Table 8).

Figure 16 Relationship of event mean concentrations of PO_4-P to average storm flow for sites a) GB025, b) GB040, c) NF020, and d) SP020. Ln represents the natural log of the data.



For comparison, flow-concentration relationships from the ANCOVA are shown for SP020 in Figure 16d. The linear "before" regression line was consistently above the linear "after" regression line indicating a clear decrease in EMCs of PO_4-P in the "after" period. The impact of the relatively low concentrations measured at SP020 is also shown by truncation of the data set at half the largest method detection limit.

There was no significant difference in EMCs of total P during the two time periods at sites NF020, GB025, SF020, and SC020 (Table 8), while a slight but significant decrease in total P was indicated from the WRS test at GB040. A significant increase in EMCs of total P were indicated for both the ANCOVA and WRS procedures at site IC020.

While decreases in P constituents were expected with the manure-composting program, expected changes in nitrogen constituents were less certain. Although less manure was applied to the land during the manure composting program, it is likely that producers applied more commercial nitrogen as fertilizer to meet crop needs. The water quality results for NH_3-N were mixed (Table 8). Ammonia decreased at sites GB040 and SP020 and increased at site IC020. At site IC020, increases in EMCs of NO_2-N+NO_3-N and TKN were apparent during the period after the implementation of the manure-composting program. Similarly, site SF020 showed an increase in NO_2-N+NO_3-N and TKN. In addition, increases in TSS were noted at sites IC020, SF020, and SP020. It is speculated that changes in land use, such as an increase in cropland farming, would increase concentrations of TSS and related constituents, but without further information detailing specific land use practices within these drainage areas, it is difficult to know why these increases and decreases occurred.

Discussion

Several factors determine the success of nutrient management practices on stream water quality within a drainage area. These factors include the effectiveness of the management (Meals, 1992; Bottcher et al., 1995), land-use type (Wang, 2001, Fisher et al., 2000), chemical and hydrologic factors (Sharpley et al. 1999; Moog and Whiting, 2002), length of monitoring (Clausen et al., 1992), and level of farmer participation (Meals, 1992). Most of these factors can be controlled when designing field plot studies, and therefore, a desired result can be obtained within a reasonable period of time. On the watershed or even subwatershed scale, it is often difficult to control these confounding factors, and changes in water quality generally occur more gradually even with fairly abrupt changes in land management. As examples of confounding factors within the microwatersheds monitored, the TCEQ inspected number of cows (Figure 17) and the amount of manure hauled per year (Figure 18) varied notably from year to year.

Figure 17 Temporal variation in estimated cow numbers in microwatersheds above sampling sites.

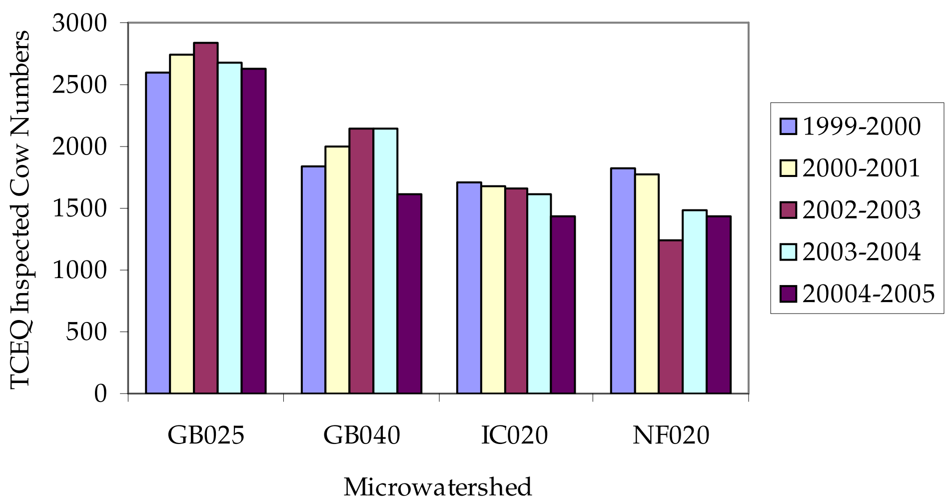
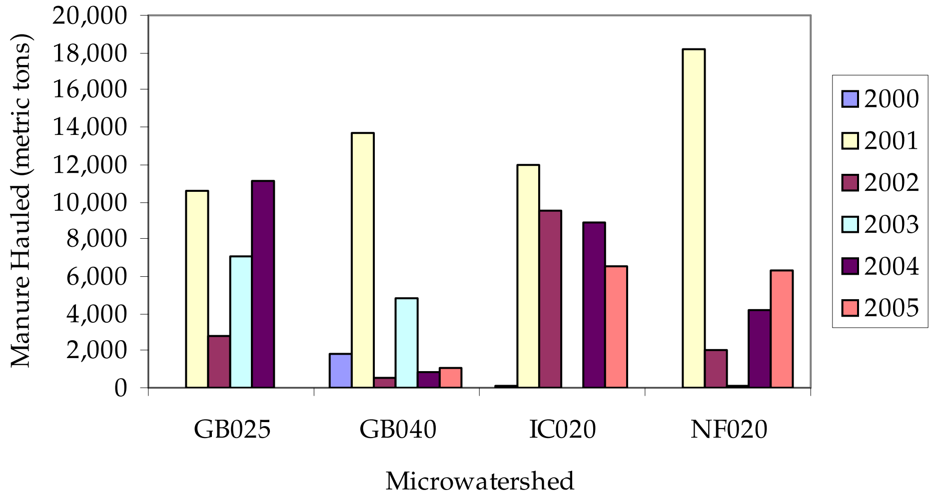


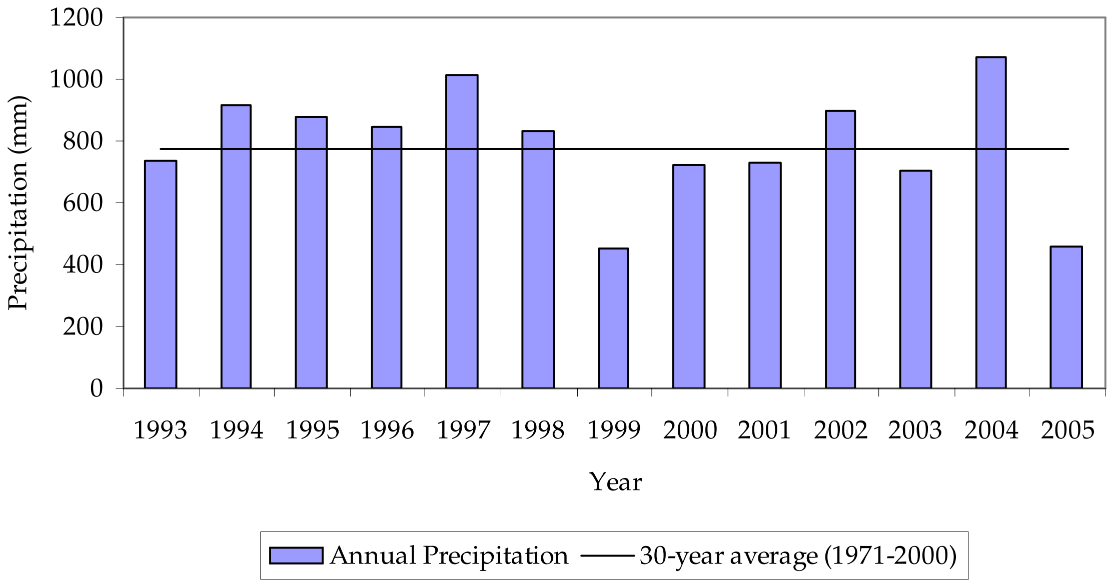
Figure 18 Temporal changes in manure hauled within microwatersheds above sampling sites.



Changes in water quality associated with nonpoint source contributions also often lag changes in land management, because of residual impacts from past management practices (Clausen et al., 1992; Meals, 1992, 1996; Nikolaidis et al., 1998). The length of this time lag can vary greatly, particularly with regard to phosphorus, based on whether the soil itself is acting as a sink or source of phosphorus (Sharpley, 1995; Sharpley and Rekolainen, 1997).

Although flow-adjusting data prior to analysis helps account for hydrologic differences that occur between storm events, antecedent weather conditions and long-term weather patterns, especially in precipitation, may still have an affect on changes in water quality with changes in management practices that is not accounted for by streamflow adjustment. The "before" and "after" monitoring design is based on the assumption that the weather conditions have, on average, remained the same during the two monitoring phases. However, historical precipitation data for Stephenville, Texas shows that precipitation after the start of the manure composting program in November 2000 was below average except in 2002 and 2004 (Figure 19). Before the start of the manure-composting program, many of the years showed precipitation well above the long-term average. With regard to antecedent conditions, precipitation in 1999 was well below average, and in 2000, while much increased compared to 1999, precipitation was still below average. These relatively dry conditions just prior to the start of the manure-composting program in late 2000 may have contributed to the lag time between implementation of the program and improvement in runoff water quality.

Figure 19 Temporal variability of annual precipitation at Stephenville, Texas. Data source: National Weather Service.



While rarely does a year represent "average" or normal precipitation conditions, it is expected that with more monitoring conditions "after" the implementation of the manure composting program will start to more closely resemble the conditions "before" the program began. As more stream data become available in the "after" period, comparisons between the two time periods should be reevaluated to make sure that PO_4-P reductions associated with the manure composting program continue to persist under varying weather conditions.

CHAPTER 5

Summary and Conclusions

An extensive effort has been made within the watershed to provide outreach to landowners, particularly dairy operators, to update WQMPs and develop CNMPs to include practices for nutrient management. Although the TMDL Implementation Plan for the North Bosque River was approved in 2002, the political and social climate for a variety of reasons, including litigation between the City of Waco and the Dairy Industry, have caused delays in the adoption of new practices by producers. This assistance program has lead to the updating of 22 WQMPs in the Upper Leon and 9 WQMPs in the Cross Timbers SWCDs. The most frequent management practices noted involved pasture planting, brush removal (chemical and mechanical), fencing, and water development via ponds and wells. While these WQMPs were not generally specific to dairy operations, these practices should help improve nutrient management in the watershed through better land use and improved flexibility in water management for crop and animal production.

Assessment of water quality was conducted at 19 microwatershed sites located in the upper third of the North Bosque River watershed, where most of the dairy operations are located. In relation to land use, storm water runoff between 2001 and 2005 indicated a strong positive association of storm water nutrients and TSS with the amount of land area associated with dairy waste application fields. Dairy waste application fields still appear to be the most prominent contributing nonpoint source in the North Bosque River watershed.

While the adoption of WQMPs and CNMPs has been quite slow, one program within the TMDL Implementation Plan that has been quite active has been the manure hauling and composting projects. Through DMES, a total of nearly 570,000 metric tons of dairy manure have been hauled to composting facilities from within the North Bosque River watershed between November 2000 and December 2005. This amount of manure represents about 50 percent of the dairy manure produced during this time.

To evaluate improvement in water quality associated with the manure haul-off and composting program, seven microwatershed monitoring sites (GB025, GB040, IC020, NF020, SC020, SF020, and SP020) with long-term data representing drainage areas with a range of land uses and participation in the composting program were evaluated. Land uses within these microwatersheds ranged from little or no land associated with dairy waste application, as in the land area above sites SP020 and SF020, to 30 to 55 percent of the land area used for dairy waste application, as in the land area above sites GB025, GB040, and NF020. The data were analyzed as a "Before/After" monitoring design using both parametric (analysis of covariance = ANCOVA) and nonparametric (Wilcoxon rank sum = WRS) procedures. For ANCOVA, data were flow adjusted by using average storm flow as a covariate. For WRS, data were flow adjusted using the locally weighted regression and smoothing scatter plots (LOWESS) procedure prior to analysis.

Statistically significant reductions in PO_4-P concentrations were observed at sites GB025, GB040, and NF020. The land area above these three sites had the highest levels of participation in the manure composting program when the amount of manure hauled was normalized on both a per cow unit and per land area basis. About 50 percent of the land area in the drainage areas above sites GB040 and NF020 were associated with dairy waste application fields indicating a relatively large land area potentially not receiving waste with manure hauled-off. The finding of reduction in PO_4-P is similar to the previous report that analyzed data through 2003 and 2004 (Bekele and McFarland, 2004a and McFarland et al., 2005).

Of note, significant changes in PO_4-P concentrations were also indicated at site SP020. Site SP020 is considered a least impacted site with no dairies and relatively little intensive agriculture in its drainage area. This decrease in PO_4-P concentrations at SP020, although highly significant, occurred at relatively low PO_4-P concentrations with mean event mean concentrations of 0.02 mg/L in the "before" period and 0.01 mg/L in the "after" period. It is suspected that improvements in the precision of laboratory techniques over the monitoring period for PO_4-P have played a role in the detection of changes in these relatively low PO_4-P concentrations, although other factors, such as differences in weather conditions and land use patterns could not be ruled out in explaining this significant decrease in storm PO_4-P concentrations. Regardless of the cause, the small absolute magnitude of the decrease at SP020 could not explain the much larger absolute decreases noted at sites GB025, GB040, and NF020.

While dairy producers should be encouraged to participate in the manure composting program, this program as well as others need to be considered as ways to improve water quality within the North Bosque River. With the implementation of the North Bosque River TMDL and with the nationally recognized need for managing animal waste, a variety of other programs are also targeting the control of nutrient runoff from animal waste application fields. An example includes the requirement of nutrient management plans for concentrated animal feeding operations (CAFO; Federal Register, 2002). The Environmental Protection Agency CAFO rule, passed in February 2003, requires development and implementation of nutrient management plans that consider nitrogen and phosphorus. This EPA rule should be implemented under Texas CAFO regulations (i.e., TCEQ, 2004) by December 2006, although extensions to this deadline are expected to occur.

Responsibilities stemming from the North Bosque River TMDLs for phosphorus require that the TSSWCB take nutrient management planning a step further by aiding in the development of CNMPs for permitted and WQMPs for unpermitted animal feeding operations in the watershed (TCEQ and TSSWCB, 2002). A CNMP targets not only animal waste application fields but the entire production system to ensure that both agricultural production goals and natural resource concerns dealing with nutrient and organic by-products and their adverse impacts on water quality are addressed. While the nutrient management activities under a CNMP do not necessarily lead to the removal of manure from the watershed, as does the manure composting program, CNMPs should better direct utilization of manure on the land leading to decreased nutrient runoff.

With only four years of post implementation monitoring, the manure composting program appears to be positively impacting stream water quality in the North Bosque River. The general decrease in PO_4-P concentrations at sites with the highest levels of manure removed per cow and drainage area (GB040, GB025, and NF020) is an initial indication that DMES project and CMIP are working. The development and implementation of WQMPs and CNMPs is also important to improving water quality in the North Bosque River watershed, but evaluating their impact with regard to water quality improvements will have to be assessed at a later date after more plans have been approved. It is anticipated that over the next year or two, management planning activities will become more apparent in the watershed and will be assessed under an extended monitoring program as a new Clean Water Act 319(h) assessment project.

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APPENDIX A

Technician Activities

Management Plans and Practices

During this project, technicians associated with the Cross Timbers and Upper Leon SWCDs were able to update 31 water quality management plans. The practices associated with these plans involved primarily brush management, pasture planting, fencing, and water development via ponds and wells. A full listing of the practices approved is shown in Table A-1. An asterisk is noted by those practices that were implemented with cost-share funding as of August 2005.

Table A–1 Practices indicated in updated water quality management plans.
UL indicates Upper Leon and CT indicates Cross Timbers. Cost-share and implementation indicated by an asterisk. Partial cost-share for a group for practices indicated by an x.

WQMP#	Practice	Fields	Cost Share (AC/ FT/Cu yds.)	District	Cost-Share as of Aug05
525-03-435	314 Brush Mgt. (Mech)	1	11.3 AC	UL	*
		2	7.7 AC		*
		3	18 AC		*
	382 Fence (5-strand)	1	725 ft		*
	512 Pasture Planting	1	11.3 AC		*
		2	7.7 AC		*
		3	18 AC		*
	600 Terrace Leveling	1	3,945 ft.		*
		2	2,730 ft		*
	642 Well	1	450 ft		*
525-04-442	314 Brush Mgt. (Chem)	1	16 AC	UL	*
	382 Fence (5-strand)	4	1390 ft		*
	512 Pasture Planting	2	8 AC		*
	550 Range Seeding	3	16 AC		*
		5	6 AC		*
		6	12 AC		*
	642 Well	4	350 ft		*
525-04-451	314 Brush Mgt. (Mech)	1	12 AC	UL	*
		2	13 AC		*
	378 Pond	3	3000 cu. Yds		*
	382 Fence (5-strand)	1	850 ft		*
		2	1000 ft		*
		3	625 ft		*
	512 Pasture Planting	1	12 AC		*
		2	15 AC		*
	642 Well	1	450 ft		*
525-03-427	314 Brush Mgt. (Mech)	1	17 AC	UL	*
	378 Pond	1	3000 cu. Yds.		
	382 Fence (5-strand)	1	1100 ft.		*

Table A–1 Practices indicated in updated water quality management plans. (continued) UL indicates Upper Leon and CT indicates Cross Timbers. Cost-share and implementation indicated by an asterisk. Partial cost-share for a group for practices indicated by an x.

WQMP#	Practice	Fields	Cost Share (AC/ FT/Cu yds.)	District	Cost-Share as of Aug05
	550 Range Seeding	1	17 AC		*
		7	21 AC		*
	642 Well	2	450 ft.		
525-03-432	378 Pond	1	3000 cu. Yds.	UL	
	512 Pasture Planting	1	30 AC		
	600 Terrace Leveling		11,000 ft		
525-04-465	314 Brush Mgt. (Mech)	1	11.2 AC	UL	
	378 Pond	2	3000 cu. Yds.		
		3	3000 cu. Yds.		
	382 Fence (5-strand)	2	3085 ft.		
		3	1500 ft.		
	512 Pasture Planting	2	63 AC		
		3	36 AC		
525-05-481	642 Well	15	400 ft.	UL	*
525-05-482	342 Critical Area Planting	2	20 AC	UL	
		8	14 AC		
		9	48 AC		
		10	14.8 AC		
525-03-434	314 Brush Mgt. (Mech)	2	16 AC	UL	*
		3	20 AC		*
		4	40 AC		*
	382 Fence (5-Strand)	1	1400 ft.		*
		2	1410 ft.		*
		4	2575 ft.		*
	512 Pasture Planting	1	25 AC		
	516 Pipeline	1	225 ft.		
	550 Range Seeding	2	16 AC		
		3	20 AC		
		4	40 AC		
	642 Well	2	450 ft.		
525-04-440	382 Fence (5-strand)	4	1920 ft.	UL	*
		6	2500 ft.		*
	512 Pasture Planting	4	39 AC		*
		5	13 AC		*
		6	32 AC		*
		7	17 AC		*
525-04-438	382 Fence (5-strand)	2	1530 ft.	UL	
		3	620 ft.		
		4	1430 ft.		
		6	1850 ft.		
	512 Pasture Planting	4	14 AC		
		6	15 AC		
	516 Pipeline	2	200 ft.		
		3	250 ft.		
		4	100 ft.		
	550 Range Seeding	3	18 AC		

Table A–1 Practices indicated in updated water quality management plans. (continued) UL indicates Upper Leon and CT indicates Cross Timbers. Cost-share and implementation indicated by an asterisk. Partial cost-share for a group for practices indicated by an x.

WQMP#	Practice	Fields	Cost Share (AC/ FT/Cu yds.)	District	Cost-Share as of Aug05
	642 Well	7	450 ft.		
525-04-444	516 Pipeline	3	600 ft.	UL	
	550 Range Seeding	1	38 AC		*
		3	30 AC		*
	642 Well	3	450 ft.		*
525-04-448	378 Pond	1	3000 cu. Yds.	UL	
		3	3000 cu. Yds.		
	382 Fence (5-strand)	3	1360 ft.		
	512 Pasture Planting	1	27 AC		*
		2	28 AC		*
525-03-425	378 Pond	6	3000 cu. Yds.	UL	*
		9	3000 cu. Yds.		*
	382 Fence (5-strand)	1	400 ft.		*
		2	1800 ft.		*
		3	900 ft.		*
		4	4000 ft.		*
		5	1500 ft.		*
		6	700 ft.		*
	512 Pasture Planting	5	38 AC		
525-03-423	382 Fence (5-strand)	10	530 ft.	UL	*
	512 Pasture Planting	9	17 AC		*
525-03-429	314 Brush Mgt (Mech)	1	8 AC	UL	
		2	6 AC		
		5	9 AC		
		6	6 AC		
	378 Pond	2	3000 cu. Yds.		
	382 Fence (5-strand)	1	700 ft.		
		4	1300 ft.		
		6	1300 ft.		
	512 Pasture Planting	1	18 AC		
		4	15 AC		
		6	10 AC		
	550 Range Seeding	2	6 AC		
525-03-445	382 Fencing (5-strand)	1	790 ft.	UL	
		2	500 ft.		
		3	500 ft.		
		4	4250 ft.		
		10	2750 ft.		
	512 Pasture Planting	10	51 AC		
525-04-450	382 Fence (5-strand)	1	1800 ft.	UL	*
		2	2380 ft.		*
	512 Pasture Planting	1	16 AC		*
	642 Well	1	400 ft.		
525-04-472	378 Pond	1	3000 cu. Yds.	UL	*

Table A–1 Practices indicated in updated water quality management plans. (continued) UL indicates Upper Leon and CT indicates Cross Timbers. Cost-share and implementation indicated by an asterisk. Partial cost-share for a group for practices indicated by an x.

WQMP#	Practice	Fields	Cost Share (AC/FT/Cu yds.)	District	Cost-Share as of Aug05
525-04-466	382 Fence (5-strand)	1	1145 ft.	UL	Canceled
		2	1740 ft.		
		4	1510 ft.		
	512 Pasture Planting	3	33.5 AC		
		4	43 AC		
525-04-460	314 Brush Mgt (Mech)	2	14.9 AC	UL	*
	378 Pond	3	3000 cu. Yds.		*
	382 Fence (5-strand)	2	1900 ft.		*
		3	2000 ft.		*
	512 Pasture Planting	2			
	642 Well	2	450 ft.		*
556-03-215	512 Pasture Planting	5,8	14 AC	CT	x
	516 Pipeline	2,5	1380 ft.		
	614 Well decommissioning	4,8	2 wells		
556-03-219	314 Brush Mgt (Mech)	3,12	13 AC	CT	*
		2,5	93 AC		*
	512 Pasture Planting	8	19 AC		*
556-04-257	382 Fence (5-strand)	1	1160 ft.	CT	*
		2	525 ft.		*
		3	685 ft.		*
		5	1360 ft.		*
	512 Pasture Planting	1,2,3,4	32 AC		*
	516 Pipeline	2	95 ft.		*
		3	275 ft.		*
		4	575 ft.		*
		5	500 ft.		*
	642 Well	5	400 ft.		*
556-03-232	314 Brush Mgt (Mech)	5	45 AC	CT	
	382 Fence (5-strand)	5,14,16	3085 ft.		
	642 Well	5	400 ft.		
556-03-222	382 Fence (5-strand)	21,22,24, 25	5622 ft.	CT	*
	512 Pasture Planting	10,13,21, 23	94 AC		*
	516 Pipeline	4,8,9,14	1880 ft.		*
525-03-421	378 Pond	1	3000 cu. Yds.	UL	x
	512 Pasture Planting	1,2	31 AC		
556-05-305	378 Pond	2	3000 cu. Yds.	CT	*
	382 Fence (5-strand)	2	2725 ft.		*
556-03-213	314 Brush Mgt (Mech)	2,3	14 AC	CT	x
	382 Fence (5-strand)	2,3,4	2215 ft.		
	512 Pasture Planting	2,3,4	29 AC		
	516 Pipeline	1,2,3,5	290 ft.		

Table A–1 Practices indicated in updated water quality management plans. (continued) UL indicates Upper Leon and CT indicates Cross Timbers. Cost-share and implementation indicated by an asterisk. Partial cost-share for a group for practices indicated by an x.

WQMP#	Practice	Fields	Cost Share (AC/FT/Cu yds.)	District	Cost-Share as of Aug05
556-03-227	351 Well decommissioning	1	1 well	CT	x
	382 Fence (5-strand)	1	1465 ft.		
	512 Pasture Planting	1,2	45 AC		
	516 Pipeline	1	315 ft.		
	642 Well	1	400 ft.		
556-05-318	378 Pond	1	3000 cu. Yds.	CT	*

Other Activities

Soil and Water Conservation District technicians hired through this project were active in a number of activities, although their primary focus was on the development and updating of water quality management plans. Other activities reported by Mr. Bubba VanZandt and Mr. Justin Odum, technicians with the Cross Timbers and Upper Leon Soil and Water Conservation Districts, are listed below:

- Developed Conservation Plans that meet RMS (Resource Management System)
- Developed Nutrient Management Plans for compost, manure, and inorganic fertilization
- Completed cost-share applications
- Certified practices that are cost shared and that have been implemented
- Assisted with district fish sale
- Assisted with district seed sales
- Supervised Flood Control Program inspections and maintenance
- Delivered and retrieved information for NRCS
- Went to different dairies and to evaluate new technologies
- Helped deliver and judge district contest at local school
- Helped set up and lead land and pasture judging school
- Met with conservation farmers, rancher, and dairyman award winners in the district to take pictures and develop slide shows for the banquet
- Assisted customers at counter with NRCS
- Assisted with booths at farm shows
- Provided technical assistance with non cost shared producers
- Helped measure practices for NRCS with GPS
- Helped stake ponds with NRCS
- Helped with compost rebate program
- Attended Upper Leon SWCD and Cross Timbers SWCD board meetings

- Assisted in the Central Texas SWCD meeting
- Attended NRCS trainings
- Took soil samples at the request of producers and for people that have EQIP contracts with USDS-NRCS
- Helped develop district calendar (annual report) and create narratives for calendar
- Attended Extension Field days
- Assisted NRCS with prescribed burns
- Helped permitted dairies with nutrient management plans and conduct soil testing
- Helped producers set up seeding equipment for grass planting
- Helped with the rental of district seeder and packer
- Worked with producers that are interested in compost rebate programs
- Printed out maps for producers
- Assisted producers on telephone with questions

APPENDIX B

Summary Statistics for Grab Sample Data

All data analyses represent grab samples collected between January 1, 2001 and December 31, 2005. Exact dates will vary by site based on monitoring history.

Table B–1 Summary Statistics for routine grab samples from site AL020 (N = number of samples).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
AL020	PO_4-P (mg/L)	0.168	0.109	0.171	0.001	0.802	60
AL020	Total-P (mg/L)	0.31	0.23	0.26	0.01	1.13	59
AL020	NH_3-N (mg/L)	0.087	0.065	0.074	0.008	0.334	60
AL020	NO_2-N + NO_3-N (mg/L)	0.695	0.210	1.040	0.008	4.19	60
AL020	TKN (mg/L)	1.22	1.13	0.54	0.49	2.74	60
AL020	TSS (mg/L)	36	12	69	1	422	60
AL020	Water Temp. (°C)	16.9	18.0	6.5	5.4	30.9	60
AL020	Conductivity (µmhos/cm)	987	874	582	97	2080	60
AL020	DO (mg/L)	7.1	6.6	3.1	1.2	13.4	60
AL020	pH (standard units)	7.9	7.9	0.3	7.4	9.0	60
AL020	Fecal Coliform (colonies/100ml)	3100	350	12700	12	69000	29
AL020	*Escherichia coli* (colonies/100ml)	2380	225	9530	8	54000	49

Table B–2 Summary Statistics for routine grab samples from site DB035 (N = number of samples).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
DB035	PO_4-P (mg/L)	0.476	0.422	0.323	0.058	1.50	40
DB035	Total-P (mg/L)	0.66	0.56	0.41	0.02	1.49	40
DB035	NH_3-N (mg/L)	0.132	0.060	0.177	0.007	0.685	40
DB035	NO_2-N + NO_3-N (mg/L)	1.45	0.881	1.70	0.004	6.03	40
DB035	TKN (mg/L)	1.80	1.69	0.79	0.25	4.22	40
DB035	TSS (mg/L)	24	14	31	2	144	40
DB035	Water Temp. (°C)	15.2	16.0	5.4	6.2	26.5	40
DB035	Conductivity (µmhos/cm)	1090	1000	532	325	2350	40
DB035	DO (mg/L)	10.1	10.3	3.5	3.8	16.5	40
DB035	pH (standard units)	8.1	8.1	0.2	7.7	8.5	40
DB035	Fecal Coliform (colonies/100ml)	1340	270	3150	52	13900	22
DB035	*Escherichia coli* (colonies/100ml)	3790	240	17200	32	105000	37

Table B–3 Summary Statistics for routine grab samples from site DC040 (N = number of samples).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
DC040	PO_4-P (mg/L)	0.025	0.014	0.036	0.001	0.289	113
DC040	Total-P (mg/L)	0.09	0.07	0.07	0.01	0.41	113
DC040	NH_3-N (mg/L)	0.037	0.024	0.040	0.007	0.243	113
DC040	NO_2-N + NO_3-N (mg/L)	0.138	0.028	0.295	0.004	1.97	113
DC040	TKN (mg/L)	0.50	0.41	0.36	0.04	2.28	113
DC040	TSS (mg/L)	8	4	11	1	68	113
DC040	Water Temp. (°C)	17.3	18.2	6.5	5.5	28.4	113
DC040	Conductivity (µmhos/cm)	587	588	105	305	1070	113
DC040	DO (mg/L)	7.5	7.1	2.9	1.3	14.4	113
DC040	pH (standard units)	7.9	7.9	0.2	7.3	8.4	113
DC040	Fecal Coliform (colonies/100ml)	711	134	2950	12	20000	46
DC040	*Escherichia coli* (colonies/100ml)	401	99	1030	5	6830	86

Table B–4 Summary statistics for routine grab samples from site GB020 (N = number of samples).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
GB020	PO_4-P (mg/L)	5.25	6.22	2.89	0.691	7.60	5
GB020	Total-P (mg/L)	10.7	7.27	10.0	3.36	28.2	5
GB020	NH_3-N (mg/L)	14.2	0.304	30.6	0.220	68.9	5
GB020	NO_2-N + NO_3-N (mg/L)	4.92	6.66	4.16	0.240	9.87	5
GB020	TKN (mg/L)	43.6	6.09	80.2	5.87	187	5
GB020	TSS (mg/L)	493	150	837	22	1980	5
GB020	Water Temp. (°C)	7.0	6.7	2.4	4.1	10.7	5
GB020	Conductivity (µmhos/cm)	1070	519	1260	178	3270	5
GB020	DO (mg/L)	9.9	11.4	2.2	6.5	11.6	5
GB020	pH (standard units)	8.2	8.1	0.2	8.0	8.5	5
GB020	Fecal Coliform (colonies/100ml)	261000	261000	.	9700	512000	2
GB020	*Escherichia coli* (colonies/100ml)	136000	20100	241000	7270	498000	4

Table B–5 Summary statistics for routine grab samples from site GB025 (N = number of samples).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
GB025	PO_4-P (mg/L)	5.01	5.01	.	3.24	6.77	2
GB025	Total-P (mg/L)	6.11	6.11	.	4.37	7.84	2
GB025	NH_3-N (mg/L)	0.879	0.879	.	0.457	1.30	2
GB025	NO_2-N + NO_3-N (mg/L)	8.40	8.40	.	5.40	11.4	2
GB025	TKN (mg/L)	5.43	5.43	.	4.64	6.21	2
GB025	TSS (mg/L)	57	57	.	47	67	2
GB025	Water Temp. (°C)	8.6	8.6	.	6.9	10.4	2
GB025	Conductivity (μmhos/cm)	489	489	.	393	585	2
GB025	DO (mg/L)	10.3	10.3	.	9.3	11.3	2
GB025	pH (standard units)	8.0	8.0	.	7.8	8.2	2
GB025	Fecal Coliform (colonies/100ml)	22000	22000	.	22000	22000	1
GB025	*Escherichia coli* (colonies/100ml)	30400	30400	.	22000	38700	2

Table B–6 Summary statistics for routine grab samples from site GB040 (N = number of samples).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
GB040	PO_4-P (mg/L)	0.825	0.607	0.853	0.007	4.36	49
GB040	Total-P (mg/L)	2.17	0.860	7.28	0.020	51.3	49
GB040	NH_3-N (mg/L)	2.23	0.411	8.94	0.018	57.1	48
GB040	NO_2-N + NO_3-N (mg/L)	15.5	15.5	12.1	0.166	40.8	48
GB040	TKN (mg/L)	7.71	2.59	29.5	0.53	204	49
GB040	TSS (mg/L)	46	22	90	2	630	49
GB040	Water Temp. (°C)	15.8	16.5	6.8	3.7	27.4	49
GB040	Conductivity (μmhos/cm)	3050	3280	1260	405	6770	49
GB040	DO (mg/L)	10.3	9.8	4.3	3.4	23.2	49
GB040	pH (standard units)	8.2	8.2	0.2	7.6	8.7	49
GB040	Fecal Coliform (colonies/100ml)	9670	8350	9030	700	38000	24
GB040	*Escherichia coli* (colonies/100ml)	15400	6200	23700	400	112000	37

Table B–7 Summary statistics for routine grab samples from site GC045 (N = number of samples).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
GC045	PO_4-P (mg/L)	0.046	0.011	0.072	0.001	0.359	58
GC045	Total-P (mg/L)	0.14	0.10	0.13	0.01	0.56	58
GC045	NH_3-N (mg/L)	0.071	0.054	0.063	0.008	0.339	58
GC045	NO_2-N + NO_3-N (mg/L)	6.11	3.71	6.06	0.004	22.2	58
GC045	TKN (mg/L)	1.06	0.86	0.54	0.17	2.31	58
GC045	TSS (mg/L)	25	16	26	2	112	57
GC045	Water Temp. (°C)	18.9	20.5	6.3	6.5	28.0	58
GC045	Conductivity (µmhos/cm)	760	742	253	306	1250	58
GC045	DO (mg/L)	7.8	7.7	2.3	3.5	13.5	58
GC045	pH (standard units)	7.9	7.9	0.2	7.3	8.4	58
GC045	Fecal Coliform (colonies/100ml)	497	163	1010	2	4500	21
GC045	*Escherichia coli* (colonies/100ml)	5520	235	34900	0	242000	48

Table B–8 Summary statistics for routine grab samples from site GM060 (N = number of samples).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
GM060	PO_4-P (mg/L)	0.082	0.020	0.159	0.002	1.03	80
GM060	Total-P (mg/L)	0.16	0.08	0.22	0.01	1.46	80
GM060	NH_3-N (mg/L)	0.052	0.025	0.117	0.007	0.917	80
GM060	NO_2-N + NO_3-N (mg/L)	0.090	0.015	0.204	0.004	1.50	80
GM060	TKN (mg/L)	0.58	0.47	0.45	0.06	2.78	80
GM060	TSS (mg/L)	7	3	10	1	47	80
GM060	Water Temp. (°C)	17.4	17.5	7.6	3.5	37.4	80
GM060	Conductivity (µmhos/cm)	938	881	317	417	1720	80
GM060	DO (mg/L)	10.0	10.1	1.9	5.9	15.1	80
GM060	pH (standard units)	8.1	8.1	0.2	7.5	8.8	80
GM060	Fecal Coliform (colonies/100ml)	794	35	4220	2	26100	38
GM060	*Escherichia coli* (colonies/100ml)	951	24	4222	0	25000	63

Table B–9 Summary statistics for routine grab samples from site HY060 (N = number of samples).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
HY060	PO_4-P (mg/L)	0.004	0.002	0.007	0.001	0.043	72
HY060	Total-P (mg/L)	0.06	0.05	0.06	0.01	0.48	72
HY060	NH_3-N (mg/L)	0.029	0.021	0.027	0.007	0.163	72
HY060	NO_2-N + NO_3-N (mg/L)	0.639	0.042	1.08	0.004	4.06	72
HY060	TKN (mg/L)	0.38	0.35	0.25	0.06	1.30	72
HY060	TSS (mg/L)	4	2	11	1	90	72
HY060	Water Temp. (°C)	18.3	19.9	6.6	5.6	28.0	72
HY060	Conductivity (µmhos/cm)	523	534	74	336	643	72
HY060	DO (mg/L)	8.5	8.3	2.1	4.4	14.8	72
HY060	pH (standard units)	7.8	7.8	0.2	7.3	8.2	72
HY060	Fecal Coliform (colonies/100ml)	139	66	257	5	1420	37
HY060	*Escherichia coli* (colonies/100ml)	125	62	197	2	1200	62

Table B–10 Summary Statistics for routine grab samples from site IC020 (N = number of samples).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
IC020	PO_4-P (mg/L)	0.363	0.193	0.533	0.007	3.010	45
IC020	Total-P (mg/L)	0.61	0.38	0.82	0.01	4.16	45
IC020	NH_3-N (mg/L)	0.460	0.070	1.33	0.008	8.07	45
IC020	NO_2-N + NO_3-N (mg/L)	2.07	1.70	2.01	0.006	8.72	45
IC020	TKN (mg/L)	2.47	1.78	2.41	0.63	15.3	45
IC020	TSS (mg/L)	24	11	45	2	240	45
IC020	Water Temp. (°C)	17.9	17.8	6.7	6.2	31.3	45
IC020	Conductivity (µmhos/cm)	1330	1325	531	458	2800	45
IC020	DO (mg/L)	12.7	12.4	3.0	6.1	20.8	45
IC020	pH (standard units)	8.3	8.3	0.3	7.5	8.9	45
IC020	Fecal Coliform (colonies/100ml)	13400	782	51300	0	219000	18
IC020	*Escherichia coli* (colonies/100ml)	5280	600	21900	0	123000	31

Table B–11 Summary statistics for routine grab samples from site LD040 (N = number of samples).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
LD040	PO_4-P (mg/L)	0.493	0.383	0.435	0.092	2.47	29
LD040	Total-P (mg/L)	0.72	0.56	0.92	0.14	5.22	29
LD040	NH_3-N (mg/L)	0.762	0.080	3.47	0.012	18.8	29
LD040	NO_2-N + NO_3-N (mg/L)	3.53	1.93	4.32	0.015	14.4	29
LD040	TKN (mg/L)	2.82	1.42	6.18	0.81	34.7	29
LD040	TSS (mg/L)	20	10	25	1	99	29
LD040	Water Temp. (°C)	15.7	16.1	5.7	6.4	26.2	29
LD040	Conductivity (μmhos/cm)	1170	1120	438	127	2230	29
LD040	DO (mg/L)	8.8	8.9	2.0	4.6	13.2	29
LD040	pH (standard units)	8.0	8.0	0.2	7.6	8.3	29
LD040	Fecal Coliform (colonies/100ml)	6170	1400	9710	46	24200	9
LD040	*Escherichia coli* (colonies/100ml)	6660	785	17800	23	77000	26

Table B–12 Summary statistics for routine grab samples from site LG060 (N = number of samples).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
LG060	PO_4-P (mg/L)	0.063	0.043	0.059	0.002	0.205	49
LG060	Total-P (mg/L)	0.17	0.11	0.13	0.01	0.59	49
LG060	NH_3-N (mg/L)	0.081	0.060	0.067	0.008	0.264	49
LG060	NO_2-N + NO_3-N (mg/L)	0.631	0.261	0.730	0.009	2.48	49
LG060	TKN (mg/L)	1.19	0.99	0.70	0.36	3.34	49
LG060	TSS (mg/L)	23	11	31	2	171	49
LG060	Water Temp. (°C)	17.5	18.1	6.6	5.3	29.0	49
LG060	Conductivity (μmhos/cm)	720	706	206	320	1050	49
LG060	DO (mg/L)	9.4	9.1	2.6	4.7	14.9	49
LG060	pH (standard units)	8.1	8.1	0.2	7.7	8.6	49
LG060	Fecal Coliform (colonies/100ml)	4430	755	10400	70	39500	21
LG060	*Escherichia coli* (colonies/100ml)	3160	393	8730	50	40800	38

Table B–13 Summary statistics for routine grab samples from site NF009 (N = number of samples).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
NF009	PO_4-P (mg/L)	0.189	0.107	0.191	0.008	0.750	52
NF009	Total-P (mg/L)	0.39	0.31	0.32	0.01	1.63	52
NF009	NH_3-N (mg/L)	0.385	0.062	1.32	0.007	9.48	52
NF009	NO_2-N + NO_3-N (mg/L)	0.387	0.051	0.797	0.004	4.01	52
NF009	TKN (mg/L)	1.91	1.35	2.24	0.31	15.9	52
NF009	TSS (mg/L)	31	19	42	1	274	52
NF009	Water Temp. (°C)	14.9	15.6	5.8	5.8	24.9	52
NF009	Conductivity (µmhos/cm)	2070	2060	1029	270	4290	52
NF009	DO (mg/L)	7.7	7.5	3.5	2.6	16.9	52
NF009	pH (standard units)	7.9	7.9	0.3	7.4	8.7	52
NF009	Fecal Coliform (colonies/100ml)	1290	210	2930	22	12400	21
NF009	*Escherichia coli* (colonies/100ml)	3300	404	13800	22	92100	44

Table B–14 Summary statistics for routine grab samples from site NF020 (N = number of samples).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
NF020	PO_4-P (mg/L)	1.22	1.09	0.877	0.156	4.08	23
NF020	Total-P (mg/L)	1.63	1.37	1.13	0.22	4.57	23
NF020	NH_3-N (mg/L)	0.318	0.105	0.417	0.008	1.69	24
NF020	NO_2-N + NO_3-N (mg/L)	0.936	0.431	1.32	0.004	5.28	24
NF020	TKN (mg/L)	3.59	2.68	2.21	1.64	9.74	24
NF020	TSS (mg/L)	37	22	44	2	192	24
NF020	Water Temp. (°C)	13.4	13.3	5.0	5.6	25.2	24
NF020	Conductivity (µmhos/cm)	2810	2446	1550	377	5400	24
NF020	DO (mg/L)	8.9	9.1	2.8	4.2	15.5	24
NF020	pH (standard units)	8.1	8.1	0.2	7.6	8.5	24
NF020	Fecal Coliform (colonies/100ml)	76900	12500	98400	166	189000	5
NF020	*Escherichia coli* (colonies/100ml)	17500	1360	41400	73	144000	20

Table B–15 Summary statistics for routine grab samples from site NF050 (N = number of samples).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
NF050	PO_4-P (mg/L)	0.310	0.283	0.187	0.045	0.796	36
NF050	Total-P (mg/L)	0.49	0.45	0.26	0.07	1.09	36
NF050	NH_3-N (mg/L)	0.138	0.062	0.212	0.010	1.05	36
NF050	NO_2-N + NO_3-N (mg/L)	0.305	0.206	0.338	0.004	1.55	36
NF050	TKN (mg/L)	1.94	1.80	0.61	1.18	4.07	36
NF050	TSS (mg/L)	25	19	24	2	133	36
NF050	Water Temp. (°C)	16.3	16.9	6.5	5.9	25.9	36
NF050	Conductivity (µmhos/cm)	682	601	432	212	1740	36
NF050	DO (mg/L)	8.6	8.5	2.8	4.0	14.9	36
NF050	pH (standard units)	8.3	8.2	0.2	7.8	9.1	36
NF050	Fecal Coliform (colonies/100ml)	4360	1110	6340	0	17000	14
NF050	*Escherichia coli* (colonies/100ml)	1860	687	2920	0	12200	35

Table B–16 Summary statistics for routine grab samples from site SC020 (N = number of samples).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
SC020	PO_4-P (mg/L)	0.042	0.022	0.065	0.001	0.399	72
SC020	Total-P (mg/L)	0.12	0.10	0.11	0.01	0.63	72
SC020	NH_3-N (mg/L)	0.067	0.047	0.077	0.007	0.529	72
SC020	NO_2-N + NO_3-N (mg/L)	0.508	0.339	0.518	0.004	2.61	72
SC020	TKN (mg/L)	0.74	0.64	0.46	0.06	2.34	72
SC020	TSS (mg/L)	15	7	22	1	132	71
SC020	Water Temp. (°C)	15.5	16.0	6.5	4.5	27.2	72
SC020	Conductivity (µmhos/cm)	671	668	136	371	1100	72
SC020	DO (mg/L)	9.6	9.9	3.0	1.6	14.6	72
SC020	pH (standard units)	8.0	8.0	0.2	7.2	8.4	72
SC020	Fecal Coliform (colonies/100ml)	2170	450	5680	10	30000	33
SC020	*Escherichia coli* (colonies/100ml)	1360	333	4150	3	27000	54

Table B–17 Summary statistics for routine grab samples from site SF020 (N = number of samples).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
SF020	PO_4-P (mg/L)	0.020	0.016	0.016	0.002	0.040	6
SF020	Total-P (mg/L)	0.12	0.15	0.07	0.03	0.18	6
SF020	NH_3-N (mg/L)	0.074	0.050	0.057	0.030	0.170	5
SF020	NO_2-N + NO_3-N (mg/L)	0.226	0.210	0.201	0.020	0.550	5
SF020	TKN (mg/L)	0.87	0.88	0.41	0.32	1.39	6
SF020	TSS (mg/L)	21	16	22	2	54	6
SF020	Water Temp. (°C)	13.5	14.4	5.6	7.2	20	6
SF020	Conductivity (µmhos/cm)	512	570	219	87	714	6
SF020	DO (mg/L)	8.4	8.8	3.1	4.9	11.5	6
SF020	pH (standard units)	8.1	8.0	0.3	7.8	8.5	6
SF020	Fecal Coliform (colonies/100ml)	34000	34000	.	34000	34000	1
SF020	*Escherichia coli* (colonies/100ml)	35000	35000	.	35000	35000	1

Table B–18 Summary statistics for routine grab samples from site SF085 (N = number of samples).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
SF085	PO_4-P (mg/L)	0.220	0.188	0.191	0.005	1.22	94
SF085	Total-P (mg/L)	0.32	0.26	0.27	0.01	1.63	94
SF085	NH_3-N (mg/L)	0.049	0.032	0.055	0.007	0.363	94
SF085	NO_2-N + NO_3-N (mg/L)	0.285	0.162	0.345	0.008	1.46	94
SF085	TKN (mg/L)	0.90	0.76	0.65	0.15	3.77	94
SF085	TSS (mg/L)	10	4	18	1	146	94
SF085	Water Temp. (°C)	16.5	16.8	7.0	2.1	28.7	94
SF085	Conductivity (µmhos/cm)	766	787	300	210	1630	94
SF085	DO (mg/L)	9.2	9.0	3.3	3.3	16.6	94
SF085	pH (standard units)	8.2	8.2	0.2	7.6	9.0	94
SF085	Fecal Coliform (colonies/100ml)	585	157	1380	5	7400	44
SF085	*Escherichia coli* (colonies/100ml)	4010	182	28700	3	242000	71

Table B–19 Summary statistics for routine grab samples from site SP020 (N = number of samples).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
SP020	PO_4-P (mg/L)	0.004	0.002	0.007	0.001	0.040	84
SP020	Total-P (mg/L)	0.06	0.04	0.04	0.01	0.28	84
SP020	NH_3-N (mg/L)	0.023	0.016	0.018	0.007	0.096	84
SP020	NO_2-N + NO_3-N (mg/L)	0.088	0.016	0.212	0.004	1.18	84
SP020	TKN (mg/L)	0.27	0.23	0.20	0.02	0.96	84
SP020	TSS (mg/L)	5	2	7	1	43	84
SP020	Water Temp. (°C)	16.2	16.2	5.8	6.6	30.1	84
SP020	Conductivity (µmhos/cm)	510	518	53.3	335	597	84
SP020	DO (mg/L)	9.3	9.2	1.4	6.0	12.3	84
SP020	pH (standard units)	7.9	7.9	0.2	7.5	8.7	84
SP020	Fecal Coliform (colonies/100ml)	284	110	845	19	5200	37
SP020	*Escherichia coli* (colonies/100ml)	237	60.2	718	9	4800	64

APPENDIX C

Summary Statistics for Storm Events

All data analyses represent storms evaluated between January 1, 2001 and December 31, 2005. Exact dates of data collected will vary by site based on monitoring history.

Table C–1 Storm event summary statistics for site AL020 (N = number of events).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
AL020	PO_4-P (mg/L)	0.232	0.226	0.172	0.001	0.595	53
AL020	Total-P (mg/L)	0.59	0.48	0.45	0.06	1.53	53
AL020	NH_3-N (mg/L)	0.100	0.068	0.097	0.007	0.461	53
AL020	NO_2-N + NO_3-N (mg/L)	1.02	0.830	1.09	0.011	5.34	53
AL020	TKN (mg/L)	2.12	1.84	1.23	0.50	5.98	53
AL020	TSS (mg/L)	216	54	309	2	1390	53

Table C–2 Storm event summary statistics for site DB035 (N = number of events).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
DB035	PO_4-P (mg/L)	0.575	0.507	0.557	0.061	4.21	61
DB035	Total-P (mg/L)	0.98	0.86	0.77	0.20	5.74	61
DB035	NH_3-N (mg/L)	0.244	0.103	0.363	0.007	2.16	61
DB035	NO_2-N + NO_3-N (mg/L)	1.12	0.815	1.15	0.037	7.45	61
DB035	TKN (mg/L)	2.38	2.01	1.20	0.93	7.89	61
DB035	TSS (mg/L)	160	82	219	5	1180	61

Table C–3 Storm event summary statistics for site DC040 (N = number of events).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
DC040	PO_4-P (mg/L)	0.053	0.036	0.054	0.001	0.208	62
DC040	Total-P (mg/L)	0.24	0.14	0.46	0.01	3.59	62
DC040	NH_3-N (mg/L)	0.058	0.046	0.062	0.007	0.385	62
DC040	NO_2-N + NO_3-N (mg/L)	0.339	0.176	0.391	0.009	1.69	62
DC040	TKN (mg/L)	1.02	0.79	0.80	0.16	4.20	62
DC040	TSS (mg/L)	73	14	135	1	831	62

Table C–4 Storm event summary statistics for site GB020 (N = number of events).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
GB020	PO_4-P (mg/L)	3.89	3.91	1.77	0.544	7.20	32
GB020	Total-P (mg/L)	5.27	5.46	1.79	1.19	9.24	32
GB020	NH_3-N (mg/L)	0.775	0.399	0.932	0.050	3.68	32
GB020	NO_2-N + NO_3-N (mg/L)	3.89	3.03	3.50	0.846	19.3	32
GB020	TKN (mg/L)	6.85	5.01	3.91	2.29	17.3	32
GB020	TSS (mg/L)	677	94	1300	3	5600	32

Table C–5 Storm event summary statistics for site GB025 (N = number of events).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
GB025	PO_4-P (mg/L)	1.59	1.53	1.11	0.265	4.74	47
GB025	Total-P (mg/L)	3.43	3.67	1.37	0.840	6.21	47
GB025	NH_3-N (mg/L)	0.618	0.284	0.908	0.063	4.51	47
GB025	NO_2-N + NO_3-N (mg/L)	1.84	1.32	1.63	0.092	7.50	47
GB025	TKN (mg/L)	9.04	7.19	5.97	1.93	28.4	47
GB025	TSS (mg/L)	2190	705	3300	56	14500	47

Table C–6 Storm event summary statistics for site GB040 (N = number of events).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
GB040	PO_4-P (mg/L)	0.991	1.01	0.428	0.184	1.97	56
GB040	Total-P (mg/L)	2.66	2.37	1.40	0.33	7.17	56
GB040	NH_3-N (mg/L)	0.556	0.393	0.481	0.039	2.44	56
GB040	NO_2-N + NO_3-N (mg/L)	5.22	2.73	6.82	0.157	34.1	56
GB040	TKN (mg/L)	7.85	6.53	5.25	1.32	24.5	56
GB040	TSS (mg/L)	1630	636	2860	65	15400	56

Table C–7 Storm event summary statistics for site GC045 (N = number of events).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
GC045	PO_4-P (mg/L)	0.081	0.062	0.083	0.001	0.295	47
GC045	Total-P (mg/L)	0.27	0.20	0.21	0.02	0.76	47
GC045	NH_3-N (mg/L)	0.089	0.059	0.088	0.007	0.421	47
GC045	NO_2-N + NO_3-N (mg/L)	4.46	1.94	5.13	0.076	19.0	47
GC045	TKN (mg/L)	1.61	1.55	0.85	0.29	3.67	47
GC045	TSS (mg/L)	102	36	154	2	830	47

Table C–8 Storm event summary statistics for site GM060 (N = number of events).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
GM060	PO_4-P (mg/L)	0.299	0.223	0.274	0.002	0.864	51
GM060	Total-P (mg/L)	0.47	0.36	0.39	0.02	1.49	51
GM060	NH_3-N (mg/L)	0.095	0.048	0.196	0.007	1.35	51
GM060	NO_2-N + NO_3-N (mg/L)	0.296	0.238	0.355	0.004	1.53	51
GM060	TKN (mg/L)	1.31	1.16	0.81	0.26	4.61	51
GM060	TSS (mg/L)	66	31	79	1	385	51

Table C–9 Storm event summary statistics for site HY060 (N = number of events).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
HY060	PO_4-P (mg/L)	0.018	0.010	0.021	0.000	0.081	54
HY060	Total-P (mg/L)	0.12	0.09	0.13	0.01	0.74	54
HY060	NH_3-N (mg/L)	0.040	0.033	0.031	0.007	0.157	54
HY060	NO_2-N + NO_3-N (mg/L)	0.974	0.451	1.20	0.008	5.43	54
HY060	TKN (mg/L)	0.87	0.75	0.64	0.08	3.04	54
HY060	TSS (mg/L)	68	19	120	1	614	54

Table C–10 Storm event summary statistics for site IC020 (N = number of events).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
IC020	PO_4-P (mg/L)	0.677	0.607	0.441	0.021	1.91	53
IC020	Total-P (mg/L)	1.25	1.18	0.64	0.11	2.75	53
IC020	NH_3-N (mg/L)	0.277	0.188	0.286	0.022	1.39	53
IC020	NO_2-N + NO_3-N (mg/L)	1.47	1.30	0.992	0.009	4.30	53
IC020	TKN (mg/L)	3.57	3.33	1.40	1.36	7.33	53
IC020	TSS (mg/L)	325	182	347	26	1390	53

Table C–11 Storm event summary statistics for site LD040 (N = number of events).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
LD040	PO_4-P (mg/L)	0.440	0.455	0.207	0.032	0.841	35
LD040	Total-P (mg/L)	1.00	0.87	0.47	0.26	2.05	35
LD040	NH_3-N (mg/L)	0.376	0.107	0.724	0.016	3.44	35
LD040	NO_2-N + NO_3-N (mg/L)	1.66	0.954	2.15	0.025	11.6	35
LD040	TKN (mg/L)	3.50	3.35	1.82	1.25	7.76	35
LD040	TSS (mg/L)	353	222	368	4	1300	35

Table C–12 Storm event summary statistics for site LG060 (N = number of events).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
LG060	PO_4-P (mg/L)	0.234	0.137	0.221	0.018	0.737	30
LG060	Total-P (mg/L)	0.88	0.46	0.88	0.05	3.28	30
LG060	NH_3-N (mg/L)	0.221	0.134	0.202	0.020	0.762	30
LG060	NO_2-N + NO_3-N (mg/L)	0.726	0.611	0.534	0.028	2.82	30
LG060	TKN (mg/L)	3.86	2.40	3.13	1.35	13.20	30
LG060	TSS (mg/L)	391	148	553	2	2140	30

Table C–13 Storm event summary statistics for site NF009 (N = number of events).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
NF009	PO_4-P (mg/L)	0.322	0.328	0.137	0.002	0.630	41
NF009	Total-P (mg/L)	0.74	0.60	0.56	0.16	3.30	39
NF009	NH_3-N (mg/L)	0.311	0.128	0.457	0.007	2.64	41
NF009	NO_2-N + NO_3-N (mg/L)	0.682	0.499	0.776	0.015	4.31	41
NF009	TKN (mg/L)	2.72	2.18	1.44	1.36	8.67	39
NF009	TSS (mg/L)	902	145	2515	13	12300	41

Table C–14 Storm event summary statistics for site NF020 (N = number of events).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
NF020	PO_4-P (mg/L)	1.04	0.996	0.697	0.028	3.82	57
NF020	Total-P (mg/L)	2.34	1.89	1.69	0.57	8.40	57
NF020	NH^3-N (mg/L)	0.394	0.190	0.472	0.026	2.02	57
NF020	NO_2-N + NO_3-N (mg/L)	1.22	0.985	0.825	0.018	4.05	57
NF020	TKN (mg/L)	6.02	4.25	4.79	1.39	26.0	57
NF020	TSS (mg/L)	881	346	2020	15	14900	57

Table C–15 Storm event summary statistics for site NF050 (N = number of events).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
NF050	PO_4-P (mg/L)	0.432	0.408	0.226	0.099	1.34	49
NF050	Total-P (mg/L)	0.81	0.76	0.40	0.13	1.74	49
NF050	NH_3-N (mg/L)	0.189	0.108	0.182	0.010	0.746	49
NF050	NO_2-N + NO_3-N (mg/L)	0.662	0.453	0.732	0.021	4.11	49
NF050	TKN (mg/L)	2.60	2.37	1.55	0.95	10.0	49
NF050	TSS (mg/L)	200	82.0	339	5	1650	49

Table C–16 Storm event summary statistics for site SC020 (N = number of events).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
SC020	PO_4-P (mg/L)	0.179	0.116	0.192	0.001	0.862	49
SC020	Total-P (mg/L)	0.44	0.38	0.40	0.02	2.06	49
SC020	NH_3-N (mg/L)	0.146	0.099	0.146	0.012	0.661	49
SC020	NO_2-N + NO_3-N (mg/L)	0.568	0.430	0.463	0.019	2.20	49
SC020	TKN (mg/L)	1.70	1.55	0.91	0.44	5.30	49
SC020	TSS (mg/L)	152	98.0	163	5	680	49

Table C–17 Storm event summary statistics for site SF020 (N = number of events).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
SF020	PO_4-P (mg/L)	0.043	0.025	0.052	0.002	0.220	25
SF020	Total-P (mg/L)	0.25	0.25	0.14	0.03	0.54	25
SF020	NH_3-N (mg/L)	0.143	0.090	0.136	0.016	0.583	25
SF020	NO_2-N + NO_3-N (mg/L)	0.462	0.398	0.241	0.140	0.985	25
SF020	TKN (mg/L)	1.90	1.78	0.97	0.46	4.27	25
SF020	TSS (mg/L)	382	216	653	2	3335	25

Table C–18 Storm event summary statistics for site SF085 (N = number of events).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
SF085	PO_4-P (mg/L)	0.230	0.215	0.120	0.016	0.646	103
SF085	Total-P (mg/L)	0.44	0.36	0.37	0.05	2.93	103
SF085	NH_3-N (mg/L)	0.113	0.058	0.223	0.007	1.86	103
SF085	NO_2-N + NO_3-N (mg/L)	0.395	0.320	0.301	0.028	1.55	103
SF085	TKN (mg/L)	1.44	1.21	1.19	0.10	9.59	103
SF085	TSS (mg/L)	87	26	187	2	1360	103

Table C–19 Storm event summary statistics for site SP020 (N = number of events).

Site	Constituent	Mean	Median	Std Dev.	Minimum	Maximum	N
SP020	PO_4-P (mg/L)	0.019	0.005	0.035	0.001	0.199	61
SP020	Total-P (mg/L)	0.13	0.09	0.11	0.01	0.47	61
SP020	NH_3-N (mg/L)	0.034	0.024	0.034	0.008	0.203	61
SP020	NO_2-N + NO_3-N (mg/L)	0.078	0.034	0.087	0.009	0.340	61
SP020	TKN (mg/L)	0.65	0.43	0.51	0.06	1.78	61
SP020	TSS (mg/L)	79	18	151	1	729	61

APPENDIX D

Record of Average Daily Flow for Each Stream Site

Figure D–1 Average daily flow at AL020 for July1, 2001 through December 31, 2005.

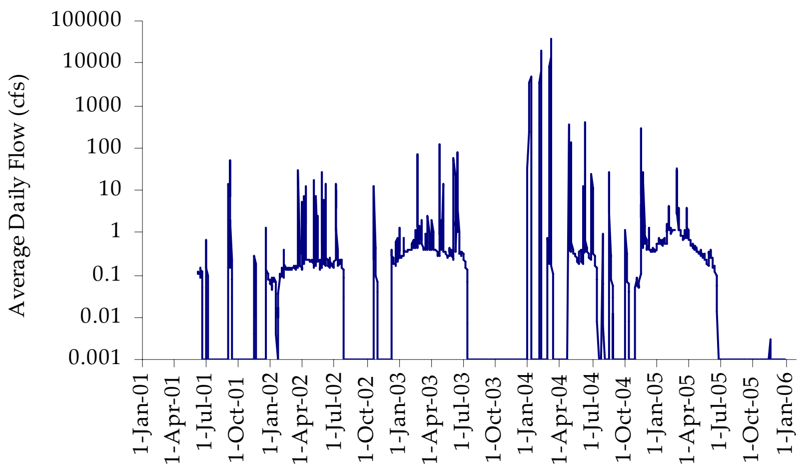


Figure D–2 Average daily flow at DB035 for January 4, 2002 through December 31, 2005.

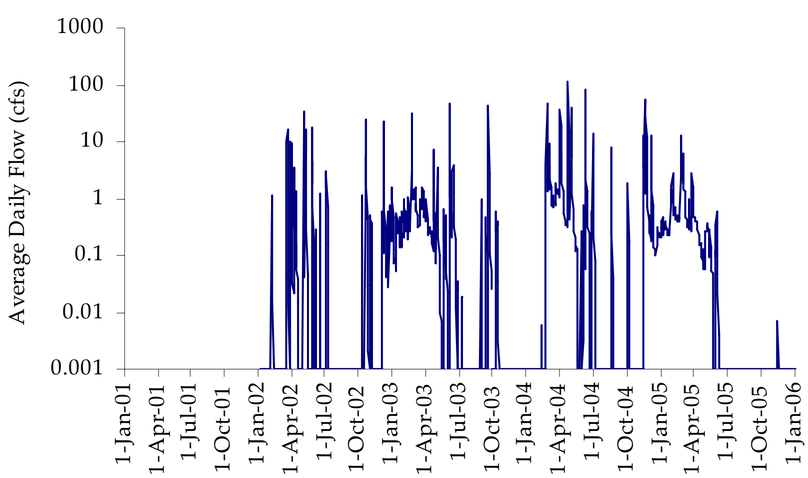


Figure D–3 Average daily flow at DC040 for April 10, 2001 through December 31, 2005.

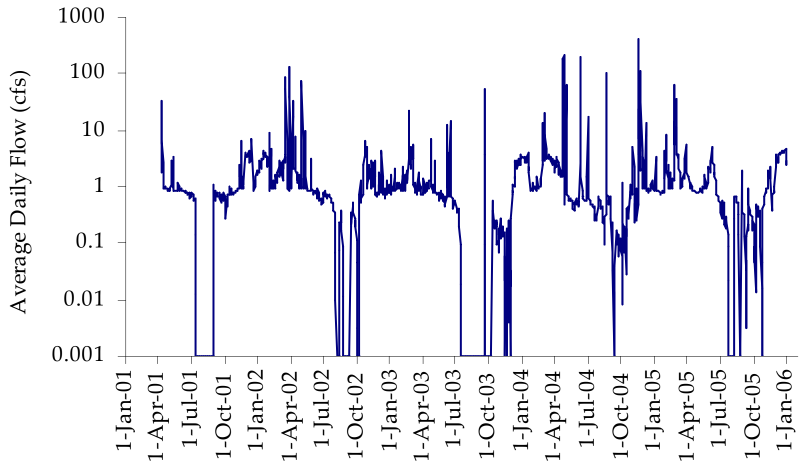


Figure D–4 Average daily flow at GB020 for January 1, 2001 through December 31, 2005.

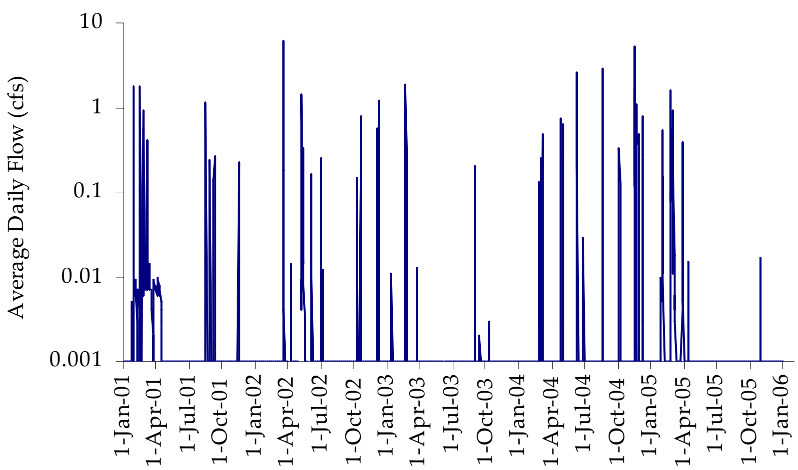


Figure D–5 Average daily flow at GB025 for January 9, 2001 through December 31, 2005.

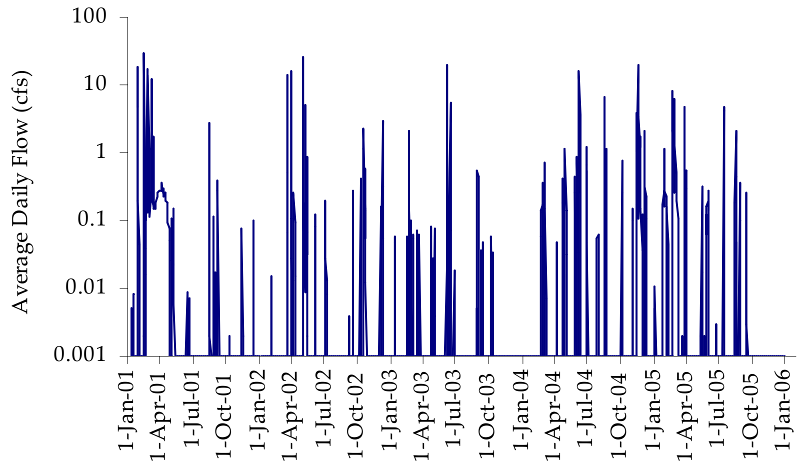


Figure D–6 Average daily flow at GB040 for January 1, 2001 through December 31, 2005.

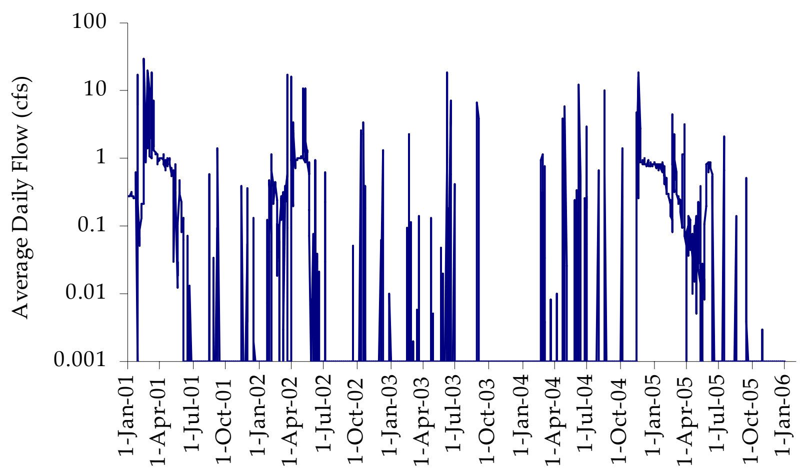
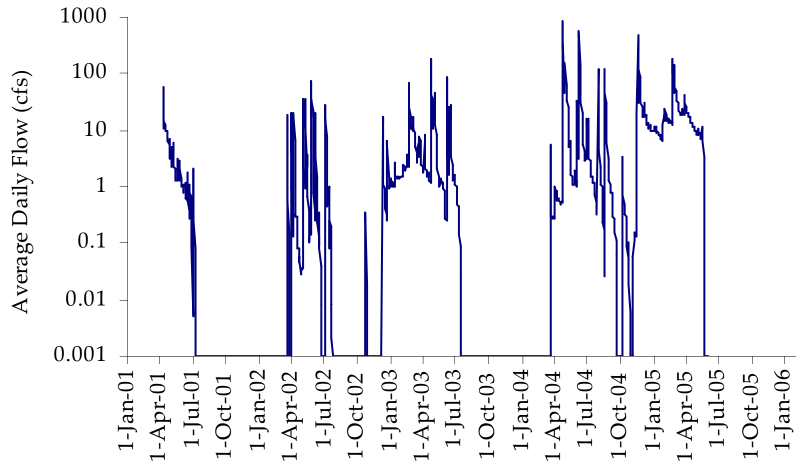


Figure D–7 Average daily flow at GC045 for April 9, 2001 through May 30, 2005*.



*Site GC045 was relocated on May 31, 2005 and as a result a rating curve has not yet been established for data past the date of relocation.

Figure D–8 Average daily flow at GM060 for March 7, 2001 through December 31, 2005.

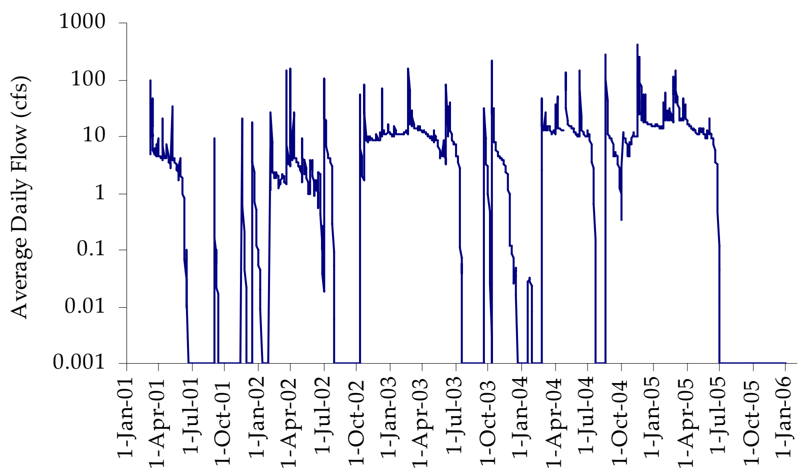


Figure D–9 Average daily flow at HY060 for April 5, 2001 through December 31, 2005.

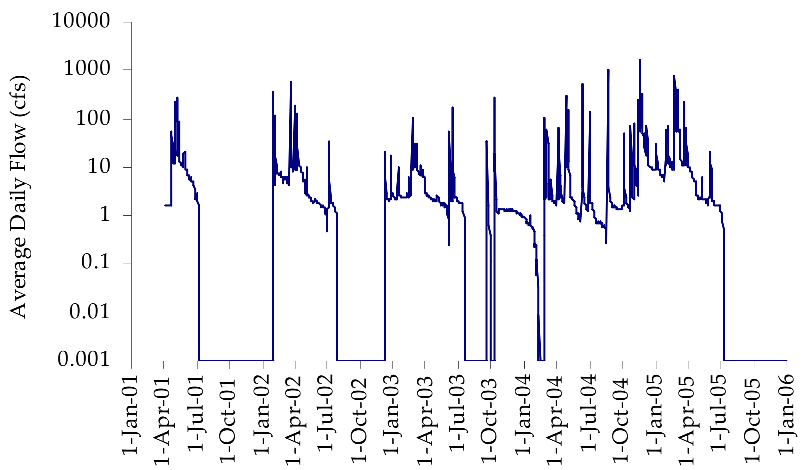


Figure D–10 Average daily flow at IC020 for January 24, 2001 through December 31, 2005.

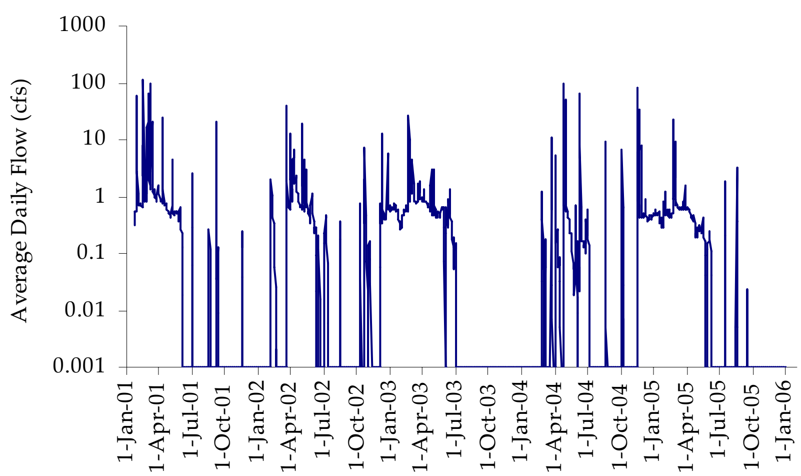


Figure D–11 Average daily flow at LD040 for June 6, 2001 through December 31, 2005.

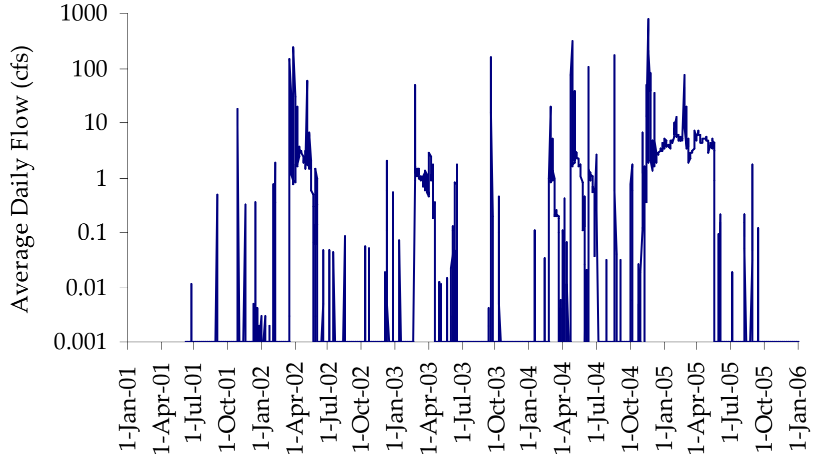


Figure D–12 Average daily flow at LG060 for June 6, 2001 through December 31, 2005.

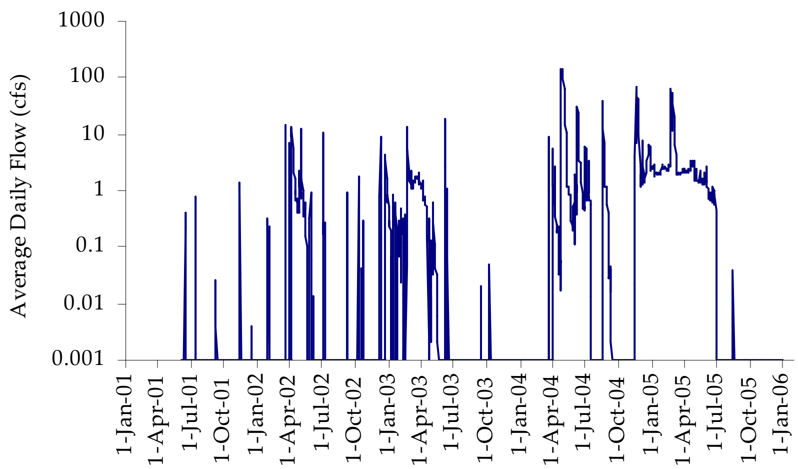


Figure D–13 Average daily flow at NF009 for January 1, 2001 through December 31, 2005.

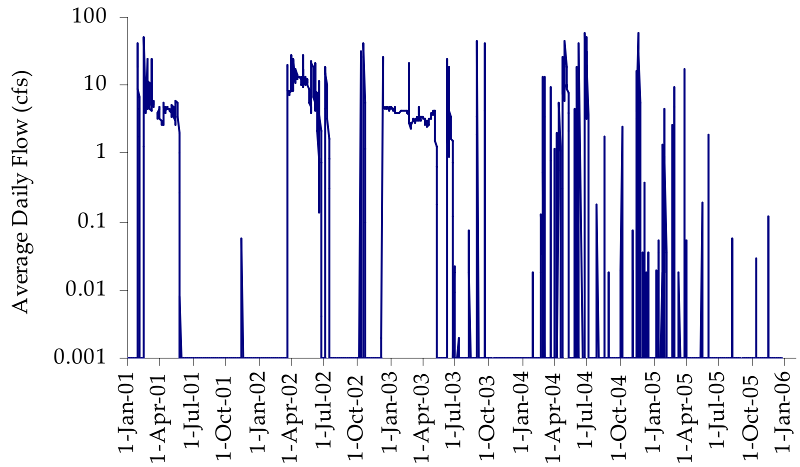


Figure D–14 Average daily flow at NF020 for January 1, 2001 through December 31, 2005.

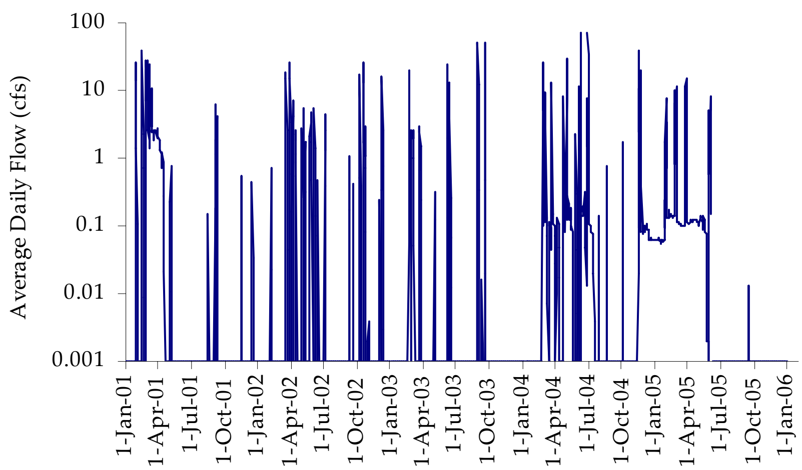


Figure D–15 Average daily flow at NF050 for April 26, 2001 through December 31, 2005. Breaks in the hydrograph indicate missing data.

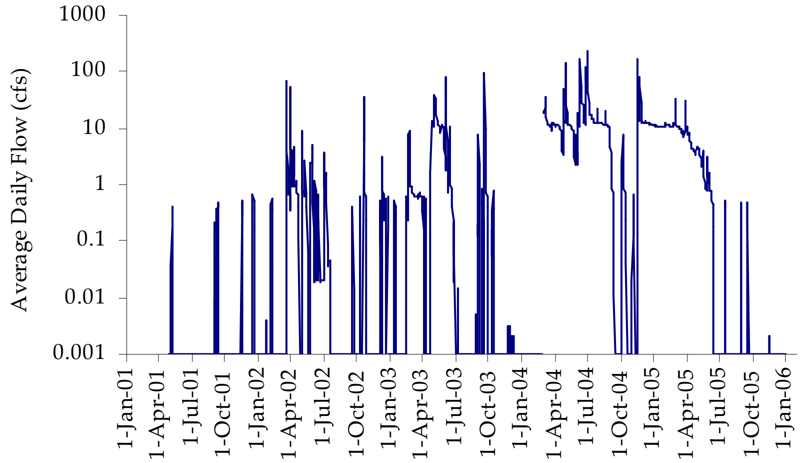


Figure D–16 Average daily flow at SC020 for March 20, 2001 through December 31, 2005.

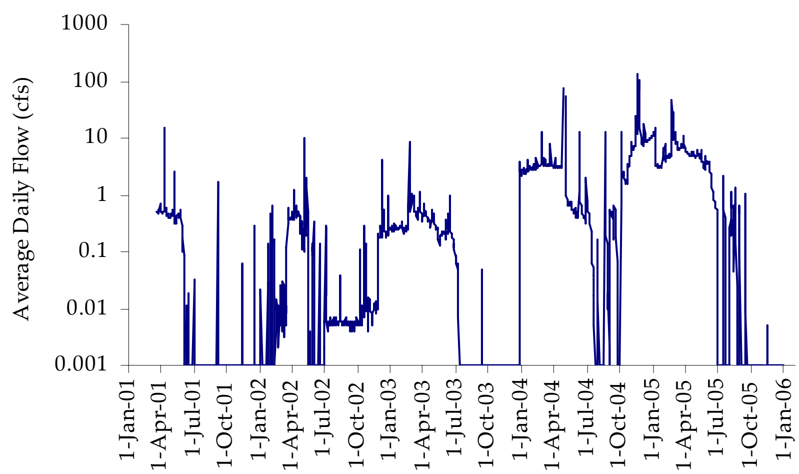


Figure D–17 Average daily flow at SF020 for January 1, 2001 through January 13, 2003.

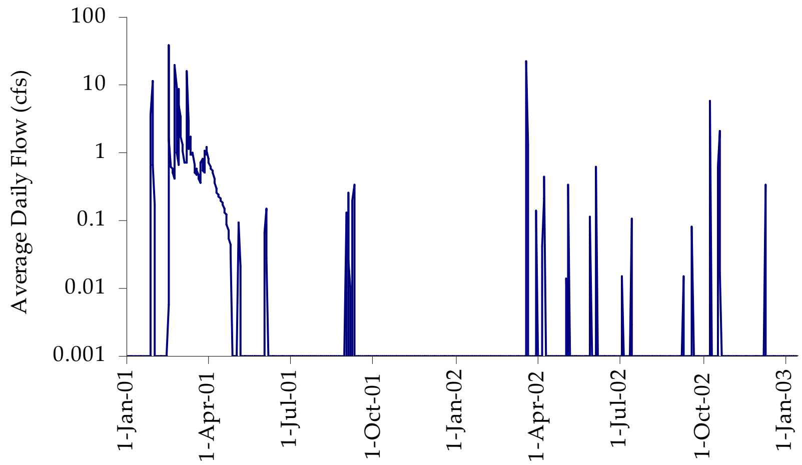


Figure D–18 Average daily flow at SF085 for May 1, 2001 through December 31, 2005.

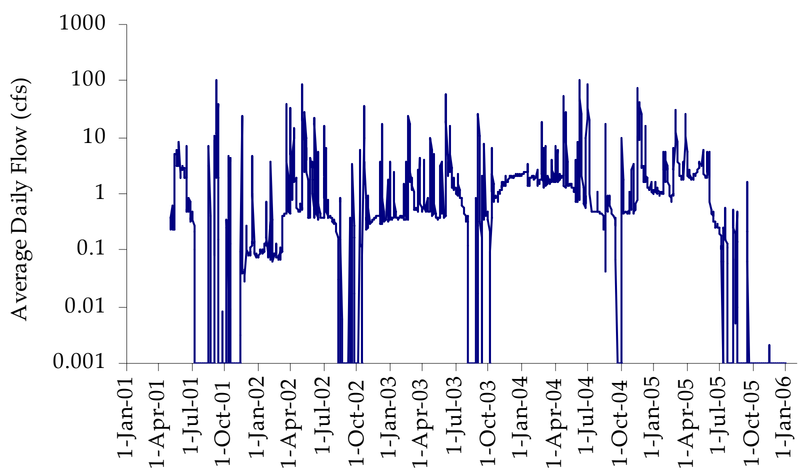


Figure D–19 Average daily flow at SP020 for January 3, 2001 through December 31, 2005.