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Nutrients, Suspended Solids, and Fecal Coliform Bacteria in Seven Mile Coulee and the Beaver Creek Basin, Stutsman County, ND

Dakotas Area Office
Bismarck, North Dakota

U.S. Department of the Interior
Bureau of Reclamation

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Report to the Stutsman County Soil Conservation District
Jamestown, North Dakota

and

Dakotas Area Office
Bismarck, North Dakota

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Report Summary

This report presents the results of an analysis of flow, gage height, and water quality data from six sites located in the Seven Mile Coulee and Beaver Creek drainage basins in Stutsman County, North Dakota. The water quality data include total phosphorus, ammonium, nitrite plus nitrate, Kjeldahl, and total nitrogen, total suspended solids concentrations, and fecal coliform counts. The data were collected from two sites (upstream and downstream) in Seven Mile Coulee and four sites in the Beaver Creek basin, including two sites on the mainstem of Beaver Creek and two sites in its tributary, Buffalo Creek. The data set encompassed the period from March 31 through October 30, 2006, although at four of the six sites, there was no flow after dates that ranged from mid-June to mid-July.

The samples were collected during 2006, which represents a relatively dry year. The precipitation data for 2006 ranked at about the 25th percentile for two stations near Jamestown; flow data for 2006 at the Pingree gage on Pipestem Creek near Jamestown also ranked at about the 25th percentile in the long-term gage record.

Regression analysis was used to develop discharge-gage height relationships. Most of the discharge-gage height relationships showed an r^2 of 0.9 or better. The discharge-gage height regressions were used to estimate flows on dates for which there were no flow measurements. Upstream sites on each of the three streams and the downstream site in Buffalo Creek, the tributary to Beaver Creek, and something of an upstream site itself, were nonperennial. All of the streams showed a gain in flow between the upstream and downstream sample sites.

Nitrite plus nitrate concentrations were compared to the instream nitrate standard of 1 mg/L. The comparison to the nitrate standard was based on the assumption that nitrite concentrations would be negligible in the surface waters that were the source of the samples. There were two nitrite plus nitrate samples that exceeded the nitrate standard at the downstream site in Seven Mile Coulee. None of the other samples at any of the sites approached the 1 mg/L nitrate standard.

There are two standards for fecal coliforms in North Dakota streams. The first is 400 colonies/100 mL for individual samples, while the second is 200 colonies/100 mL for the geometric mean of samples collected within a 30-day period. For the second, a running 30-day geometric mean was calculated for the comparison. Fecal coliform counts in individual samples exceeded the 400/100 mL standard at most sites, but not in most samples. For the most part, one or two samples exceeded the standard at five of the six sites and none of the geometric means exceeded the 200/100 mL standard at those sites. However, at the downstream site in Seven Mile Coulee, beginning in late May and continuing through September, all of the individual samples and the geometric mean fecal coliform counts exceeded their respective standards.

The nutrient analysis focused on concentrations and loads of total phosphorus, total nitrogen, and its principal component, organic nitrogen. Ammonium-nitrogen and nitrite plus nitrate-nitrogen were a small component of the total nitrogen at all sites.

Total phosphorus concentrations at both sites in Seven Mile Coulee were greater than a background concentration as determined by the US Geological Survey for US streams. There were large increases in both the concentrations and loads of total phosphorus between the two sites in Seven Mile Coulee. The increase in the total phosphorus load during July and August was virtually identical to that of the inflow from the malt plant upstream from the site near the mouth of Seven Mile Coulee. However, the load in the coulee was less than the inflow from the malt plant earlier in the season, indicating a loss of phosphorus between the effluent discharge point and the downstream sample site during that period.

Among the nitrogen concentrations in Seven Mile Coulee, there was a significant increase in nitrite plus nitrate only. However, there was an increase in the loads of total nitrogen and all of the nitrogen species, reflecting the increase in flow. The downstream organic nitrogen load in Seven Mile Coulee was very near the load in the malt plant effluent. There were no total nitrogen data for the malt plant effluent to evaluate its loading to the coulee. There was also a large loading of ammonium-nitrogen from the malt plant to the coulee, but much of this was apparently lost to nitrification in transit to the downstream sample site in Seven Mile Coulee.

The concentrations of all of the nutrients except for ammonium decreased between sites in Buffalo Creek, indicating either a loss in transit between the sites or dilution by inflows with lower nutrient concentrations. However, the loads of all of the nutrients increased, indicating that any losses were not large, and dilution was likely the cause of the decrease in concentrations. The increase in nutrient loads, despite decreases in nutrient concentrations, was a reflection of an increase in flow, the other component of the nutrient load.

Concentrations of total phosphorus and organic and total nitrogen decreased between the sample sites on the mainstem of Beaver Creek, while those of ammonium and nitrite plus nitrate showed no change. As was the case in Buffalo Creek, whether there was a decrease in the concentration or no change in the concentration of the nutrient in question did not matter, there was an increase in its nutrient load between sites on the mainstem of Beaver Creek.

Concentrations of suspended solids were generally low at all sites in each of the basins, particularly during the spring. The greatest suspended solids concentrations of any of the sample sites occurred at the downstream site in Seven Mile Coulee, reaching their peak during the low flow period. In the Beaver Creek basin, including Buffalo Creek, suspended solids concentrations decreased between sites, but suspended solids loads increased.

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Introduction

The Stutsman County Soil Conservation District received a grant from the North Dakota Department of Health to conduct studies in several watersheds in the James River basin. The sampled streams that are the subject of this report are located in two watersheds near Jamestown, North Dakota. Two sites were located in Seven Mile Coulee (Figure 1) and four sites were located in the Beaver Creek watershed (Figure 2). The four sites in the Beaver Creek watershed included two sites in the mainstem of Beaver Creek and two sites in its tributary, Buffalo Creek. Samples were collected on a near weekly basis from March 31 through October 30, 2006. The data were provided by Ryan Odenbach of the Jamestown Soil Conservation District (personal communication, email of December 22, 2006 to Merlynn Bender, Bureau of Reclamation), who serves as Reclamation's contact for the study.

The North Dakota Department of Health prepared a Quality Assurance Project Plan (QAPP) for the sampling and analysis of samples (Meeks, 2005). The QAPP lays out sampling protocols and details laboratory analytical methods. The QAPP should be consulted for methods. In addition, the QAPP lists the goals of the study. The goals include the following:

1) assess, using chemical, physical, and biological data, the current water quality condition of Beaver Creek and Seven Mile Coulee;
2) assess the status of aquatic life and recreational uses; and
3) identify and assess potential stressors and sources for any aquatic life or recreational use impairments indicated by the data.

This report will provide the results of the analysis of nutrient, total suspended solids (TSS), and fecal coliform bacterial data collected during 2006 from the sites in the Beaver Creek and Seven Mile Coulee basins to define the existing water quality and fulfill goal number 1. In addition, potential impairment of recreational use in the streams will be evaluated using data on fecal coliform bacteria, in partial fulfillment of goal number 3. Goal number 2 requires data that are not available for this aspect of the study.

Initially, Reclamation was approached with a request to develop a watershed model of the basins for which data had been collected. The data available at the time included results from March through June. The funds available did not seem adequate to develop a model, and Reclamation countered with an offer to evaluate the data and make recommendations relating to possible further analysis. This report will focus on that analysis of the full data set and attempt to define relationships among the various water quality constituents, both in terms of concentrations and loads. Stage-discharge relationships for the six staff gages installed during the study will be developed. Within stream gains and losses of water, nutrients, and TSS will be evaluated. Water quality relationships will also be evaluated using standard statistical techniques, *e.g.* correlation and regression. Changes between sites within streams will be evaluated using either paired or unpaired t-Tests or in some cases, the nonparametric equivalent of an unpaired t-Test, the Mann-Whitney Test. The statistical analyses were performed using the statistical package, SYSTAT, version 11 (SYSTAT , 2005) or in some cases, in an Excel spreadsheet.

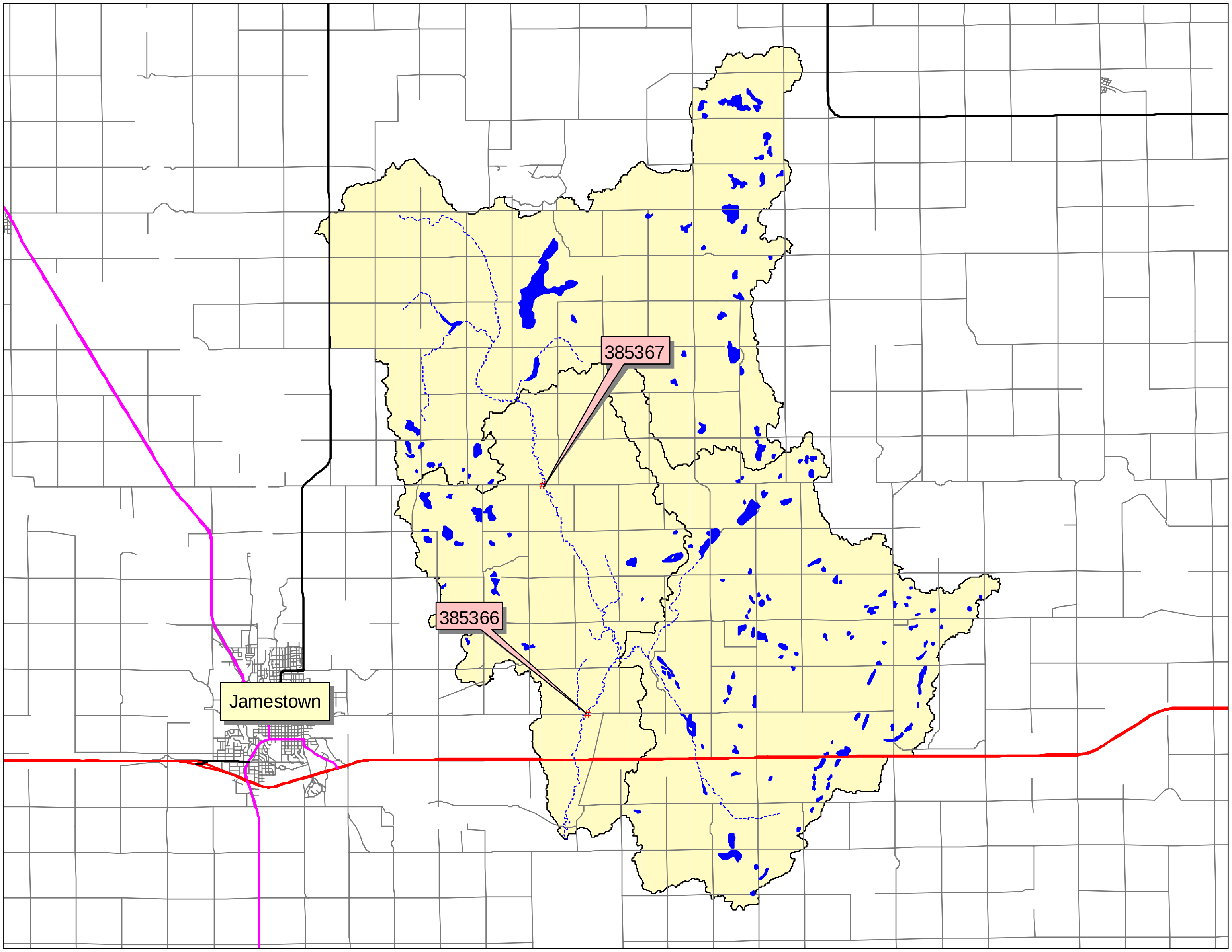


Figure 1: Location of sample sites in Seven Mile Coulee (Source: Meeks, 2005)

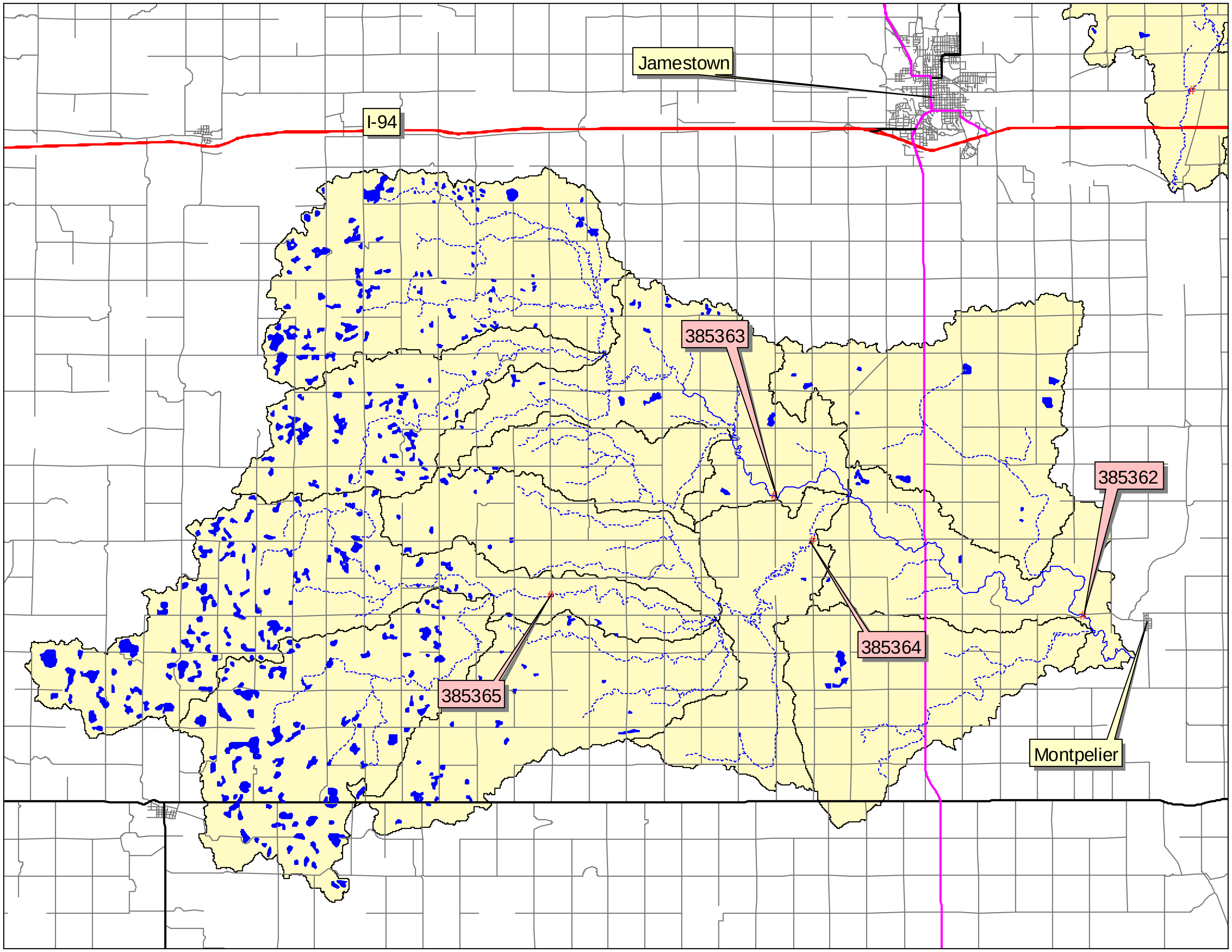


Figure 2. Location of sample sites in the Beaver Creek watershed (Source: Meeks, 2005)

The major component of the data set consists of nutrient data. North Dakota does not have a phosphorus standard, but does have an instream nitrate standard (as N) of 1 mg/L. EPA is in the process of developing nutrient criteria for streams. Draft nutrient criteria for streams were published in 2000 (EPA, 2000a), but those met with considerable resistance because of concerns over the science that was used to develop the criteria. Because of those concerns, EPA is reconsidering the approach. Another approach has been developed that is more site specific. That newly developed approach is currently being evaluated.

The EPA draft nutrient criteria were based on what were termed nutrient ecoregions (EPA, 2000a). The Stutsman County study area is in nutrient ecoregion VI, the Corn Belt and Northern Great Plains (EPA, 2000b). Within the broad ecoregion there are a number of subecoregions. The study area is within the Northern Glaciated Plains subecoregion. EPA (2000b) gives reference conditions for both the nutrient ecoregion and subecoregions. The reference conditions could be used as a basis for evaluation of the data from Seven Mile Coulee and the Beaver Creek basin.

The USGS has a National Water Quality Assessment Program (NAWQA). The program is currently in its second round of studying river basins. The results from the initial round of studies have been (and are being) evaluated. The USGS (1999) released a report on nutrients from the first round of studies that included an estimate of background nutrient concentrations in the Nation's rivers and streams. The USGS (1999) background nutrient concentrations are virtually identical to the reference nutrient concentrations from the subecoregion in which the study area is located. Because of the controversial nature of the EPA criteria documents, the USGS (1999) values will be used to evaluate the nutrient concentrations in Seven Mile Coulee and the Beaver Creek basin against background concentrations, although it really does not make much difference which source is used to define the background.

Flow – stage relationships

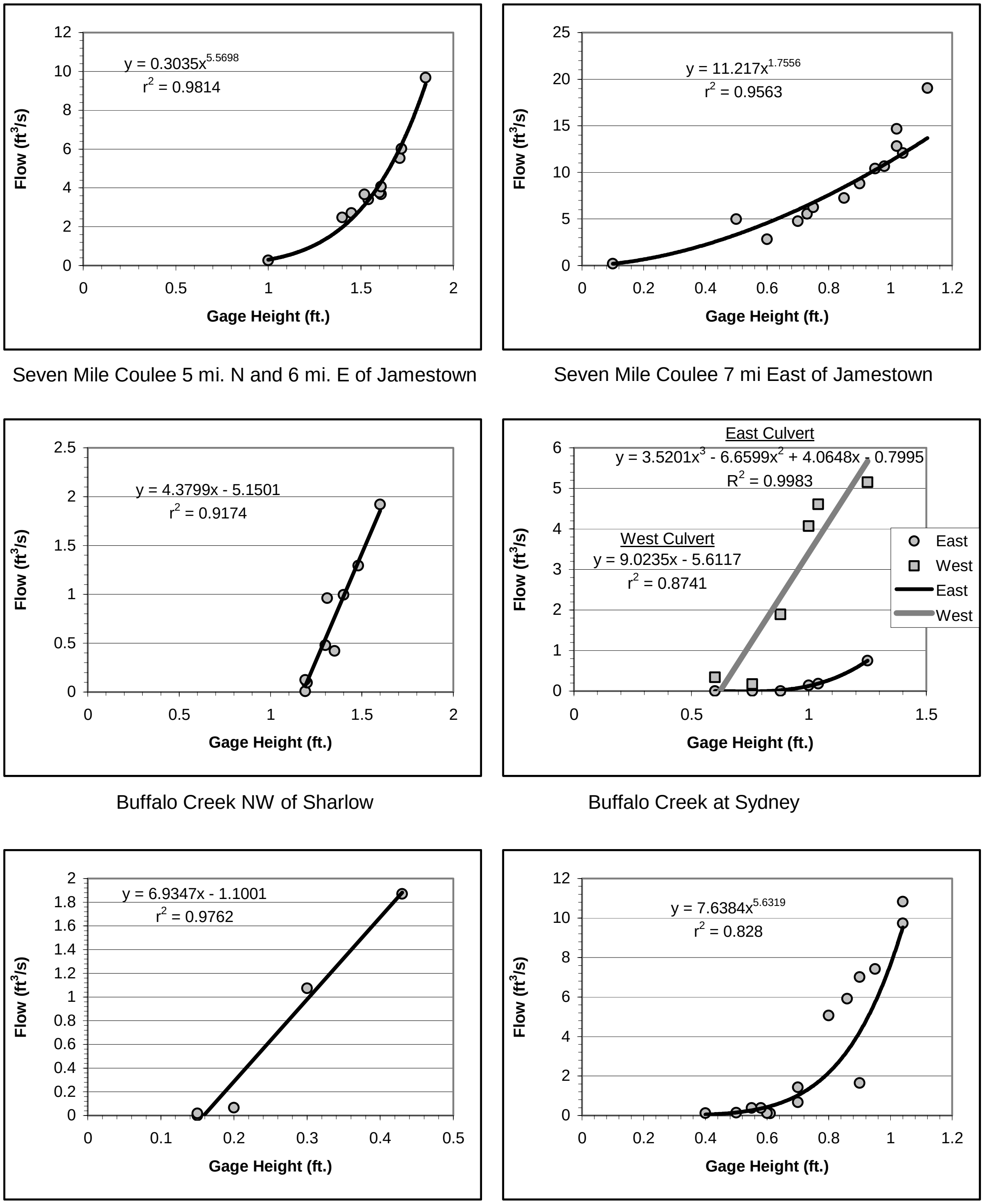
The instantaneous load is the product of the concentration of the constituent for which the load is being calculated and the flow at which the sample was collected. The daily load is calculated by converting the instantaneous flow to a daily value (1 ft^3/s = 1.9835 acre-feet/day). Unless the concentration of the constituent for which the load is being calculated is inordinately high, the flow component usually accounts for the larger part of the load. For the same reason, the flow component of the load may be the source of the greatest error in the load estimate. Because of the potential for relative error, a discussion of the flow calculations in the three streams follows.

The data sets for the Seven Mile Coulee and the Buffalo-Beaver Creek basins have many more gage height readings than there are flow measurements. To calculate the loads on dates when there were no discharge measurements, a stage-discharge relationship was developed for each site to supplement the flow data. These relationships are shown on Figure 3. There is considerable scatter in some of the data sets on Figure 3. This could indicate that there is instability in the channel. However, without better data, the relationships shown on Figure 3 were used to estimate the nutrient loads at the various sites.

The stage measurements represent staff gage readings. The relationships between gage height (stage) and flow assume that the channels are reasonably stable throughout the study period at the staff gage locations. Problems with maintaining gages and the changes in the relationships between gage heights and calculated discharges are presented in Kennedy (1983; 1984). Many of these relate to the bed behavior and the channel structure and some of these will be highlighted later.

Figure 3 shows the best fit relationships between the measured gage heights and discharge at each of the sites. As can be seen from the equations on the plots, the relationships between gage height and flow vary from site to site. There are three power fit (log-linear) equations, three linear equations, and one third degree polynomial. There are seven equations for the six sites because of a split flow through two culverts at different elevations at the Buffalo Creek site at Sydney (Figure 3).

The plots on Figure 3 show the coefficients of determination (r^2) for each equation. The r^2 reflects the percent of variation in the dependent variable (flow) that is explained by the independent variable (gage height). On this basis, the polynomial regression for the data from the east culvert at the Buffalo Creek at Sydney would be the best regression. However, the data set for the site is small, with only six discharge measurements and three of those were 0 flow. In reality a better measure of the significance of a regression is its F-value. On that basis, the best regression fits to the data are the ones from the Seven Mile Coulee, with probabilities of a greater F-statistic occurring by chance alone that are less than 1 in 100 million. The equivalent probability associated with the F-statistic for the above referenced polynomial regression is 0.003 (3 in 1000). The regression for the west culvert is only slightly poorer based on its F-statistic, which has an associated probability of 0.006, although its r^2 is much smaller. The difference in the



Seven Mile Coulee 5 mi. N and 6 mi. E of Jamestown

Seven Mile Coulee 7 mi East of Jamestown

Buffalo Creek NW of Sharlow

Buffalo Creek at Sydney

Beaver Creek NW of Sydney

Beaver Creek at Montpelier

Figure 3. Flow-discharge relationships for each of the six sample sites in the Seven Mile Coulee and Buffalo-Beaver Creek basins.

significance in the two regressions for the culverts is that the polynomial regression has three coefficients, while the linear regression has only one.

One further consideration relates to the plots themselves on Figure 3. Predicted flows from the regressions will fall exactly on the lines shown on the plots, while at most of the sites, at least some of the discharge measurements do not. Load calculations are based on the actual measurements when they exist, but in the remaining cases, the load will be based on the flows estimated from the regressions shown on Figure 3. If nothing else, errors in the estimated loads will be in proportion to the scatter about the regression lines on Figure 3.

Measured and calculated flows at the sample sites

This section of the report will present the measured and calculated flows for each of the sites for their respective periods of record during 2006. Most of the sample sites (4 of 6) are not perennial. Flows ceased in those sites in June or July. The following plots will show when flows ceased. In addition, the three sets of plots will present the flows for each of the two sites in each of the streams, along with a statistical comparison of the flows. The comparison will allow an evaluation of whether the streams are losing or gaining flow between the sites and a further evaluation of whether or not the flow changes are significant.

Figure 4 shows hydrographs for the two sites in Seven Mile Coulee during the 2006 sampling period. With the exception of March 31, flows at the upstream site in the coulee are consistently (and, based on the t-Test on Figure 4, significantly) lower than those downstream. On March 31, the flow was about 3 ft^3/s greater upstream. On the remaining days when there was flow at both sites, the gain averaged about 6.5 ft^3/s. The pattern of flow appears similar at the sites, and there is a reasonably good correlation between the flows at the two sites ($r = 0.68$).

As is evident on Figure 4, flow at the upstream Seven Mile Coulee site fell off dramatically to less than 1 ft^3/s in the middle of June. By late July, there was no flow at the upstream site. At the downstream site, the flow did not decrease greatly until July. Flow at the downstream site in the coulee remained relatively steady until September, when it inexplicably dropped below 1 ft^3/s. However, the flow subsequently rose slightly during September at which time it remained between 1 and 2 ft^3/s. The flow at the downstream site rose again in late October to over 7 ft^3/s. The flow remained around 7 ft^3/s at the site until sampling ended in early November.

Neither site in Buffalo Creek was perennial during 2006. Flow ceased at both sites in the creek in mid-June (Figure 5). During most of the period that there was flow in the creek, there was a significant gain in flow between the sites, based on the t-Test summarized on Figure 5. However, the flow was never very large at either site in the creek with maxima at each of the sites less than 10 ft^3/s.

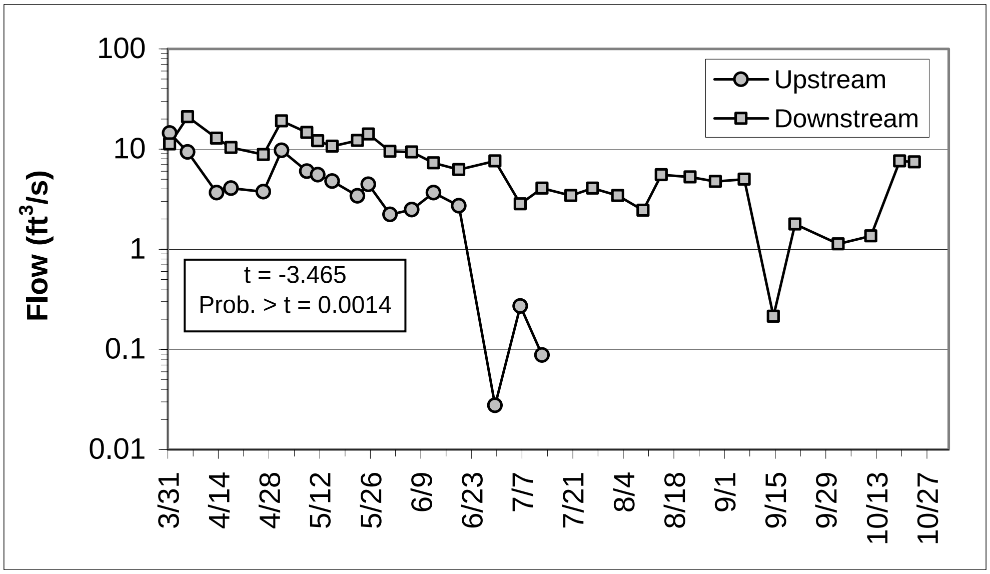


Figure 4. Seven Mile Coulee Flow with log-transformed 2-tailed t-Test
t-Test based on March 31 through July 12 data only

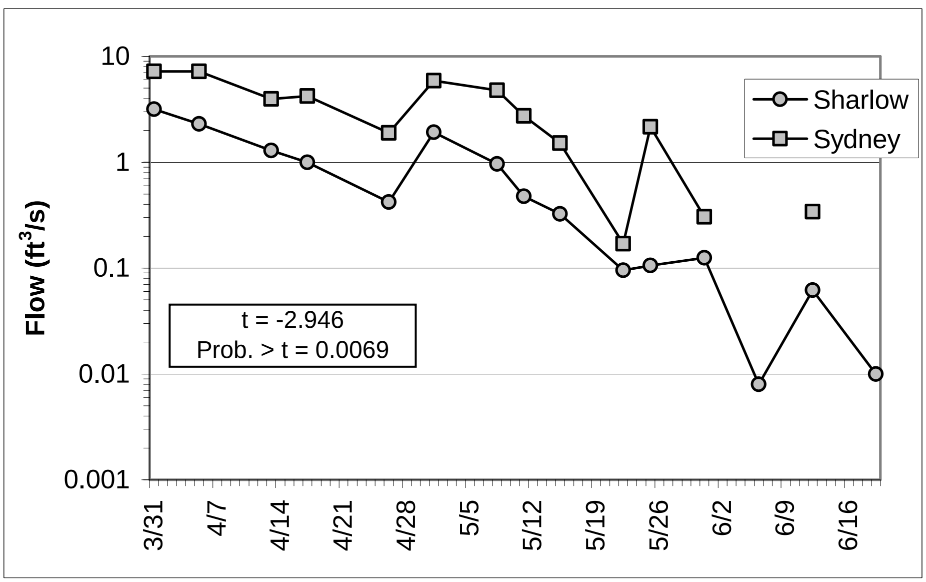


Figure 5. Buffalo Creek Flow with log-transformed 2-tailed t-Test

All of the flows at the Sydney sampling site (downstream) shown on Figure 5 are greater than those upstream at the Sharlow site. However, there was no flow at the Sharlow site on the June 6 sampling date. Because the *y*-axis on Figure 5 is log-scale, a 0 flow cannot be plotted. The fact that there was no flow downstream on June 6 indicates that what little flow there was upstream was lost in transit between the two sites. The same thing happened on the June 19 sampling date, when there was no flow at the Sydney site. Once again, the flow at the upstream site was extremely low on that date.

Figure 6 shows the measured and computed flows for two 2006 sample sites in Beaver Creek. Beaver Creek at the upstream site northwest of Sydney ceased flowing in late May. This was the earliest that any of the nonperennial sites quit flowing. True to its name, the creek was dominated by beaver dams upstream from the site; the dams may have controlled the flow to a large extent (Ryan Odenbach, personal communication, email of March 31, 2007). As was the case in Seven Mile Coulee, the downstream site was perennial throughout the study period in 2006, although the flow at the site was extremely small. The low base flow is consistent with the observations of Christensen and Miller (1988). They indicate that there are only five perennial tributaries to the lower James River. These include Seven Mile Coulee and Beaver Creek. However, Christensen and Miller (1988) also indicates that the total base flow of the tributaries, excluding Pipestem Creek, is less than one ft^3/s. That statement is consistent with the results here.

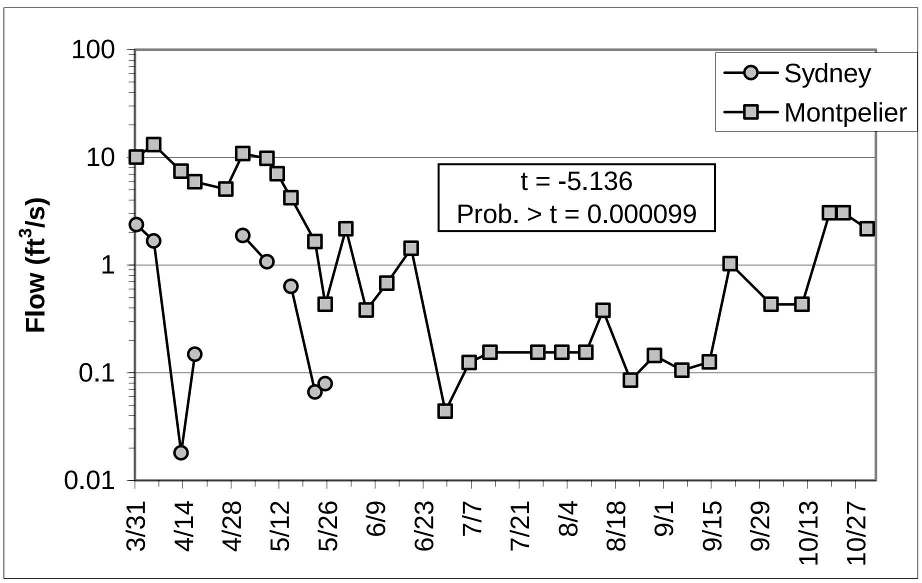


Figure 6. Beaver Creek Flow with log-transformed 2-tailed t-Test
t-Test based on March 31 through May 25 data only

There are two missing dates in the flow record for the site in Beaver Creek northwest of Sydney (upstream). There must have been flow on those dates – water quality samples were collected. The missing flows (actually, gage heights) mean that the nutrient loads calculated later will not be based on actual data, but rather on interpolated flows.

The flow at the downstream Beaver Creek site remained between 0.1 and 0.2 ft^3/s throughout the summer. These low flows are followed by an increase in flow to near where the flows were late in the spring. This is consistent with observations in small streams elsewhere in the arid to semi-arid West. Such decreases in flow have been attributed to uptake by riparian vegetation. Such depletions by phreatophytes tend to only be noticeable on the hydrograph of small streams, where the depletion of a few tenths of a ft^3/s is a relatively high percentage of the base flow. It should be noted that even if the hydrograph reflects a phreatophytic depletion, there is still a gain in flow between the two sites in Beaver Creek. It should also be noted that the inflow between the sites is not due to tributary inflows from Buffalo Creek, although that does not rule out ground-water inflow from the Buffalo Creek alluvium.

Flow data limitations and error

In their study of the drought of 1988, Odenbach and Padmanabhan (1990) make an observation concerning rating curves that has implications for this study. They indicate that the rating curves derived from a limited range of data may take a number of forms, and it may not be valid to extend those curves beyond the range of data used in their derivation. The reason that this is undoubtedly true here has to do with the earlier described linear relationships between stage and flow at two of the sites (actually, three if the west culvert in Buffalo Creek at Sydney is included). At higher flows, the linear relationship tends to break down. Channels tend to become increasingly wider as they deepen. In other words, there tends to be more and more flow per unit of elevation of stage as the flow increases. This can be illustrated by a typical stage-discharge rating curve as presented in Kennedy (1984 – Figure 7). The first thing to note is that the curve is plotted on a log-log graph. A log-log relationship between flow and stage was derived for three of the sites in this study, both of the sites in Seven Mile Coulee and the Beaver Creek site at Montpelier (Figure 3). However, Figure 8 indicates that there are essentially three log-linear segments of the typical curve. This could indicate that even the log-log curves may not be extended beyond the range of the data on which they are based. Note also that the flow-stage relationship for the east culvert is a 3rd degree polynomial (Figure 3). A 3rd degree polynomial will begin to cycle as the higher order terms in the equation interact. For this reason, no polynomial can be extended beyond the upper limit of the data used to derive it.

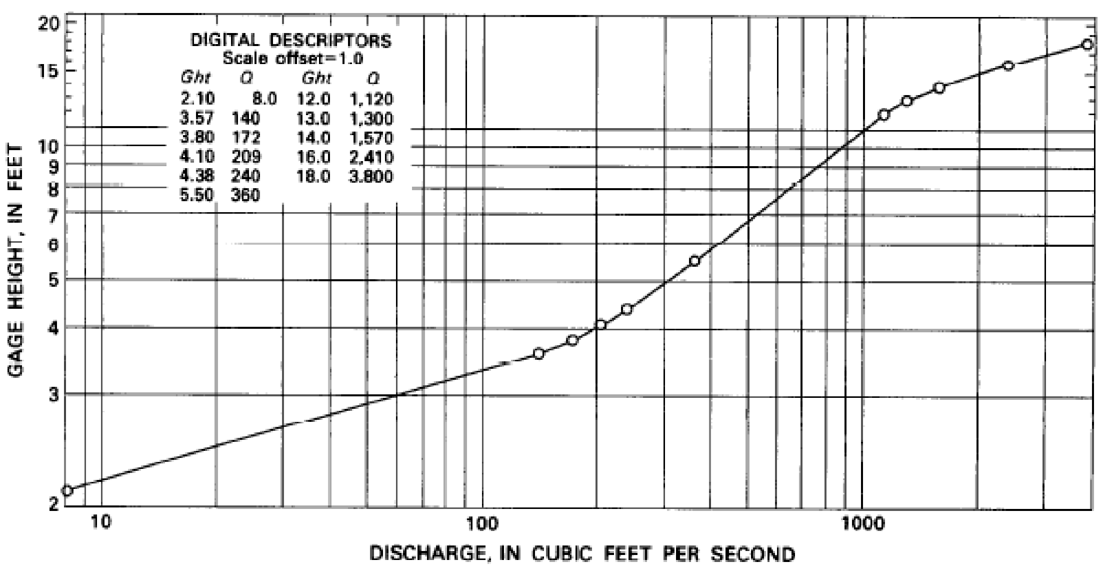


FIGURE 7.—Typical logarithmic rating curve with corresponding digital descriptors.

Figure 7. Reproduction of Figure 7 from Kennedy (1984)

Another concern is that 2006 was a relatively dry year. Data from two nearby precipitation stations, the North Dakota State Hospital in Jamestown and the FAA station at the Jamestown Airport, indicate that 2006 was within the 25th percentile of precipitation, when ranked from low to high (*i.e.*, 24th of 106 [22nd percentile] and 14th of 58 [24th percentile] years respectively). In addition, 2006 ranked 8th out of 33 years of record at the Pingree gage on Pipestem Creek (*i.e.* 24th percentile). The Pipestem Creek basin lies between the Beaver Creek and Seven Mile Coulee basins and should be a good indicator of the long-term position of 2006 in the longer-term flow record of the basins in the study areas, if there were long-term records to evaluate. The agreement among the three long-term surrogate records would indicate that 2006 should have been relatively dry, but not extremely dry, in the study area streams.

The Pingree gage on Pipestem Creek can also be used to illustrate another potential error in relating discharge to stage. The relationship can change over time, with periodic increases and decreases in flow at a given stage as the channel fills and degrades over time. The USGS accounts for this by applying a shift to the rating curve (Kennedy, 1983). Figure 8 shows the shifts that have been applied to the Pingree gage rating curve during water years 2000 through 2006. As can be seen on Figure 8, shifts are frequent. In addition, some of the shifts are quite large, *e.g.* ½ foot or greater. All of the larger shifts are negative, indicating that the unadjusted gage height would be too large for the measured flow. The changes are likely due to recent dredging and chanelization at the site (Ryan Odenbach, personal communication, email of March 31, 2007). In other words, without the application of the shift adjustment, the flow would be overestimated.

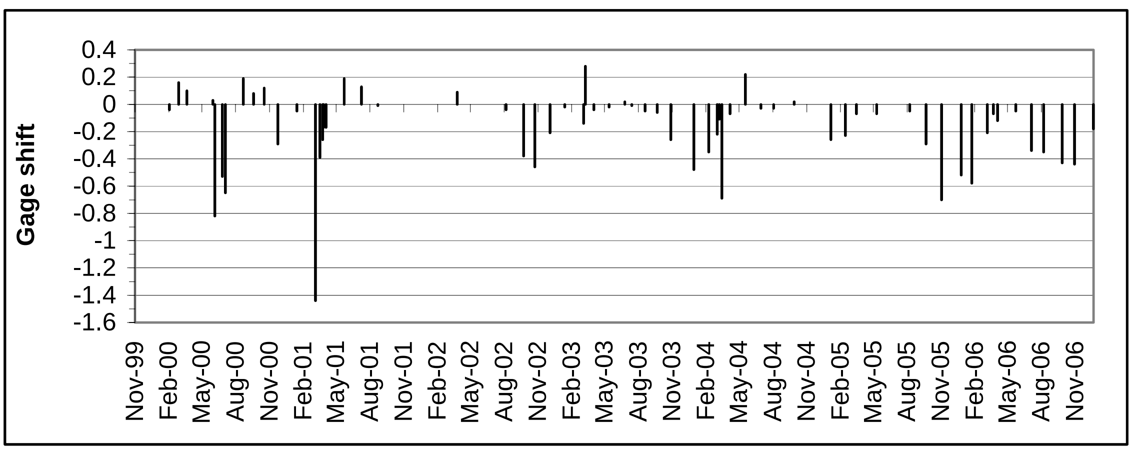


Figure 8. Gage shifts at time of discharge measurements at the Pingree gage on Pipestem Creek

The point of the preceding is that the flows estimated from the stage data for the sites in Seven Mile Coulee and the Beaver Creek basin are likely subject to the same types of errors. No adjustments are being applied, because the curves shown on Figure 3 represent the best fit to the data. However, changes in the channel at the location of the staff gages and stage recorders are subject to the same factors that lead to shift adjustments at the long-term USGS gages. In the case of the sample sites in this study, such factors would lead to a reduced r^2 in the stage-discharge curves used to calculate the flow from the gage height data.

In an attempt to put the preceding into perspective, the stage-discharge data from the Pingree gage on Pipestem Creek were broken into data sets for each water year. A regression of the flow on gage height was developed from each of these data sets. The results are summarized in Table 1. The r^2 values for the regressions for water years 2000 through 2005 are rather good; all are greater than 0.8 and most (6 of 7) round to 0.9. However, five of the regressions are linear and only one is log-linear, the latter of which is the expected case. The troubling thing about the regressions is that the r^2 for water year 2006 regression is less than 0.5 (Table 1). This seems to indicate that water year 2006 is exceptional. However, this may be another example of the effects of the channel maintenance activities described above.

Table 1. Best regression by year – Pipestem Creek at the Pingree gage

Water Year	Stage (H)	Flow (Q)	r	r^2
2000	Stage	Q	0.979	0.959
2001	Stage	Q	0.973	0.947
2002	$\log_{10}H$	$\log_{10}Q$	0.971	0.942
2003	Stage	Q	0.905	0.819
2004	Stage	Q	0.940	0.883
2005	Stage	Q	0.937	0.877
2006	$\log_{10}H$	$\log_{10}Q$	0.698	0.487

The main point in bringing in the Pipestem data is to illustrate that conditions can change from year to year. Whether the exact conditions are something that would translate to the data from Seven Mile Coulee and the Beaver Creek basin is unknown, but such changes in a well established gage are a consideration in trying to apply the 2006 data to any conclusions relating to longer term relationships concerning flow or nutrient and TSS loads and the potential error in their calculation from short term gage records.

Water Quality Standards

Water quality samples from the six sites were analyzed in the laboratory for total phosphorus (total P), ammonium-nitrogen (NH_4-N), nitrite + nitrate nitrogen (NO_2+NO_3-N), total Kjeldahl nitrogen, total suspended solids (TSS), and fecal coliform bacterial counts (FC). The result of the Kjeldahl nitrogen analysis represents the concentration of NH_4-N plus organic nitrogen. For purposes of this report, the organic nitrogen concentration was calculated by subtracting the NH_4-N concentration from the Kjeldahl nitrogen concentration. The data analysis focuses on the organic nitrogen concentration because Kjeldahl nitrogen is not something that is important in natural settings. In addition, total nitrogen is calculated as the sum of NO_2+NO_3-N and Kjeldahl nitrogen concentrations and will be included in the analysis.

For water quality purposes, streams in North Dakota are classified as Class I, II, or III (NDCC, 2006). Seven Mile Coulee is classified as Class III. Beaver Creek is classified as Class II. Buffalo Creek is a tributary to Beaver Creek, but from its flow characteristics is Class III. From the perspective of the preceding water quality constituents, the classifications do not make any difference in the water quality standards in the respective Seven Mile Coulee and Beaver Creek basins.

There is no water quality standard for total P in North Dakota. There is a standard for orthophosphate (*o*PO_4-P), but that standard is only applicable to lakes and reservoirs. However, the objective of the study as it relates to nutrients, such as total P, is to characterize their temporal and spatial trends (Meek, 2005). The data are adequate for that task.

There is a water quality standard for NH_4-N. The standard is temperature and pH dependent. Meek (2005) indicates that temperature measurements were to be made at the time that water quality samples were collected. However, no pH measurements were made. As a consequence, the water quality standards for NH_4-N cannot be calculated. Like total P, NH_4-N is also a nutrient and its temporal and spatial trends will be evaluated later in this report.

There is an instream water quality standard for NO_3-N that is set at 1 mg/L. As is noted in NDCC (2006):

> The standard for nitrates (N) is intended as an interim guideline limit. Since each stream or lake has unique characteristics which determine the levels of these constituents that will cause excessive plant growth (eutrophication), the department reserves the right to review this standard after additional study and to set specific limitations on any waters of the state.

As was noted above, the nitrate data for this study actually include nitrite as well. In nature, nitrite is a transient nitrogen species in an oxidized environment. Most streams represent oxidizing environments. It can usually be assumed that the NO_2-N component of the NO_2+NO_3-N analyte will be small. For purposes of comparison with the NO_3-N standard, the NO_2+NO_3-N will be assumed to be essentially all NO_3-N. Temporal and spatial trends can also be evaluated.

There are no standards for Kjeldahl nitrogen or total nitrogen (total N). Likewise, there is no standard for organic nitrogen. These can be evaluated in terms of their temporal and spatial trends.

There is similarly no standard for TSS in North Dakota. TSS are usually indicative of erosion. In addition to an evaluation of temporal and spatial trends, correlations with TSS may be useful in defining the form of other water quality constituents, *e.g.* dissolved or suspended.

The standards for fecal coliforms are the same for all waters. The differences in the different classes of water for recreation, to which the fecal coliform standard applies, is related to the characteristics of streams and their ability to support recreation,, not to the stream's quality. The fecal coliform standards only apply to the period of May 1 through September 30 of each year.

There are two different parts to the fecal coliform standard for recreation. These are equivalent to an acute and a chronic standard for aquatic life support. The first part of the standard is defined as a geometric mean of 30-day consecutive period samples of less than 200 individuals (usually defined as plate colonies or colony-forming units), abbreviated here as #/100 mL. In the case of the 400 /100 mL aspect of the standard, the evaluation criterion is that not more 10 percent of the samples collected in a 30 consecutive day period cannot exceed the standard. In both cases, the 30 consecutive days are defined as a calendar month. In the case of the geometric mean, this is not exactly the way the data are to be presented. For purposes of this report, a running average (geometric) was calculated based on a 30-day averaging period for the samples. As a result, there is a value for each sample date beginning 30 days after May 1. The last value for each month would represent the geometric mean that would conform to the evaluation criterion of the North Dakota Department of Health, the agency responsible for water quality standards administration.

Comparisons to water quality standards

Figure 9 shows a time series plot of the NO_2+NO_3-N concentrations in Seven Mile Coulee to the water quality standard for NO_3-N. The NO_2+NO_3-N concentrations are low throughout the period for which there are data (March 31 through July 12) at the upstream site located 5 miles north and 6 miles east of Jamestown. The coulee went dry in mid-July; so no further water samples could be collected. All of the NO_2+NO_3-N samples at the site remained well below the NO_3-N standard.

At the downstream site located 7 miles east of Jamestown the NO_2+NO_3-N concentrations were initially similar to those at the upstream site and remained so until the end of May (Figure 9). In early June, the NO_2+NO_3-N concentrations began to rise to their peak in late June. Following that, there was a brief decline in NO_2+NO_3-N, after

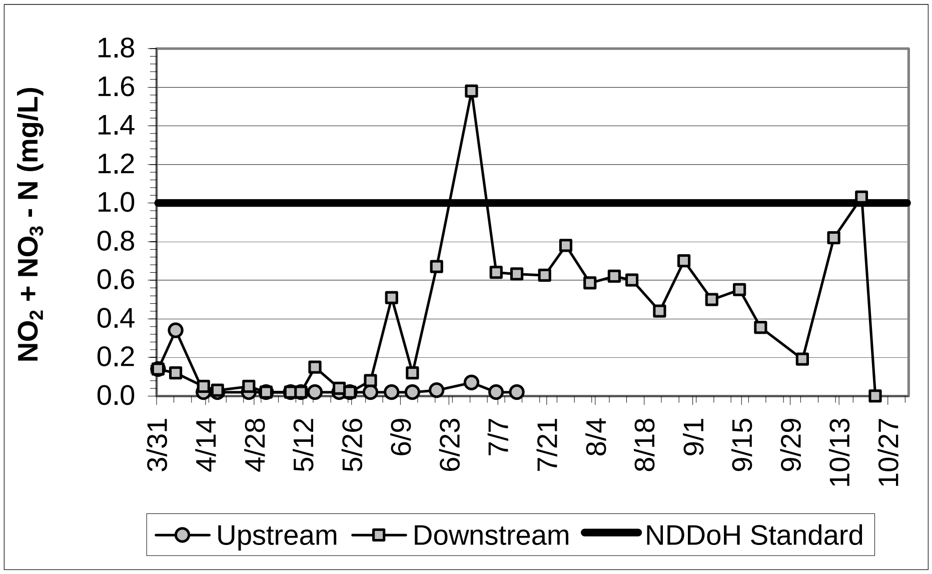


Figure 9. Comparison of NO_2+NO_3-N concentrations in Seven Mile Coulee to the State instream NO_3-N water quality standard

which the concentrations remained fairly constant until mid-September. There was another increase in NO_2+NO_3-N in October with a second peak in the middle of the month. In both cases the peak concentrations of NO_2+NO_3-N exceeded the NO_3-N standard, although the October peak was only slightly above the standard. According to the wording of the NO_3-N standard, the standard is only exceeded if 10 percent of the samples collected in a 30 day period are greater than 1 mg/L. In the case of each of the peak NO_2+NO_3-N concentrations, there would be 4 or 5 samples collected during the 30 days before or after the peak. On that basis, one sample in excess of 1 mg/L would constitute more than 10 percent. Whether either of these would actually be a violation of the NO_3-N standard would have to be determined by the responsible agency, the North Dakota Department of Health.

Table 2 shows the maximum concentrations of NO_2+NO_3-N at the four sites in the Beaver Creek basin. As can be seen in Table 2, the maximum concentrations of NO_2+NO_3-N are well below the NO_3-N standard of 1 mg/L at three of the four sites. The remaining site, Buffalo Creek northwest of Sharlow, had a maximum NO_2+NO_3-N of 0.58 mg/L, which is slightly more than half of the standard and still well below it. Because none of the maximum NO_2+NO_3-N concentrations in the Beaver Creek basin were near the standard, the NO_2+NO_3-N data from the basin have not been plotted.

Table 2. Maximum NO_3+NO_2-N (mg/L) at each site in the Beaver Creek basin (Std. = 1 mg/L)

Site	NO_3+NO_2-N
Buffalo Creek NW of Sharlow	0.58
Buffalo Creek at Sydney	0.12
Beaver Creek NW of Sydney	0.07
Beaver Creek at Montpelier	0.15

Fecal samples were collected at all sites during the recreation season defined by the water quality standards. However, 4 of the 6 sites had no flow during the summer and samples at those sites were only collected when there was flow during the spring. Because these streams are so small, it is doubtful that they receive much recreation use.

Figure 10 shows the fecal coliform counts at the upstream site in Seven Mile Coulee. The period of record at the site during 2006 was from May 1 through July 12, after which there was no flow in the stream at the site.

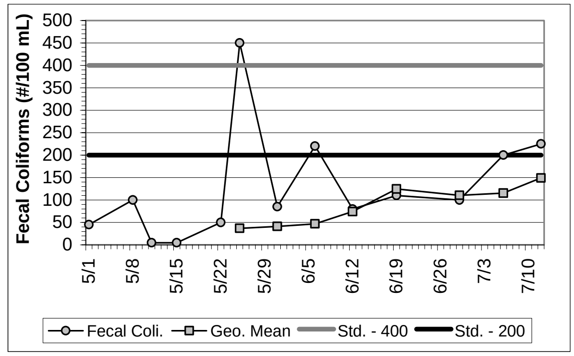


Figure 10. Fecal coliform counts at the Seven-Mile Coulee site 5 miles north and 6 miles west of Jamestown

Figure 10 also shows the running geometric mean for the period of record at the site. The first geometric mean on the plot appears at the end of May and is based on the five samples collected during the month. As a basis for comparison, Figure 10 also emphasizes the 200 and 400 colony per 100 mL levels on the *y*-axis grid lines.

There is only one fecal coliform sample that exceeded the 400/100mL standard during 2006 at the upstream site in Seven Mile Coulee (Figure 10). Since there were five samples collected during May, one sample in excess of the standard amounts to 20 percent. Alternatively, none of the samples collected during June or July were greater than the 400/100mL standard. None of the geometric means exceeded the 200/100mL standard. Based on the evaluation criterion in the water quality standards, the only geometric means that would be important would be the one at the end of May and the one at the end of June. The first is less than 50/100 mL and the second is near 100/100 mL (or about ½ the standard). The largest geometric mean fecal coliform count is represented by the last sample in July, when the flow was extremely low. That geometric mean fecal coliform count is 150/100 mL and still well below the 200/100mL standard. In conclusion, the water at the upstream site in Seven Mile Coulee meets the fecal coliform standard, at least in the vast majority of the samples collected during 2006.

Figure 11 shows a similar plot to Figure 10 based on the fecal coliform samples collected at the downstream site in Seven Mile Coulee. The sample period for the downstream site encompassed the entire recreation season, but flows during most of September were rather low – near or below 1 ft^3/s.

Fecal coliform counts at the downstream site in Seven Mile Coulee showed an extremely large range. To make the results more comprehensible, the *y*-axis on Figure 11 is on a logarithmic scale. The results on Figure 11 range over 3 orders of magnitude ($10^1 – 10^4$). The extra heavy gridlines on Figure 11 define the 200 and 400/100 mL standards and provide an additional point of reference on the plot.

Fecal coliform counts at the downstream site in Seven Mile Coulee were relatively low during most of May (Figure 11). The count rose during the latter part of the month and

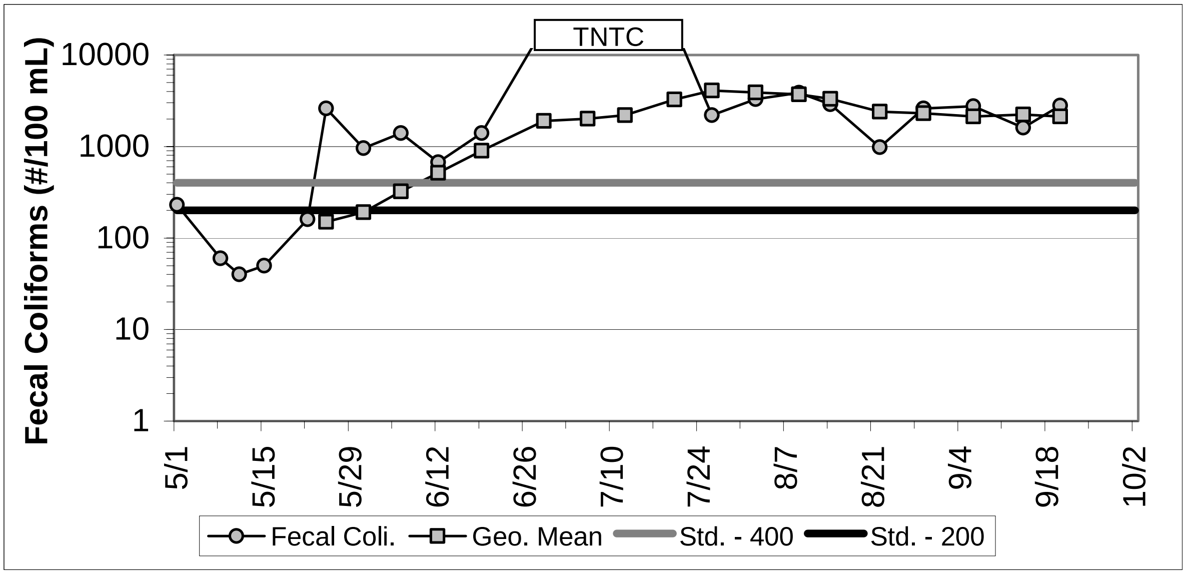


Figure 11. Fecal coliform counts at the Seven-Mile Coulee site 7 miles east of Jamestown (TNTC = too numerous to count: > 4000 colonies/100 mL)

after that, the samples decreased somewhat during the first part of June. Beginning in the middle of June and continuing through much of July, the fecal coliform counts exceeded the maximum plate count that could be accurately enumerated. Although the caption to Figure 11 indicates that the results were greater than 4000, the actual number is unknown. The 4000 value appears reasonable because it is greater than the maximum quantitated result of 3850 colonies/100 mL. The actual value depends on a number of factors, including the number of dilutions, size of the colonies, among others. What is certain is that all of those samples exceeded the 400 colony/100 mL standard, as did all of the subsequent samples collected at the site.

The first of the geometric means on Figure 11 appears at the end of May after sufficient samples had been collected to calculate a monthly mean. That geometric mean indicates that the 200/100 mL standard was met during May. The individual fecal coliform samples showed a rather dramatic increase at the end of May, followed by reasonably stable counts through part of June. After that, a set of four results are not quantitative. Although geometric means are shown for that period, those are not exactly quantitative either. For calculating the geometric means, the individual sample results were set to 5000 colonies/100 mL. The running geometric mean plot increases gradually during that period. When the data became quantitative at the end of July, the geometric means and the individual samples are nearly overlain on Figure 11 from mid-August until the end of sampling in late September. This result indicates that there is little variation in the fecal coliform counts during that period. The one thing that is obvious from the data is that both the individual samples and the geometric means are greater than the higher of the standards throughout the summer.

A comparison of figures 10 and 11 shows that there is an increase in fecal coliforms between the upstream and downstream sites in Seven Mile Coulee. Changes in various measures of water quality in Seven Mile Coulee will be addressed in more detail later in this report.

Figure 12 shows fecal coliform counts at the upstream site in Buffalo Creek northwest of Sharlow. The samples at the Sharlow site in Buffalo Creek encompass the period of May 1 through June 19, following which the stream was dry. None of the individual samples exceeded the 400/100 mL. Samples collected during mid- to late May had fecal coliform counts that were extremely low, preceding their rise to the highest counts at the end of May. The maximum fecal coliform count was 370/100 mL and near the standard on May 31 in Buffalo Creek.

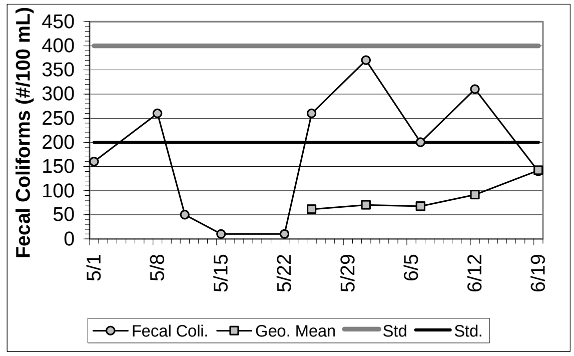


Figure 12. Fecal coliform counts at the Buffalo Creek site northwest of Sharlow

The geometric mean fecal coliform counts show a general increase in Buffalo Creek at the upstream site during the monitoring period (Figure 12). The pattern of the plot of the geometric mean fecal coliform is one of convergence with the individual sample counts. As the fecal coliform counts decline in the individual samples, the running geometric mean increases. The geometric means are being influenced by the data from late May and early June and are rising as the very low counts from mid-May are dropped from the calculation of the geometric means.

Figure 13 shows the fecal coliform data from the downstream site in Buffalo Creek at Sydney. The last sample was collected from the downstream site a week earlier than that from the Sharlow site. As can be seen from Figure 13, the fecal coliform counts at the site on Buffalo Creek at Sydney are rather erratic. In early May, the fecal coliform count is generally low, although it was right at the 400/100 mL standard on May 8 (Figure 13). On May 31, the fecal coliform count reached its maximum at 1,300/100 mL or more than three times the standard. The last sample showed a decrease in the fecal coliform count, but it was still near 1000/100 mL. Alternatively, the geometric mean fecal coliform count was rather steady (admittedly there were only three values) at about ½ the standard (Figure 13).

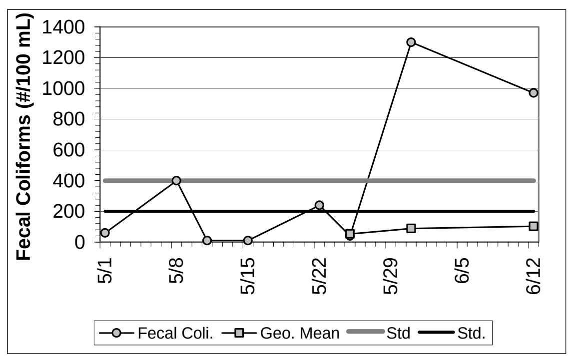


Figure 13. Fecal coliform counts at the Buffalo Creek site at Sydney

The upstream site on Beaver Creek is located northwest of Sydney and upstream from the mouth of Buffalo Creek (Figure 1). There was no flow in the stream after the samples were collected in mid-June. The fecal coliform counts from samples at the upstream site on Beaver Creek are shown on Figure 14. Samples collected in the first half of May were at or below the minimum number of colonies grown in culture that are considered within an acceptable range for a statistically adequate result (5/100 mL). Samples collected later in May and in June were within a more suitable range, with counts between 50 and 250/100 mL on each of the 5 sample dates. None of the samples exceeded the 400/100 mL standard for individual samples. In concert with that result, none of the geometric means exceeded its 200/100 mL standard. The maximum geometric mean fecal coliform count was 100/100 mL or ½ of the 200/100 mL standard for geometric means.

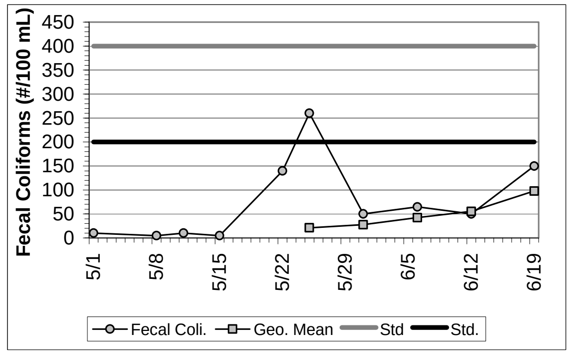


Figure 14. Fecal coliform counts at the Beaver Creek site northwest of Sydney

Figure 15 shows the fecal coliform counts at the downstream site on Beaver Creek, which is located at Montpelier. As can be seen on Figure 15, the samples from the downstream site on Beaver Creek continued throughout the summer, with the last sample collected on September 20.

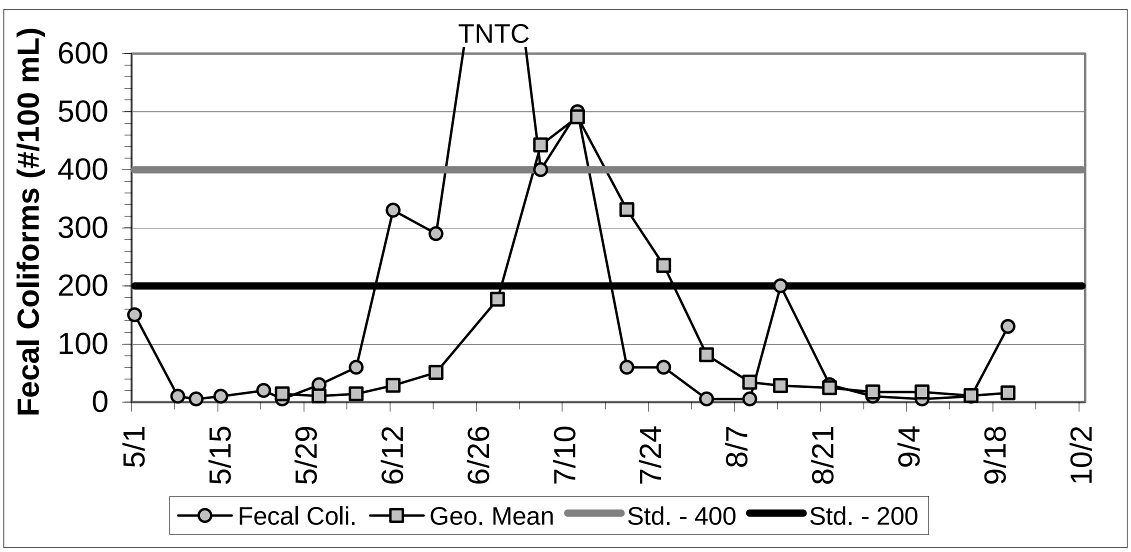


Figure 15. Fecal coliform counts at the Beaver Creek site at Montpelier

The maximum fecal coliform count, as occurred at the downstream site in Seven Mile Coulee, was too numerous to count (TNTC – Figure 15). The maximum reported value was 500/100 mL, which occurred on July 12. These results were the only observations that exceeded the 400/100 mL standard during 2006, although the sample collected on July 6 was right at the standard with a count of 400/100 mL. The two samples prior to that were collected in mid- to late June and had fecal coliform counts around 300/100 mL. For some reason, the samples collected during the four week period from June 12 to July 12 had fecal coliform counts that were much higher than at any other time during the

2006 recreation season. The sample from July 12 was one of four samples collected in July, making 25 percent of the samples greater than the standard. In other words, more than 10 percent of the July samples were greater than the 400/100 mL standard. The same would have been true in June. The sample reported as TNTC was collected on June 29 and was one of four samples collected in June. Although the actual count is unknown, it would be greater than the standard, with the result that 25 percent of the June samples exceeded the standard.

As can be seen on Figure 15, three of the running geometric mean fecal coliform counts exceeded the 200/100 mL standard during July. However, the last of the July geometric means would be the one that is based solely on the July samples. That geometric mean did not exceed the standard. Based on the evaluation criterion that the samples must be within a 30-day period within a calendar month, none of the geometric means that count exceeded the standard. Actually, none of the geometric mean fecal coliform counts from the other months approached the 200/100 mL fecal coliform standard.

In summary, there were fecal coliform counts that exceeded the 400/100 mL standard at four of the six sample sites during the 2006 recreation season. At three of those four sites, there were only one or two samples that exceeded that standard. The only site that had fecal coliform counts consistently greater than both of the fecal coliform standards was the downstream site in Seven Mile Coulee.

Nutrients

As was noted above, there are no water quality standards for most of the nutrients that were analytically determined in Seven Mile Coulee, Buffalo Creek, and Beaver Creek. This section of the report will describe the nutrient concentrations in the three basins at the different sites in relative terms. Changes in the concentrations between sites in the 3 streams will also be evaluated. Finally, nutrient loads will be calculated and compared between sample sites.

Earlier, t-Tests were used to compare flows at the upstream and downstream sites within each of the streams in the study areas. An evaluation of the raw and transformed data indicated that the log-transformations failed to normalize the flow data in most cases. The same was true of the water quality data. To avoid problems with non-normality in the data, upstream-downstream comparisons are performed using the nonparametric (distribution-free) Mann-Whitney Test. Looking at the changes in flow, along with the nutrient concentrations, will allow an evaluation of which component of the load may be the more important.

Seven Mile Coulee

Table 3 summarizes the water quality data (nutrients and total suspended solids (TSS) for the two sites in Seven Mile Coulee. The data are presented in two data sets. The first is based on the March 31 through June period. This first period is consistent with the period of record when there were flows in the intermittent streams in the Beaver Creek basin. Although the upstream site in Seven Mile Coulee was also intermittent, as was earlier shown on Figure 4, flow persisted at the site until mid-July. The second data set in Table 3 includes the entire period of record for the nutrient and TSS data at both of the Seven Mile Coulee sites. That record extended until October 23 at the downstream site.

Table 4 summarizes the results of the Mann-Whitney tests for the Seven Mile Coulee sites for each of the data sets summarized in Table 3. Those results indicate that there are significant differences in flow, total phosphorus, nitrate + nitrite, and total suspended solids (TSS) between the 2 sites in the spring (March through June) in Seven Mile Coulee. Table 3 also indicates that in all cases these differences constitute an increase. When the complete data sets are included, except for flow, the above differences become more significant. For the complete data sets, there is a difference in ammonium as well.

In the case of total phosphorus, the Mann-Whiney U is 0. The Mann-Whitney Test defines significance on the basis of the U being smaller than the tabular value corresponding to the degrees of freedom for the test. A U-value of 0 indicates absolutely no overlap (see Figure 16) between the data sets, *i.e.* the minimum total phosphorus concentration from samples at the downstream site is greater than the maximum in samples from the upstream site (see also Table 3).

The total phosphorus data provide an example of the Mann-Whitney results. Figure 16 provides a display of the data leading to those results. As can be seen on Figure 16, total

Table 3. Summary of water quality data from Seven Mile Coulee							
A. March-June samples only and B. All samples (all in mg/L)							
Data Set A.	Statistic	Total P	NH_4-N	NO_3+NO_2-N	Organic N	Total N	TSS
Upstream	Minimum	0.162	< 0.010	0.020	0.36	0.388	< 5
	1st Quartile	0.199	< 0.010	0.020	1.15	1.175	< 5
	Median	0.238	< 0.010	0.020	1.27	1.325	< 5
	3rd Quartile	0.320	< 0.010	0.025	1.54	1.650	< 5
	Maximum	0.453	0.063	0.340	1.82	1.890	7
	Samples	16	16	16	16	16	16
Downstream	Minimum	0.852	< 0.010	0.020	0.34	0.366	< 5
	1st Quartile	0.993	< 0.010	0.025	1.17	1.200	< 5
	Median	1.585	0.010	0.065	1.24	1.375	7
	3rd Quartile	2.685	0.066	0.145	1.58	1.930	9
	Maximum	6.775	0.767	0.670	1.84	3.275	38
	Samples	16	16	16	16	16	16
Data Set B.	Statistic	Total P	NH_4-N	NO_3+NO_2-N	Organic N	Total N	TSS
Upstream	Minimum	0.162	< 0.010	0.020	0.36	0.388	< 5
	1st Quartile	0.205	< 0.010	0.020	1.18	1.200	< 5
	Median	0.272	< 0.010	0.020	1.35	1.410	< 5
	3rd Quartile	0.423	0.019	0.020	1.66	1.740	< 5
	Maximum	0.628	0.104	0.340	2.40	2.525	10
	Samples	18	18	18	18	18	18
Downstream	Minimum	0.852	< 0.010	0.020	0.34	0.366	< 5
	1st Quartile	1.585	< 0.010	0.065	1.19	1.285	7
	Median	3.540	0.045	0.398	1.48	2.113	13
	3rd Quartile	6.548	0.116	0.629	1.78	2.553	26
	Maximum	9.650	0.839	1.580	2.35	4.050	59
	Samples	32	32	32	32	32	32

Table 4. Comparison of upstream and downstream flow and water quality measures in Seven Mile Coulee – Mann-Whitney Test (U-Statistic)						
Variable	Mar-June			All Data		
	M-W U	χ^2	Probability	M-W U	χ^2	Probability
Flow	24	15.36	0.000089	175	5.22	0.022369
Total P	0	23.27	0.000001	0	33.88	< 0.000001
NH_4-N	85	3.66	0.055758	136	10.32	0.001319
NO_3+NO_2-N	62	7.07	0.007819	67	20.93	0.000005
Kjeldahl N	114	0.28	0.597309	214	2.24	0.134627
Organic N	127	0.00	0.969908	236.5	1.08	0.297803
Total N	107.5	0.60	0.439494	164	6.28	0.012189
TSS	65	7.86	0.005046	83.5	18.69	0.000015
Fecal Coliform	26.5	4.04	0.044482	34.5	11.67	0.000634

phosphorus at the upstream site is low throughout the period for which there are data (all dates with flow). There is a slight upturn in the total phosphorus concentrations just before the stream dried up in July. Meanwhile, total phosphorus begins at its lowest, although the concentration is still greater than what is seen at the upstream site. Total phosphorus at the downstream site remains relatively low until only mid-May. The most dramatic increase in total phosphorus at the downstream site begins in mid-June and culminates with its maximum concentration near 10 mg/L in early July (Figure 16).

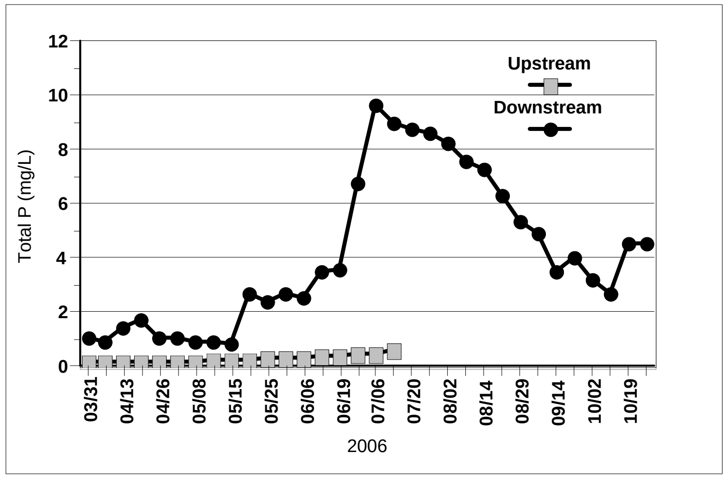


Figure 16. Total phosphorus concentrations at 2 sites in Seven Mile Coulee during 2006

The period in which the total phosphorus concentrations are at their highest at the downstream site in Seven Mile Coulee coincides with the lowest flows (compare figures 1 and 16). Such a result usually reflects a system that is dilution dominated. Dilution driven systems tend to be dominated by dissolved species. Only total phosphorus data are available from the 2006 study; so the dominance by the dissolved fraction of the total phosphorus cannot be verified from the existing data.

As was noted above, the addition of the higher total phosphorus later in the year increases the significance of the difference in the concentrations between the two sites in Seven Mile Coulee (Table 4). As is shown in Table 3, there is a small increase in the median total phosphorus at the upstream site from 0.24 to 0.27 mg/L with the addition of the July samples. On the other hand, the median total phosphorus concentration more than doubles with the addition of the later data at the downstream site, *i.e.* from 1.58 mg/L to 3.54 mg/L (Table 3).

To put the preceding into perspective, the USGS (1999) shows a background total phosphorus concentration for the US of 0.1 mg/L. The median concentration at the upstream site in Seven Mile Coulee is more than twice that background total phosphorus concentration at 0.23 mg/L (or 0.27 mg/L if the July data are included – Table 3). However, the median total phosphorus concentration at the downstream site is over 1.5 mg/L during the spring period and is increased to over 3.5 mg/L when the lower flow period is included in the data set used to develop the median total phosphorus concentration. Obviously, both sites are enriched in total phosphorus relative to the USGS background, and the downstream site in Seven Mile Coulee is extremely enriched.

Although organic nitrogen is by far the predominant nitrogen species at both sites (Table 3), ammonium and nitrate are the nitrogen forms that show significant changes between sites in Seven Mile Coulee. The USGS (1999) indicate that average background concentrations of ammonium- and nitrate-nitrogen in US waters are 0.1 and 0.6 mg/L respectively. The median ammonium- and nitrate-nitrogen concentrations at both sites in Seven Mile Coulee are well below those USGS average background concentrations (compare with Table 3). In the case of ammonium, the median concentration is below detection at the upstream site in both data sets, while the median ammonium concentration is at the detection limit during the spring months, but increases by a factor of 4 with the inclusion of the low flow data (Table 3). Alternatively, USGS (1999) found a background total nitrogen concentration of 1 mg/L. The median total nitrogen concentration at the upstream station in Seven Mile Coulee is greater than the USGS (1999) background by 0.3-0.4 mg/L depending on the data set used for comparison (Table 3). Unlike total phosphorus, the median total nitrogen concentration at the downstream site is only slightly higher than that upstream during the spring months (compare in Table 3). However, the difference is much greater when the lower flow period is included in that there is little change in the median total nitrogen at the upstream site with the addition those data, but the median increases considerably at the downstream site from 1.4 mg/L to 2.1 mg/L.

The differences in the relative total nitrogen concentrations observed and Seven Mile Coulee relative to the USGS background is entirely due to the high concentration of organic nitrogen in the coulee. The majority of the organic nitrogen originates above the upstream site. The organic nitrogen concentration is greater at the upstream site than that at the downstream site during the spring months. However, the difference is not statistically significant (Table 4), indicating that there is no real difference. There must also be a source or sources of organic downstream from that site in that the organic nitrogen concentration at the downstream site increases with the inclusion of the low flow months in database. The organic nitrogen must originate from sources in the intervening reach between the sites, because there was no flow upstream for most of the period after June (see Figure 4). Without additional information, it would be highly speculative to try to assign a source to the organic nitrogen. The organic nitrogen concentrations are high at the upstream site. If there are no anthropogenic sources in the watershed above that site, the source may be natural. If this is not true, then the sources of organic nitrogen at both sites should be of a similar type.

Table 3 also summarizes TSS data from the Seven Mile Coulee. TSS are not a measure of nutrients, but the TSS data are included with the nutrients for convenience. This saves creating another section of the report for a single water quality constituent.

At the upstream site in Seven Mile Coulee, over ¾ of the samples (3^{rd} quartile) are below the minimum laboratory quantifiable concentration of 5 mg/L in both data sets. The inclusion of the July samples increases the maximum TSS from 7 to 10 mg/L. At the downstream site, the median TSS is 7 mg/L in the spring sample, but it increases to 13 mg/L with the inclusion of the samples from later in the year. However, the largest increases in the TSS with the inclusion of the low-flow data are with the 3^{rd} quartile and the maximum (Table 3). This indicates that the TSS are greater when the flows are low than when they are high. This result would indicate that the TSS concentrations are not likely due to erosion, which would be associated with higher flows. The result more likely indicates that the TSS are either fine particles or organic matter that are carried by flows independent of turbulent transport mechanisms. An inverse correlation would indicate dilution of a constant source of these fine particulate solids.

Attachment B includes tables that summarize correlations among all of the variables from each of the sites. The tables are somewhat extensive and are included in the attachment to keep from breaking up the text more than necessary.

Table B-1 includes the correlations from the upstream site in Seven Mile Coulee, and Table B-2 includes the equivalent correlations for the data from the downstream site. The correlations also include date among the variables. A correlations with date in the context of these data sets would indicate an increasing or decreasing trend through the monitoring period. Flow and TSS are also included among the variables in the tables. The TSS-flow relationship for Seven Mile Coulee was interpreted above.

The bottom row of each of the tables in Attachment B indicates that statistical significance should be defined based on the 0.01 probability of a greater correlation coefficient (r) occurring by chance alone. Frequently, statistical significance is defined by a probability (or α) level of 0.05. At the 0.05 α-level, the probability of a greater r occurring by chance alone is 1 in 20. There are 45 correlations in tables B-1 and B-2. At the 0.05 α-level, two correlations in each table would be expected to show significance based on random chance. Decreasing the α-level to 0.01 reduces the chances of coincidental (and likely, spurious) correlations being mistaken for significant relationships.

At the upstream site in Seven Mile Coulee, the significant correlations with date include those with flow and stage (decreasing) and total P (increasing). Total P correlates inversely with both flow and stage. As noted above, inverse correlations with flow indicate dilution of a constant or near constant source, while positive correlations with flow indicate erosion or a source that increases the inflow of a constituent along with flow. Total P, total N, and organic N are highly correlated, indicating a common control. The majority of the total N is in the organic fraction (Table 3); the total P-organic N correlation may indicate that the same is true of phosphorus.

Fecal coliform bacteria counts do not correlate with anything. Ammonium correlates with TSS. The ammonium-TSS correlation is the only significant one for TSS and does not particularly make sense. Ammonium is highly soluble and would be expected to be in the dissolved form rather than a particulate one. This correlation seems likely to be due to random chance.

At the downstream site in Seven Mile Coulee, with few exceptions, virtually all of the variables are correlated with each other. All of the correlations with flow and stage are inverse, which indicates dilution or possibly, it reflects the coincident seasonality of the data sets with no physical relationship actually existing. Correlations in and of themselves do not define any causative relationship, just a common pattern over time in this case. Fecal coliforms correlate with all other variables – inversely with flow and positively with nutrients. The inverse correlation with flow is not what is expected and should reflect the effects of dilution. It seems likely that all of the correlations reflect coincident seasonality, but what is behind the seasonality, except for that for flow, is not evident.

Table B-7 shows correlations of total N, total P, and flow between sites and repeats the correlations with date. In this case, there are 21 correlations in the table; so once again it seems reasonable to base statistical significance on a probability of less than or equal to 0.01 to avoid spurious relationships as much as possible.

Correlations of flow, total P, and total N between sites in the coulee indicate that the downstream flow and concentrations relate to those upstream. The best correlation is between total P at the 2 sites ($r = 0.9103$). The correlations indicate that the same factors control the season patterns of the concentrations of total P & N at the sites, although the concentrations are significantly higher downstream. This is consistent with a constant loading between sites that changes the concentration downstream, but does not change the seasonal distribution downstream.

Malting Plant

There is a malting plant located on a small tributary that drains to Seven Mile Coulee in the reach between the two monitoring sites. The malting plant discharges process water to the coulee. Monitoring data on the plant effluent were provided by Ryan Odenbach (personal communication of February 7, 2007). The effluent monitoring included flow, 5-day biochemical oxygen demand, dissolved oxygen, pH, total P, ammonium-nitrogen and Kjeldahl nitrogen, total dissolved solids, and TSS. The ammonium and Kjeldahl nitrogen concentrations were used to calculate an organic nitrogen concentration as was done with the stream data.

With the exception of June 1, there is very little variation in total P in the malt plant effluent (Figure 17). Alternatively, there is considerable variation in organic nitrogen and ammonium-nitrogen in the malt plant effluent over time. There are no total nitrogen data because there are no data on NO_2+NO_3-N to calculate the total nitrogen in the effluent. Figure 17 also shows time series plots of TSS and flow. The TSS is relatively constant with the exception of the first and last samples. Flow on the other hand tends to show summertime peaks, presumably reflecting an increase in production at the plant. The increase in flow should lead to an increase in loadings to the receiving stream.

Seven Mile Coulee Nutrient Loads

Table 5 shows the average daily nutrient and TSS loads at the two sites in Seven Mile Coulee during 2006. The data for the upstream site (5 miles north and 6 miles east of Jamestown) are averaged over the entire period for which samples were collected, *i.e.* March 31 through July 12. The data for the downstream site are averaged over

Table 5. Average daily nutrient and TSS loads (lbs/day) in Seven-Mile Coulee during 2006

Constituent	5 miles north and 6 mi. east of Jamestown	7 miles east of Jamestown	
	Mar.-July	Mar.-July	Mar.-Oct.
Total Phosphorus	2.70	63.66	61.12
Ammonium (N)	0.16	3.38	2.32
Nitrate + Nitrite (N)	0.86	4.67	5.33
Organic Nitrogen	14.38	38.02	26.89
Nitrogen (Total)	15.40	46.07	34.54
Suspended Solids	37	310	251

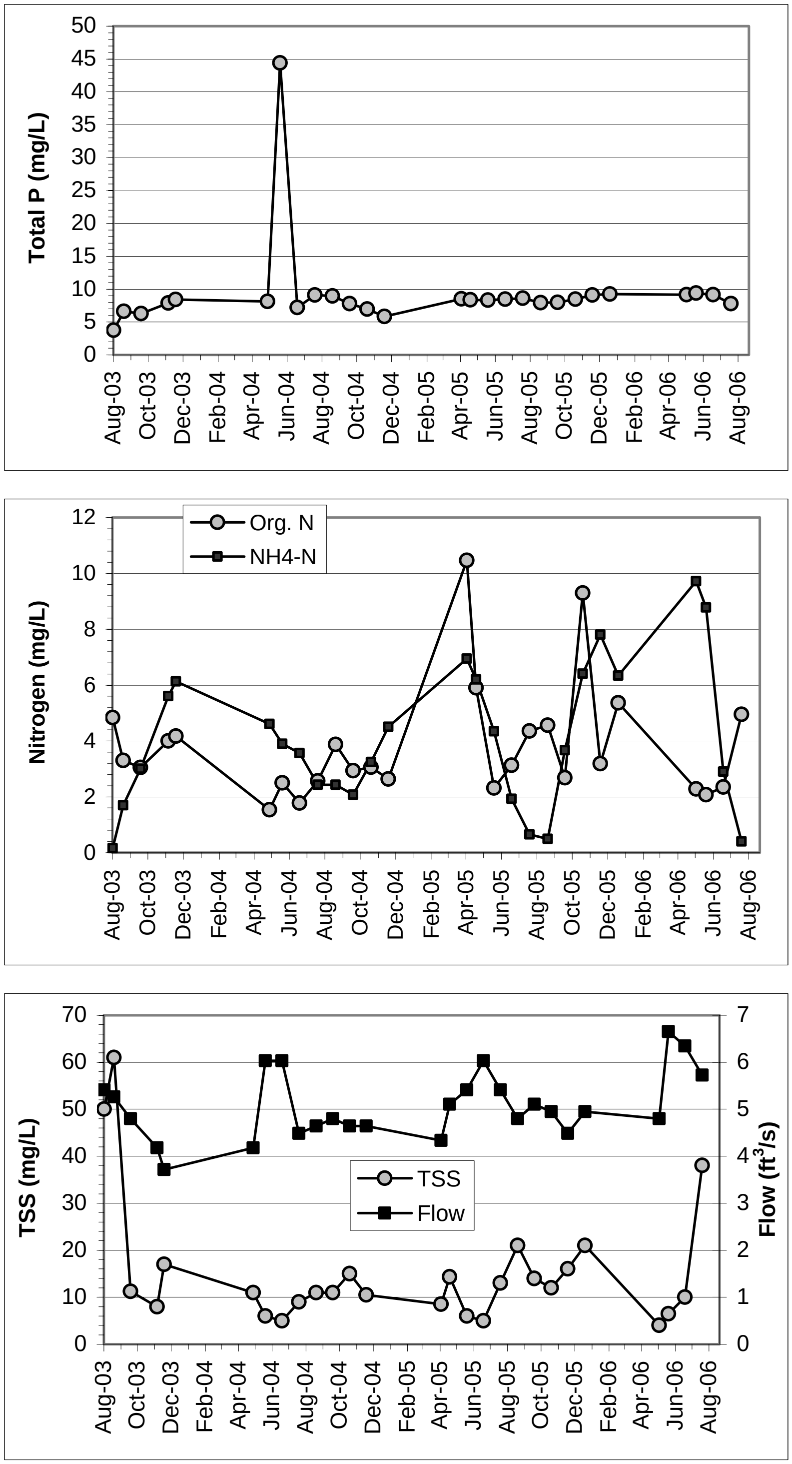


Figure 17. Nutrient and total suspended solids concentrations in the malt plant effluent from 2003 through 2006

two different periods, the first of which coincides with the data set from the upstream site and the second of which encompasses the entire data set for the downstream site, *i.e.* March 31 through October 23.

The daily average nutrient and TSS loads in Table 5 are time-weighted averages. The average daily loads were calculated by averaging the flow and nutrient or TSS concentrations in succeeding samples and calculating the average load between sample dates. The averages were then multiplied by the number of days between samples. The total load was then calculated by summing the loads over the period of record of interest. In the case of the incremental load for the downstream site in Seven Mile Coulee, the total load was calculated for the period of March 31 through July 12. The total was then divided by the number of days between those dates to get the average daily load. For the entire period, the data were summed over all dates and that total load was divided by the number of days between March 31 and October 23.

There are large increases in the nutrient loads downstream in Seven Mile Coulee when compared to those upstream (Table 5). The downstream nutrient loads are from 3 to over 20 times higher downstream during the higher flow period of March through mid-July. When all of the data are used to calculate the downstream daily loads, then the increases are somewhat less for most of the nutrients, particularly the nitrogen species. The exception is the NO_2+NO_3-N load, which shows an increase when the summer data are included in the data set from which the average was calculated. There was little change in the downstream total phosphorus load with the inclusion of the summer data.. Although the flow was lower during the summer and fall, the increase in the phosphorus concentration shown on Figure 18 was apparently more than enough to offset the flow decrease. Another thing to keep in mind is that all of the load at the downstream site originates from areas between the sites after July 12, after which there was no flow at the upstream site.

Figure 18 shows a comparison between the nutrient loads (total phosphorus and organic nitrogen) at the two sites in Seven Mile Coulee and in the malt plant effluent on the 4 dates in 2006 that fall within the period that the coulee was sampled. The loads on Figure 18 were calculated by multiplying the observed concentration by the total daily flow for the day. Sample dates are only coincidental on May 15. The other three dates on which samples were collected at the malt plant fall between sample dates in the coulee.

The upper plot on Figure 18 shows total phosphorus loads. The effluent total phosphorus on May 15, when there are data for both stream sites and the malt plant effluent, is much larger than that at the downstream site in the coulee. The same is true in late May-early June, although the sample dates do not coincide at that time. In both cases, these results indicate that there is a loss of total phosphorus upstream from the downstream sample site. The possible reasons for the loss are likely dependent on the form of the total phosphorus. If it is primarily particulate, then it may have settled out. Alternatively, if it is primarily dissolved, then it could have been taken up by algae. The best correlation for total phosphorus at the downstream site on Seven Mile Coulee is with NO_2+NO_3-N (see attachment), which would indicate that the total phosphorus was primarily dissolved.

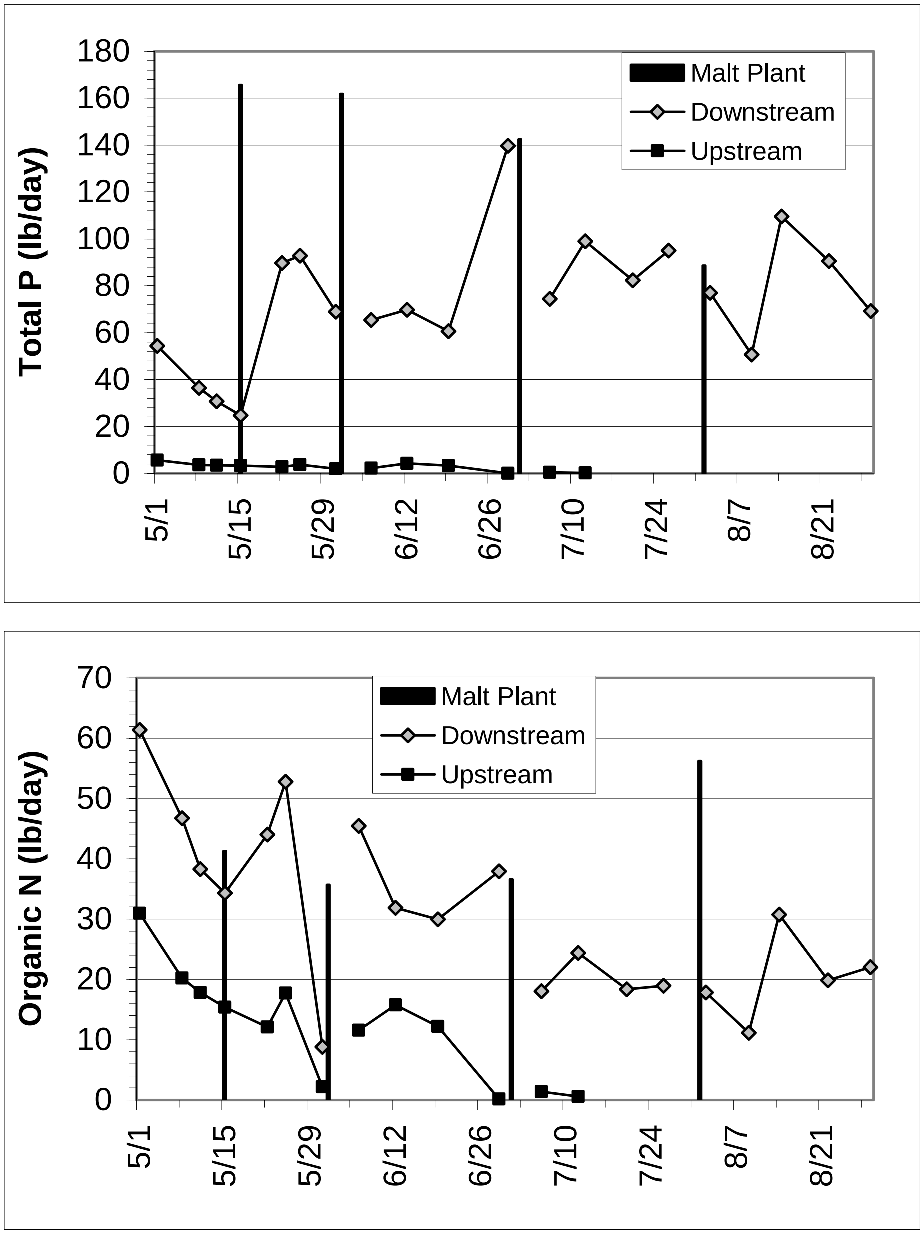


Figure 18. Total phosphorus and organic nitrogen loads in Seven Mile Coulee in comparison with those of the malt plant effluent in 2006

Algae, particularly diatoms, which frequently dominate the periphyton in streams, are highly productive in the spring and could account for phosphorus uptake. The total phosphorus data from the later dates indicate that the loads at the downstream site are virtually the same as those of the effluent. With the much lower flows during the summer, there would be less area available to support periphyton. In addition, diatoms would be much less productive during the warmer weather. All of which could lead to little change in the phosphorus load between the discharge point and the downstream water quality monitoring site. In which case, virtually all of the total phosphorus in the lower coulee could be attributed to the malt plant discharge.

There is no water quality standard for total phosphorus in North Dakota. The phosphorus standard is for phosphate (PO_4-P ≤ 0.02 mg/L), which is the form that is considered most bioavailable. The standard applies only to lakes and reservoirs. If the decrease in phosphorus is due to biological uptake, then it seems likely that the PO_4-P standard is being exceeded. However, this is only a hypothesis at this time. More data would be needed for confirmation. It should also be noted that any exceedence of the PO_4-P standard is only for evaluation purposes and used as a basis for defining an elevated concentration. However, given that the median total phosphorus concentration at the site is over 3.5 mg/L and over 75 percent of the observations are greater than 1.5 mg/L, it is rather obvious that total phosphorus is elevated. As noted earlier, USGS (1999) found a background total phosphorus concentration for the US of 0.1 mg/L in the NAWQA Program. A total phosphorus concentration of 0.1 mg/L or less is also an EPA goal for surface waters. Concentrations of total phosphorus greater than 0.1 mg/L are to be considered elevated (*ibid.*).

The project QAPP indicates that there should be DO data available. If so, these could be evaluated for nutrient effects. If there are large populations of algae present, then there should be wide diurnal swings in DO in the stream. If so, mid-day DO measurements should show DO supersaturation. This could be used as a surrogate to further evaluate, but not confirm, the above hypothesis concerning algal productivity. However, no DO measurements were made in Seven Mile Coulee during 2006.

Figure 18 also shows a plot of organic nitrogen concentrations similar to the total phosphorus plot. With the exception of the August 1 effluent sample, organic nitrogen loads in the effluent are in line with those at the downstream site in Seven Mile Coulee. The August 1 malt plant effluent load is about 3 times that at the downstream site in the coulee, indicating that there was a loss during transport between the discharge point and the downstream monitoring site.

Organic nitrogen is plotted on Figure 18 because it was the predominant nitrogen species in the coulee. Because there are no NO_2+NO_3-N data for the malt plant effluent, neither concentrations nor loads can be calculated for total nitrogen. There are ammonium data for the effluent and these are plotted against ammonium data from the coulee. The malt plant effluent had extremely high ammonium-nitrogen loads in the spring. At the scale of the malt plant ammonium-nitrogen loads, those in the coulee at either site essentially plot on the abscissa. The ammonium-nitrogen loads in the effluent decrease during the summer, and the August 1 sample results in a load comparable to what is shown in the coulee.

It is possible that the ammonium-nitrogen was oxidized during transport to the downstream site in the coulee. If so, it would be oxidized to nitrite, then nitrate. The second plot on Figure 19 shows the ammonium-nitrogen load from the malt plant plotted against the NO_2+NO_3-N loads at the two sites in Seven Mile Coulee. As was the case with the spring ammonium-nitrogen loads in the coulee, the ammonium-nitrogen load from the malt plant is well in excess of the NO_2+NO_3-N load in the coulee. As can be seen from Figure 19, the ammonium-nitrogen load from the malt plant is also well in

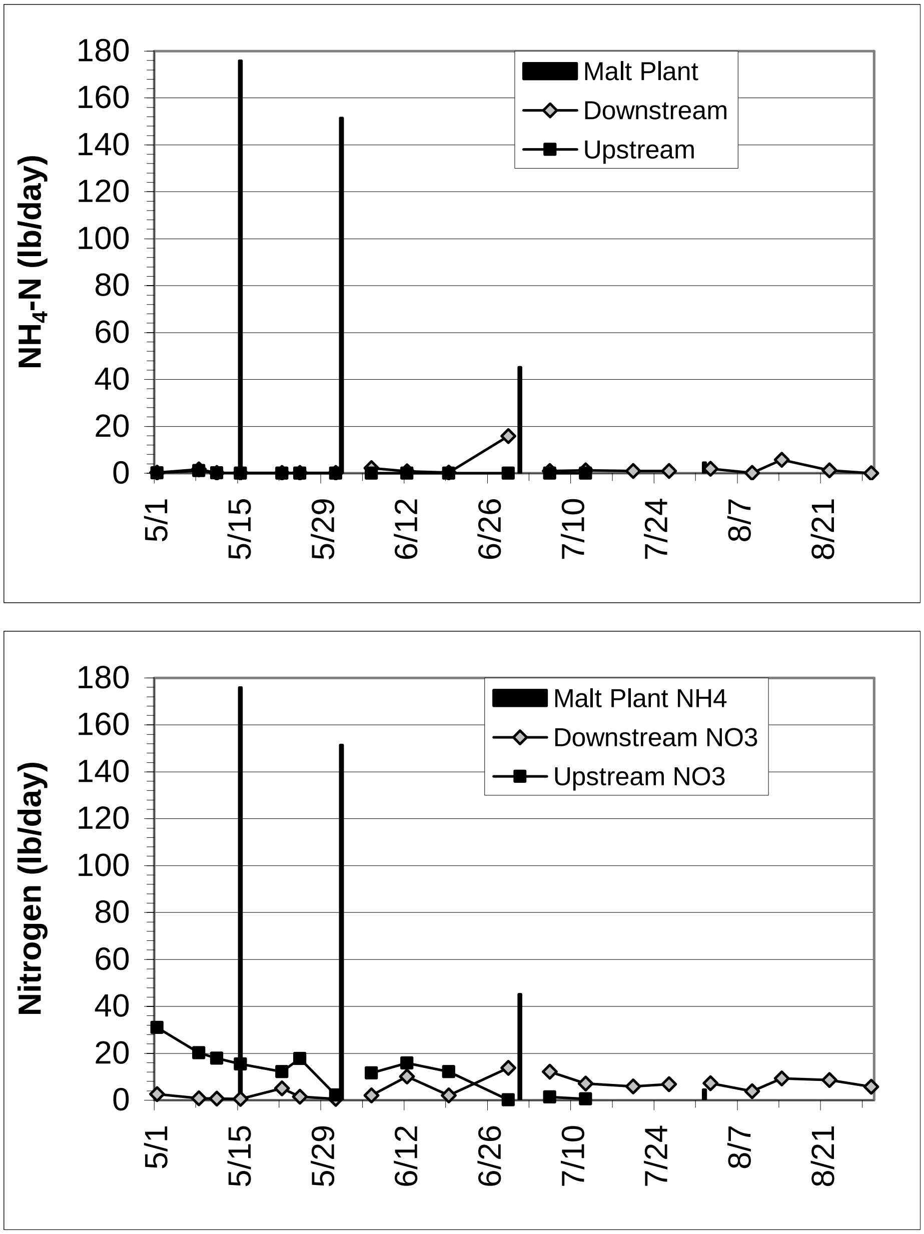


Figure 19. NH_4-N and NO_2+NO_3-N loads in Seven Mile Coulee
in comparison with NH_4-N loads in the malt plant effluent in 2006

excess of the total of inorganic nitrogen (sum of the NH_4-N and NO_2+NO_3-N) load in the stream. This raises the question, where did the NH_4-N go? One possibility was that it was lost as nitrogen gas (N_2) during ammonium oxidation (nitrification). Alternatively, it could have been lost as ammonia gas. Anyway, there would need to be additional study to determine what exactly is occurring in the coulee.

The preceding hypothesized a number of factors that could have been responsible for changes in nutrient concentrations and loads between the malt plant discharge and the downstream monitoring site. As is shown on Figure 20, the discharge is to a short

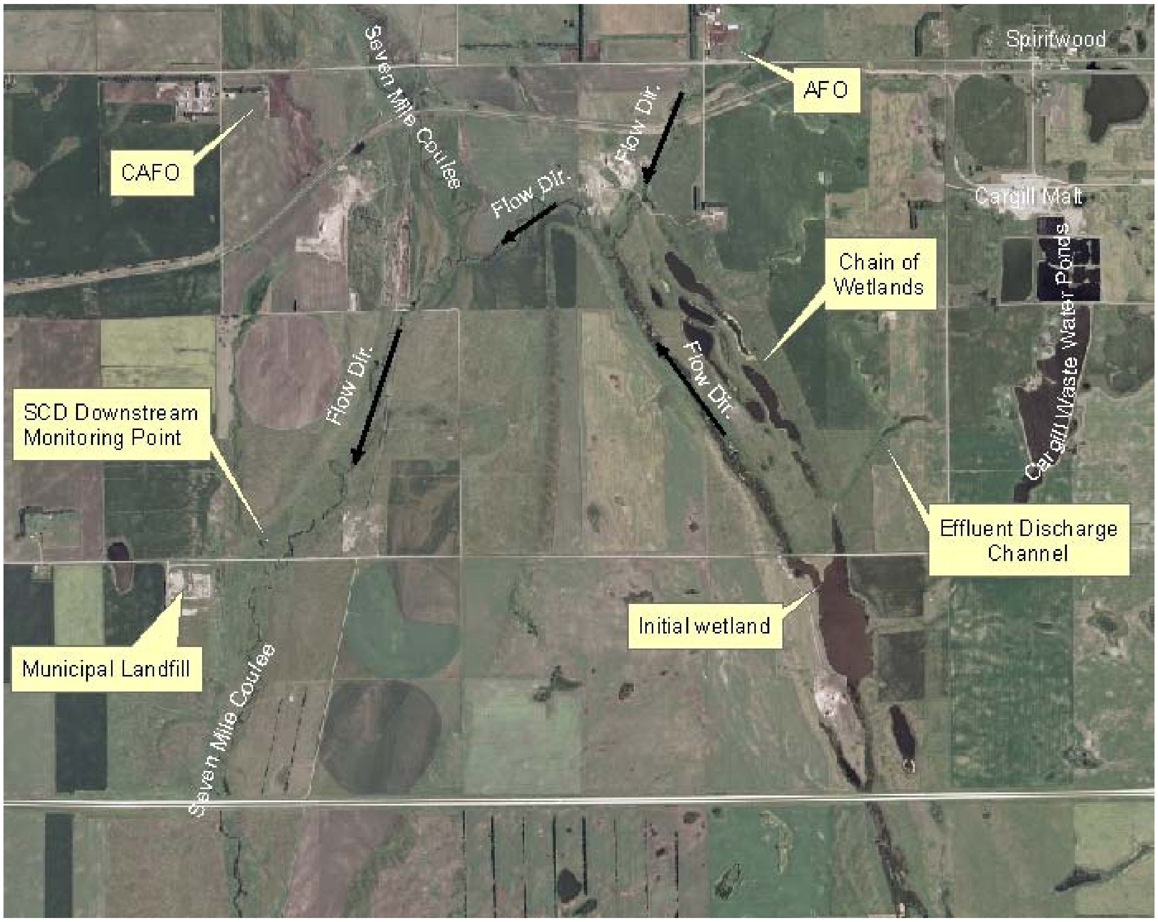


Figure 20. Annotated aerial photograph of the area encompassing the malt plant discharge. (Photograph provided by Ryan Odenbach, Stutsman County Soil Conservation District)

channel that flows into a tributary to Seven Mile Coulee. The flow in the tributary passes through a series of ponds and wetlands. Wetlands have been used as treatments for nutrient removal. However, the actual effects of wetlands on nutrient (nitrogen and phosphorus) removal can be complex, primarily reflecting the difference in the nitrogen and phosphorus sinks. The primary sink for nitrogen is the atmosphere, while that for phosphorus is the sediments. In the case of nitrogen, once it is in the atmosphere, it is essentially lost to the system. Alternatively, sediment phosphorus can be resolubilized, particularly in anaerobic sediments. As a consequence, phosphorus concentrations can sometimes show an increase within and downstream from wetlands, but in the long-term there will be a net loss of phosphorus..

Wetlands have been shown to be extremely effective at removing inorganic nitrogen. As is shown on Figure 19, there is a large decrease in the ammonium-nitrogen load. During the spring, there is also a decrease in nitrate-nitrogen, but there is an increase later in the year, when flow at the upstream site in Seven Mile Coulee is either very low or nonexistent. The former condition may reflect uptake of nitrate by periphyton or other algae in the wetlands. This latter condition is also consistent with nitrification. The problem is that there are no data for nitrate-nitrogen in the malt plant discharge, which may be a source of nitrate. What is evident is that there is an overall loss in inorganic nitrogen between the malt plant effluent and the downstream monitoring site in Seven Mile Coulee. One thing seems certain – without the wetlands in the tributary, the effect of the malt plant discharge would be much greater than it is currently.

The increase in organic nitrogen between the sites in Seven Mile Coulee is consistent with any of the three mechanisms described above. It could be due to the malt plant discharge, which appears to be the dominant mechanism. The increase could also be due to either nitrifying bacteria or algae, the latter of which have incorporated inorganic nitrogen into their cells. The organic nitrogen could be in any of numerous forms, including various compounds within either bacterial or algal cells or their metabolic wastes. The same could also be said of other source that have not been previously mentioned, such as livestock or wildlife.

Buffalo Creek

Buffalo Creek samples from both of the sites located in the basin are confined to the months of March through June. There was no flow in the creek at either site beginning in the latter part of June. The nutrient and TSS data from the two Buffalo Creek sites are summarized in Table 6 and a statistical comparison of those data between sites is included in Table 7.

Table 6. Summary of Buffalo Creek nutrient data (all in mg/L)

Location	Statistic	Total P	NH_4-N	NO_3+NO_2-N	Organic N	Total N	TSS
Upstream (Sharlow)	Minimum	0.127	< 0.010	0.020	0.60	0.629	< 5
	1st Quartile	0.151	< 0.010	0.023	1.16	1.205	9
	Median	0.167	0.015	0.040	1.29	1.380	11
	3rd Quartile	0.199	0.039	0.058	1.36	1.505	19
	Maximum	0.392	0.219	0.580	1.56	2.170	174
	Samples	15	15	15	15	15	15
Downstream (Sydney)	Minimum	0.086	< 0.010	< 0.020	0.42	0.447	5
	1st Quartile	0.092	< 0.010	< 0.020	0.81	0.940	6
	Median	0.119	< 0.010	0.020	0.94	1.010	10
	3rd Quartile	0.148	0.024	0.023	1.08	1.123	32
	Maximum	0.357	0.287	0.120	1.20	1.230	161
	Samples	13	13	13	13	13	13

As was noted earlier, the flow in Buffalo Creek was significantly greater at the downstream site at Sydney based on a parametric t-Test (Figure 5). Table 7 indicates that the same is true based on the Mann-Whitney Test. Table 7 also shows that there are significant differences in total phosphorus and all of the nitrogen species except for ammonium, which for the most part was below the detection limit of 0.01 mg/L (Table 6). In terms of the changes between sites, the most significant difference based on the Mann-Whiney Test is in the total nitrogen concentration. Table 6 indicates that the differences in the nutrient concentrations between the sites in Buffalo Creek, unlike those in Seven Mile Coulee, were decreases, rather than increases. The decrease in concentrations would indicate that there is a loss in transit, either through uptake by vegetation or deposition to the sediments, or there is dilution by inflows from tributaries in the intervening reach between the sites. Because there was a flow increase, it seems likely that the decreases reflected dilution.

Table 7. Comparison of upstream and downstream flow and water quality measures in Buffalo Creek			
Variable	M-W U	χ^2	Probability
Flow	35	8.29	0.003983
Total P	161	8.56	0.003443
NH_4-N	110	0.38	0.538223
NO_3+NO_2-N	154.5	7.20	0.007283
Organic N	174	12.42	0.000425
Total N	174.5	12.59	0.000388
TSS	110	0.33	0.563616
Fecal Coliform	37	0.07	0.788635
NOTE – all data were collected during the months of March through June			

Table 8 shows the average daily loads of total phosphorus, nitrogen species, including total nitrogen, and TSS. All of the loads increase, except for TSS, for which there are decreases at each of the quartiles, except for the minimum. The decrease in the TSS load indicates that there was a loss of suspended solids in the intervening reach of the creek, while the increase in the loads downstream indicates that there was a gain in the nutrient constituents in transit. If there is a gain in the load, then dilution between the two sites due to tributary inflows is even more probable. If the tributary inflows have lower concentrations of nutrients than the receiving stream, the concentrations in the receiving stream will be reduced. The changes in the nutrient concentrations at the Sydney sampling site are consistent with dilution by tributary inflows with lower concentrations, in that the concentrations downstream decrease while the average daily nutrient loads increase.

Table 8. Average Daily loads (lbs/day) in Buffalo Creek during March-June 2006		
Constituent	NW of Sharlow	At Sydney
Total Phosphorus	0.33	0.76
Ammonium (N)	0.05	0.17
Nitrate + Nitrite (N)	0.18	0.22
Organic Nitrogen (Total)	2.00	6.11
Nitrogen (Total)	2.24	6.52
Suspended Solids (Total)	34	79

The median total P concentration is greater than the USGS (1999) background concentration of 0.1 mg/L at both sites in Buffalo Creek (Table 6). Because of the decrease in total P between sites, the median total P at the downstream site at Sydney is only slightly greater than the USGS (1999) background concentration. The median ammonium and nitrate concentrations at both sites are below the USGS (1999) background. At each of the sites, only the maximum ammonium and nitrate concentrations exceed the respective USGS (1999) background concentrations. Since the USGS (1999) background concentrations are based on averages, some of the observations used in the calculation of the background would also have exceeded the average. On this basis, the ammonium and nitrate in Buffalo Creek are apparently not elevated relative to the USGS (1999) background concentrations at either site. Alternatively, the median total N is somewhat greater than the USGS (1999) background of 1 mg/L at the Sharlow site, but is essentially equal to the background at the downstream site. These differences from the inorganic N species as they relate to the USGS (1999) background are due to the influence of organic N, the predominant N-species at both sites in Buffalo Creek (Table 6).

Correlations among flow and the various water quality constituents are shown in Attachment B (Table B-3). The best correlations are between flow and stage and of flow and stage with date, reflecting the decrease in flow over time that is observed at the site. Total P does not correlate with any of the other variables. Ammonium, nitrate, and total N correlate with TSS. This is odd, because both ammonium and nitrate would be expected to be in the dissolved state, rather than in a particulate form, as would be the case for TSS. Each of the nitrogen species correlate significantly with total N. The poorest of the correlations is between organic N and total N, which is not what would be expected in that organic N is the predominant N-species at the site (Table 6). There is a very strong correlation between ammonium and nitrate that may reflect a fertilizer source – ammonium nitrate is a common fertilizer.

Fecal coliforms could be an indicator of the source of nutrients. However, the fecal coliforms do not correlate with any of the other variables at the Sharlow site and cannot provide any insight into possible sources for the other water quality constituents.

Correlations among the flow and water quality constituents at the downstream site in Buffalo Creek are shown in attachment B in Table B-4. The best correlations are between flow and of flow and stage with date, as above. In addition, as at Sharlow, total P does not correlate with any of the other variables. Unlike the correlations from the Sharlow site, the ammonium and nitrate at the Sydney site do not correlate with total N. Alternatively, organic N and total N do correlate. Organic N correlates inversely with TSS in what would be a rather complex relationship if there were any physical basis for the correlation. Again, as at Sharlow, fecal coliforms do not correlate with any of the other variables.

Table B-7 in Attachment B shows correlations between the flow, total P, and total N concentrations at the upstream and downstream sites in Buffalo Creek. Date is also included among those correlations. Flow at each of the sites correlates with date and even better with each other, reflecting their common seasonality (Figure 5). Neither total N nor total P correlates significantly with its counterpart at the other site. These results indicate that flows at the two Buffalo Creek sites have similar distributions of inflows from ground and surface water sources, but there is apparently a difference in the factors that control total N and total P concentrations between the sites.

Beaver Creek

The nutrient and TSS data collected from Beaver Creek during 2006 are summarized in Table 9. As was shown earlier, the upstream site in Beaver Creek (northwest of Sydney) ceased flowing in late May, but the downstream site (at Montpelier) was perennial throughout the sampling period. To make the data from the downstream site compatible with those from the upstream site, the data from the Montpelier site are presented as two different data sets. The first encompasses the period during which there was upstream flow, while the second includes all of the data from the downstream site. This latter data set includes the same period of record as the downstream site in Seven Mile Coulee and could serve as a season-long basis for comparison with that site.

Table 9. Summary of Beaver Creek nutrient data (all in mg/L)							
Location	Statistic	Total P	NH_4-N	NO_3+NO_2-N	Organic N	Total N	TSS
Upstream	Minimum	0.145	< 0.010	< 0.020	0.39	0.412	7
	1st Quartile	0.208	< 0.010	< 0.020	1.29	1.333	11
	Median	0.316	0.011	< 0.020	1.35	1.380	13
	3rd Quartile	0.356	0.027	0.020	1.47	1.500	16
	Maximum	0.724	0.202	0.070	2.34	2.610	32
	Samples	15	15	15	15	15	15
Downstream (Mar-June)	Minimum	0.113	< 0.010	< 0.020	0.35	0.453	< 5
	1st Quartile	0.130	< 0.010	< 0.020	0.89	0.974	< 5
	Median	0.142	0.034	< 0.020	0.97	1.020	< 5
	3rd Quartile	0.201	0.058	0.020	1.03	1.075	7
	Maximum	0.279	0.262	0.150	1.82	2.100	47
	Number	16	16	16	16	16	16
Downstream (All Data)	Minimum	0.042	< 0.010	< 0.020	0.35	0.453	< 5
	1st Quartile	0.127	< 0.010	< 0.020	0.90	0.988	6
	Median	0.148	0.024	0.020	0.90	0.988	6
	3rd Quartile	0.246	0.081	0.020	1.00	1.095	8
	Maximum	0.710	0.262	0.150	1.82	2.100	47
	Samples	33	33	33	33	33	33

The median total P concentration at the upstream site in Beaver Creek is over three times the USGS (1999) background concentration of 0.1 mg/L (Table 9). During the equivalent spring months, the median total P concentration at the downstream site decreased to less than ½ of that of the upstream site. There is little difference in the median total P or its 1st and 3rd quartiles at the site when all of the data are included in the data set. However, the minimum and maximum total P concentrations change with the inclusion of the summer and fall data, with the result that the range in total P is expanded considerably. The minimum decreased by more than ½, while the maximum increased by a factor of about three (Table 9).

The decrease in total P between the sites in Beaver Creek during the spring months is statistically significant, based on the Mann-Whitney test (Table 10). The inclusion of the complete data set does not change the probability level that is the measure of significance to any great extent. This latter result would indicate that the inflow from Buffalo Creek was not likely to be an overriding factor in the decrease in total P between the sites, because there was no inflow Buffalo Creek during that later period.

The median ammonium and nitrate at both sites in Beaver Creek are well below the USGS (1999) background concentrations of 0.1 and 0.6 mg/L respectively (Table 9). Total N is slightly above the USGS (1999) background of 1 mg/L at the upstream site, but decreases to concentrations that are approximately equal to the background at the downstream site in both of its data sets. The decrease in total nitrogen is entirely due to the decrease in organic nitrogen (Table 9). The median ammonium concentrations are higher downstream than upstream (Table 9), although from a statistical perspective there is no change (Table 10). Nitrate does not change either (*ibid.*), although there is a slight increase when the complete data set is considered (Table 9). Alternatively, the decreases in total nitrogen and its principal component species are statistically significant (Table

Table 10. Comparison of flow and water quality constituents at the upstream and downstream sites in Beaver Creek						
Variable	Mar-June			All Data		
	M-W U	χ^2	Probability	M-W U	χ^2	Probability
Flow	179	10.84	0.000991	317	7.46	0.006297
Total P	30	12.66	0.000374	119	8.17	0.004259
NH_4-N	141.5	0.80	0.372422	310.5	2.09	0.147925
NO_3+NO_2-N	143	1.06	0.303360	311	2.40	0.121014
Organic N	28	13.23	0.000276	46	20.09	0.000007
Total N	29	12.97	0.000316	68	15.95	0.000065
TSS	17	16.97	0.000038	50.5	19.76	0.000009
Fecal Coliform	50.5	0.00	0.969598	111.5	0.00	0.950930

10). These decreases are consistent with what was observed with total phosphorus and may indicate a consistent mechanism. Conclusions related to ammonium and nitrate are difficult to draw, because a large percentage of the results are below the respective reporting limits for those constituents (Table 9).

TSS also decreased at the downstream site, although the maximum TSS was greater downstream(Table 9). Interestingly, the majority of the TSS concentrations at the downstream site were below the reporting limit during the spring, when flows were somewhat higher and TSS would be expected to be at their greatest concentrations, at least if the major source were related to erosion, either from lands in the basin or from the stream bed and banks. However, flows were never very large in Beaver Creek during 2006, although the flow was generally much greater at the downstream site (Figure 6).

Correlations among the constituents from the upstream site in Beaver Creek northwest of Sydney are included in Attachment B, Table B-5. There is an extremely good correlation between stage and flow. As was the case at other sites in the study area. both stage and flow decrease over time, as indicated by their inverse correlations with date. However, unlike the previous sites in this study, the correlations with data are not quite significant at $\alpha < 0.01$, but they are close to being significant. Part of the problem is that there were no stage or flow measurements during part of May, as indicated by the lower n-values for the flow correlations relative to those for the other variables in the correlation matrix (see Table B-5). Organic and total N show an almost perfect correlation, but nitrate and ammonia also correlate with total N. Actually, all N-species correlated significantly among themselves. Total P only correlated with nitrate, although the correlation with total N approaches significance.

Fecal coliforms and TSS do not correlate with any of the other variables at the site. This is consistent with the results from the Buffalo Creek tributary, which enters Beaver Creek downstream from the site, at least when there is flow. Although they are not close to being statistically significant, the correlation coefficients of TSS with stage and flow are both negative, indicating a general decrease in TSS as flow increases. This phenomenon was noted for the downstream site, but is apparently also true to some degree at the upstream site as well. In addition, the TSS correlation with date approaches statistical significance and indicates greater TSS later in the study period at the site.

Correlations among the flow and water quality constituents at the Montpelier site in Beaver Creek are shown in Attachment B, Table B-6. All of the correlations are based on the complete data sets from the site.

There are a number of significant correlations with date, including those with organic and total N and flow and stage. All of those significant correlations are inverse, indicating a seasonal decrease over time during the study period. There is a relatively good correlation between stage and flow at the site, although the r-value is somewhat lower than those for most other sites (the exception is for the upstream site on Seven Mile Coulee – compare Table B-1).

Ammonium, organic N, and total N are all correlated with each other; each of these constituents are also correlated significantly with total P. However, nitrate does not correlate with total N or the other N-species (nor with total P). It should be noted that many of the r-values for these significant correlations are not very large. This is a reflection of the much greater number of observations at the site relative to the upstream site. Despite the relatively small r-values, the fact that they are significant would indicate a certain degree of commonality in the sources of the correlated constituents, based on the similarity of the patterns in their concentrations over time.

As has been the case at most sites, fecal coliforms do not correlate with any other variables. It should be noted that the number of observations for fecal coliform bacteria is smaller than for other variables, based on their importance being confined to the recreation season. As a result, there are no samples from early in the season when there is seasonal variation in many of the other variables, especially in flow.

TSS at the downstream site in Beaver Creek correlates with total P, ammonium, organic N, and total N. In other words, all of the variables that correlate with each other. The correlations with TSS would usually indicate that nitrogen, including its correlated species, and phosphorus are predominantly in the particulate form. On the other hand, the correlation between ammonium and TSS should not indicate that at all; ammonium is highly soluble and should be dissolved. To further complicate matters, the total P is inversely correlated with stage, which should indicate dilution and a predominance of dissolved P. While there is no definitive explanation for these results, hypothetically, the TSS could be behaving as if they were dissolved solids. As was shown in Table 9, the TSS concentrations are generally low. There is no size-gradation of the TSS, but they may be virtually all fines. Considering that the flows are low throughout the study, it is unlikely that coarse particles could be transported, further supporting an hypothetical TSS that is either predominantly or completely composed of fines, which may respond physically somewhat differently from what is usually found as suspended solids. To determine what is occurring at the site would require additional investigation.

Correlations of flow, total N, and total P within and between the sites in Beaver Creek are included in Attachment B, Table B-9. Developing correlations between sites has the effect of confining the data from the Montpelier site to those samples collected during March through May, the period during which samples were collected at the site northwest of Sydney. This factor changes the results of the preceding correlation analysis for the Montpelier site considerably. For example, there is no longer a significant correlation between total N and total P. As a matter of fact, the r-value for the correlation between total N and total P is now negative, although this is likely a matter of randomness as much as anything.

The reason for presenting the correlations between sites is to examine if the downstream concentrations of total N and total P are related to those at the upstream site. Table B-9 indicates that the upstream concentrations of total N and total P are related to those downstream. This further indicates that whatever is causing the unmeasured decrease in their concentrations downstream probably has a similar temporal distribution to those constituents as there is upstream. At least, these unmeasured inflows are not distributed differently enough over time from the measured data to eliminate any upstream to downstream relationship.

As was done for the previous two basins, an exploration of the average daily loads at the two sites in Beaver Creek can be used to provide additional insight into what is occurring between the sites. Table 11 shows average daily loads for the two sites in Beaver Creek. To evaluate the above referenced correlations between sites, the average daily loads for the Montpelier site are presented in two columns based on the same two periods of record that were used in the comparison of the nutrient concentrations. The data for the entire period of record (all data) indicate that the average daily load of the nutrients is roughly doubled between the sites. However, for most of that period (June through October), the upstream site did not contribute. The third column of Table 12 shows the average daily loads of the nutrients during the period during which there was flow at the upstream site. When the average daily load is computed based on the period during which there was a contribution from upstream, the downstream nutrient loads are greater by a factor of five or more. Obviously, there is a large loading from other sources. One of those sources is Buffalo Creek. However, adding the load from Buffalo Creek still leaves a large contribution from other sources.

Table 11. Average Daily loads (lbs/day) in Beaver Creek during 2006

Constituent	NW of Sydney	At Montpelier	
		All Data	Mar-May
Total Phosphorus	0.54	0.91	2.62
Ammonium (N)	0.07	0.15	0.35
Nitrate + Nitrite (N)	0.05	0.13	0.38
Organic Nitrogen (Total)	2.91	5.76	17.42
Nitrogen (Total)	3.03	6.08	18.27
Suspended Solids (Total)	31	29	84

The advantage to evaluating loads is that they are additive. To take advantage of that factor, Table 12 evaluates the measured upstream loads against the measured load at the Montpelier site on Beaver Creek. The average daily load for Buffalo Creek has been adjusted for the period during which there was a contribution from the upstream site on Beaver Creek. Actually, Buffalo Creek would have contributed loadings to Beaver Creek for an additional six weeks, but that period was not included in the average daily load calculation for the Montpelier site and was not included in the Buffalo Creek calculation either.

Table 12. Average daily measured and unmeasured loads between the upstream site and the Montpelier site in Beaver Creek (lbs/day)						
Constituent	Buffalo Creek at Sydney	Beaver Creek NW of Sydney	Buffalo Creek + Beaver Creek	Beaver Creek At Montpelier	Unmeasured	Percent Unmeasured
Total Phosphorus	1.09	0.54	1.63	2.62	0.99	38%
Ammonium (N)	0.26	0.07	0.33	0.35	0.02	5%
Nitrate + Nitrite (N)	0.33	0.05	0.38	0.38	0.00	0%
Organic Nitrogen (Total)	9.25	2.91	12.16	17.42	5.26	30%
Nitrogen (Total)	9.88	3.03	12.91	18.27	5.37	29%

The results in Table 12 indicate that the loadings of total P and organic and total N from upstream and from Buffalo Creek account for between 60 and 70 percent of the load at the Montpelier site on Beaver Creek. This is an extremely small range in percent contribution considering the error that is likely in the load calculations. Alternatively, the same type of calculations for ammonium and nitrate indicate that those same upstream contributions account for virtually all of the ammonium and nitrate loads at Montpelier. However, both ammonium and nitrate are very biologically influenced and it seems highly probable that there was uptake by periphyton in the intervening reach of Beaver Creek between both its upstream site and the mouth of Buffalo Creek. In other words, in addition to the measured loadings from the two upstream sites, there would be loadings from other sources as well, but the equivalent to those other loads are lost to biological activity within the Beaver Creek stream channel.

Total Nutrient Loads

Only two of the sample sites had perennial flow throughout the study period. The other four sites were not perennial, and flow ended between the end of May and mid-July among those nonperennial sites. The nonperennial sites included each of the three upstream sites and the downstream site on Buffalo Creek. None of these sites were reported as having flow after July 12. There may have been brief periods of flow after that, but none were reported, and presumably, not observed. The total loads for each site are based on the periods for which there was flow. Consequently, the perennial sites would be expected to have a larger total nutrient load then nonperennial sites. For this reason, the duration of flow at each site is an important consideration in the total nutrient load at the sites.

Table 13 shows the estimated total nutrient and TSS load for each of the sites included in the study during the period that there was flow at the sample site. Because of the importance of the duration of flow in the total load calculation, the number of days between March 31 and the date that the stream either dried up or sampling ended is also included in Table 13. Those data indicate that the sampling period for the perennial streams was about twice as long as the streams that were intermittent. As a point of reference, if the loads were otherwise equal, then the loads from the perennial streams

Table 13. Total nutrient and TSS loads (lbs) and days of continuous flow for each study site during the period of March 31 through October 30, 2006						
Constituent	Seven-Mile Coulee		Buffalo Creek		Beaver Creek	
	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
Total Phosphorus	278	12592	34	74	56	193
Ammonium (N)	17	477	6	16	7	31
Nitrate + Nitrite (N)	88	1098	19	21	5	28
Organic Nitrogen	1481	5540	206	593	300	1227
Nitrogen (Total)	1586	7115	231	632	312	1294
Suspended Solids	3811	51802	3485	7633	3160	6188
Days in Total	103	206	103	97	103	213

should be about twice those of the other streams. As is obvious from Table 13, the loads are not otherwise equal.

The total P load at the downstream site in Seven Mile Coulee is much larger than the total P load at any of the other 5 sites shown in Table 13. Since the average daily total P load was greater at the downstream site in Seven Mile Coulee than any of the other sites (compare tables 3, 6, and 9), the load at the site would be expected to be larger than the others. Another factor is the fact that flow was perennial. However, the total P load at the other perennial site, Beaver Creek at Montpelier, is only about ⅔ of that at the nonperennial upstream site in Seven Mile Coulee. This apparently high total P at the upstream site in Seven Mile Coulee may indicate that the coulee is naturally higher in total P than the sites in other streams in the study area.

To further investigate the possibility of naturally high concentrations of phosphorus in Seven Mile Coulee in comparison with sites in the Beaver Creek basin, the components of the total phosphorus load, *i.e.* flow and the total phosphorus concentration, were compared using Fisher's Least Significance (LSD) Test (Table 14). The LSD is a multiple comparison test that is the equivalent to running multiple t-Tests across data sets. To make sure there are differences, a oneway analysis of variance (ANOVA) was performed. The ANOVA results appear in the left hand column of Table 14. The heavy lines indicate when there are differences (breaks) and when there are not (overlapping) at an α-level of 0.01. The data were log-transformed for the ANOVA and LSD. Therefore, the flows and total P concentrations in Table 14 are geometric means. In addition, the data were confined to the period March 31 through June 30 to keep the data sets reasonably consistent.

The ANOVA results indicate that there are significant differences in both flow and total P across the six sites (probability of a greater F is less than one in one million – Table 14). The downstream site in Seven Mile Coulee had a significantly higher flow and total P concentration than any of the other sites did. The flow at the upstream site in Seven Mile Coulee ranks second highest, but it was not significantly higher than those of the downstream sites in Buffalo Creek nor Beaver Creek. The flow at the upstream site in Seven Mile Coulee was significantly higher than the other two upstream sites. The total P concentration at the upstream site in Seven Mile Coulee was not significantly different from that of the upstream site in Beaver Creek, but it was significantly higher than that of the other three sites. On this basis, the higher total P load at the upstream site in Seven

Table 14. Fisher's Least-Significant-Difference Test for flow and total phosphorus concentrations among sites and between basins - significance at the 0.01 α-level

Flow	Buffalo Cr. Sharlow	Beaver Cr. Sydney	Buffalo Cr. Sydney	Beaver Cr. Montpelier	7-Mi. Coul. Upstream	7-Mi. Coul. Downstream
ft^3/s	0.29	0.35	1.98	2.49	3.36	11.09
F-ratio 13.37 Prob. > F < 0.000001						
Total Phosphorus	**Buffalo Cr. Sydney**	**Beaver Cr. Montpelier**	**Buffalo Cr. Sharlow**	**7-Mi. Coul. Upstream**	**Beaver Cr. Sydney**	**7-Mi. Coul. Downstream**
mg/L	0.13	0.16	0.19	0.26	0.28	1.75
F-ratio 78.03 Prob. > F < 0.000001						

Mile Coulee was primarily a reflection of its higher flow, rather than a higher total P concentration. This result further exemplifies the effect of the malt plant loadings between the two sites on Seven Mile Coulee.

The downstream site in Seven Mile Coulee also has a much higher load of each of the nitrogen species, total nitrogen, and TSS in comparison with the other sites sampled during the study (Table 13). That result is primarily due to the combination of higher flows in the spring and a longer period of flow. For example, the downstream site in Seven Mile Coulee only ranks third highest in organic N, but its organic N load is several times higher than the site with the next highest organic N load.

As was noted above, nitrogen in the system appears to be either biologically or chemically (or both) very active, but it seems obvious that nitrogen is not behaving at all conservatively in any of the streams. In the earlier part of this report, it was noted that none of the sites exceeded the USGS (1999) background concentrations for the inorganic nitrogen species ammonium or nitrate. However, most sites exceeded the USGS (1999) total N background. By process of elimination, the excessive nitrogen must be in the organic form. There are myriad organic nitrogen compounds and the exact composition of the organic N cannot be determined from the available data. From the available data, it is not possible to define what is occurring. It would likely involve some intensive ecological investigation to determine what the mechanisms are that are controlling nitrogen in the system.

Table B-10 (Attachment B) shows correlations of flow, total P, and total N across sites. For the most part, total N is correlated among the sites at the 0.01 α-level. Of those that do not correlate, the probabilities associated with the correlations are on the order of 0.011, which would indicate a correlation without the use of the more conservative α-level used here. These results seem to indicate that whatever is going on with the nitrogen at each of the sites is likely to be in common with all of the sites. Alternatively, the same cannot be said of the total P correlations. While there are several that are significant, there are also several that have probabilities that approach one and are associated with correlation coefficients that are near zero.

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ATTACHMENT A

LISTING OF MONITORING DATA FOR ALL SITES

Table A-1. Seven Mile Coulee 5 miles north and 6 miles east of Jamestown									
Date (2006)	Stage (ft.)	Flow (ft^3/s)	Total P (mg/L)	NH_4 N (mg/L)	NO_3+NO_2-N (mg/L)	Kjeldahl N (mg/L)	Total N (mg/L)	TSS (mg/L)	Fecal Coliform #/100 mL
3/31	2	14.41	0.16	0.042	0.140	1.430	1.570	< 5	—
4/5	1.85	9.34	0.18	0.019	0.340	1.510	1.850	7	—
4/13	1.61	3.67	0.19	< 0.010	< 0.020	1.100	1.120	6	—
4/17	1.61	4.06	0.19	< 0.010	< 0.020	1.090	1.110	< 5	—
4/26	1.6	3.76	0.21	< 0.010	< 0.020	1.130	1.150	< 5	—
5/1	1.85	9.68	0.21	< 0.010	< 0.020	1.180	1.200	< 5	45
5/8	1.72	6.02	0.22	0.063	< 0.020	1.300	1.320	< 5	100
5/11	1.71	5.53	0.23	< 0.010	0.020	1.190	1.210	< 5	5
5/15	1.64	4.77	0.25	< 0.010	0.020	1.190	1.210	< 5	5
5/22	1.54	3.41	0.29	< 0.010	< 0.020	1.310	1.330	< 5	50
5/25	1.62	4.46	0.30	< 0.010	0.020	1.470	1.490	< 5	450
5/31	1.43	2.22	0.31	< 0.010	0.020	0.368	0.388	< 5	85
6/6	1.4	2.48	0.33	< 0.010	0.020	1.720	1.740	< 5	220
6/12	1.52	3.66	0.42	< 0.010	< 0.020	1.590	1.610	< 5	80
6/19	1.45	2.71	0.44	< 0.010	0.030	1.660	1.690	< 5	110
6/29	0.65	0.03	0.45	< 0.010	0.070	1.820	1.890	< 5	100
7/6	1	0.27	0.49	0.020	0.020	1.930	1.950	< 5	200
7/12	0.8	0.09	0.63	0.104	< 0.020	2.505	2.525	10	225

Table A-2. Seven Mile Coulee 7 miles east of Jamestown									
Date (2006)	Stage (ft.)	Flow (ft^3/s)	Total P (mg/L)	NH_4 N (mg/L)	NO_3+NO_2-N (mg/L)	Kjeldahl N (mg/L)	Total N (mg/L)	TSS (mg/L)	Fecal Coliform #/100 mL
3/31	1	11.22	1.09	0.484	0.20	2.03	2.23	9	—
4/5	1.43	21.02	0.93	0.312	0.14	1.59	1.73	26	—
4/13	1.02	12.813	1.45	0.015	0.12	1.21	1.33	3	—
4/17	0.95	10.39	1.72	< 0.010	0.05	1.14	1.19	3	—
4/26	0.9	8.788	1.07	< 0.010	0.03	1.04	1.07	7	—
5/1	1.12	19.055	1.05	< 0.010	0.05	1.19	1.24	9	230
5/8	1.02	14.685	0.91	< 0.010	0.02	1.21	1.23	3	60
5/11	1.04	12.082	0.94	< 0.010	0.02	1.17	1.19	3	40
5/15	0.98	10.648	0.85	< 0.010	0.02	1.19	1.21	3	50
5/22	1.05	12.22	2.70	< 0.010	0.15	1.33	1.48	6	160
5/25	1.14	14.12	2.42	< 0.010	0.04	1.38	1.42	3	2600
5/31	0.91	9.51	2.67	< 0.010	0.02	0.35	0.37	8	960
6/6	0.9	9.32	2.58	0.087	0.08	1.88	1.96	8	1400
6/12	0.85	7.25	3.54	0.045	0.51	1.66	2.17	3	670
6/19	0.75	6.246	3.57	0.017	0.12	1.78	1.90	22	1400
6/29	0.8	7.58	6.78	0.767	0.67	2.61	3.28	38	—
7/6	0.6	2.834	9.65	0.124	1.58	2.47	4.05	11	—
7/12	0.56	4.05	8.98	0.108	0.64	2.32	2.96	30	—
7/20	0.51	3.44	8.80	0.096	0.63	2.06	2.70	28	—
7/26	0.56	4.05	8.63	0.085	0.63	1.81	2.43	27	2200
8/2	0.51	3.44	8.24	0.210	0.78	2.12	2.90	21	3300
8/9	0.42	2.45	7.62	0.020	0.59	1.70	2.28	21	3850
8/14	0.73	5.532	7.28	0.378	0.62	2.42	3.04	17	2900
8/22	0.65	5.27	6.32	0.089	0.60	1.48	2.08	15	980
8/29	0.7	4.749	5.36	0.005	0.44	1.71	2.15	14	2600
9/6	0.5	4.996	4.96	0.142	0.70	1.92	2.62	28	2750
9/14	0.1	0.214	3.54	0.090	0.50	1.84	2.34	59	1600
9/20	0.35	1.78	4.02	0.839	0.55	2.67	3.22	30	2800
10/2	0.27	1.13	3.22	0.022	0.36	1.25	1.61	43	—
10/11	0.3	1.35	2.72	0.045	0.19	0.93	1.12	19	—
10/19	0.8	7.58	4.52	0.044	0.82	1.45	2.27	9	—
10/23	0.79	7.42	4.55	0.048	1.03	1.46	2.49	9	—

Table A-3. Buffalo Creek northwest of Sharlow									
Date (2006)	Stage (ft.)	Flow (ft^3/s)	Total P (mg/L)	NH_4 N (mg/L)	NO_3+NO_2-N (mg/L)	Kjeldahl N (mg/L)	Total N (mg/L)	TSS (mg/L)	Fecal Coliform #/100 mL
3/31	1.9	3.17	0.370	0.179	0.53	1.47	2.00	71	—
4/5	1.7	2.30	0.221	< 0.010	0.06	1.35	1.41	14	—
4/13	1.48	1.293	0.198	< 0.010	0.04	1.13	1.17	20	—
4/17	1.4	0.995	0.154	< 0.010	0.04	1.18	1.22	11	—
4/26	1.35	0.421	0.150	0.015	0.03	1.17	1.20	11	—
5/1	1.6	1.921	0.146	< 0.010	0.05	1.09	1.14	7	160
5/8	1.31	0.96	0.162	0.021	0.03	1.35	1.38	9	260
5/11	1.3	0.477	0.157	0.044	0.05	1.27	1.32	9	50
5/15	1.25	0.32	0.167	0.072	0.06	1.34	1.40	10	10
5/22	1.2	0.095	0.127	< 0.010	0.02	1.34	1.36	2.5	10
5/25	1.2	0.11	0.141	< 0.010	0.03	1.43	1.46	9	260
5/31	1.19	0.125	0.192	< 0.010	0.02	0.609	0.629	22	370
6/6	1.19	0.008	0.392	0.024	0.02	1.58	1.60	17	200
6/12	1.19	0.06	0.199	0.219	0.58	1.59	2.17	174	310
6/19	1.17	0.01	0.170	0.017	0.02	1.50	1.52	11	140

Table A-4. Buffalo Creek at Sydney									
Date (2006)	Stage (ft.)	Flow (ft^3/s)	Total P (mg/L)	NH_4 N (mg/L)	NO_3+NO_2-N (mg/L)	Kjeldahl N (mg/L)	Total N (mg/L)	TSS (mg/L)	Fecal Coliform #/100 mL
3/31	1.31	7.22	0.152	0.071	0.12	0.89	1.01	10	—
4/5	1.31	7.22	0.140	< 0.010	0.06	1.14	1.20	6	—
4/13	1.04	3.96	0.107	0.012	< 0.02	1.04	1.06	5	—
4/17	1.00	4.21	0.120	< 0.010	< 0.02	1.17	1.19	7	—
4/26	0.88	1.89	0.093	< 0.010	0.02	1.06	1.08	10	—
5/1	1.25	5.90	0.089	< 0.010	0.03	0.753	0.783	5	60
5/8	1.04	4.79	0.091	0.050	< 0.02	0.902	0.922	9	400
5/11	0.92	2.73	0.092	0.015	0.02	0.926	0.946	6	10
5/15	0.79	1.52	0.086	0.287	0.02	1.08	1.10	78	10
5/22	0.76	0.17	0.147	< 0.010	< 0.02	0.99	1.01	44	240
5/25	0.86	2.16	0.119	< 0.010	0.02	0.942	0.962	18	40
5/31	0.58	0.30	0.225	< 0.010	< 0.02	0.427	0.447	161	1300
6/12	0.60	0.34	0.357	0.011	0.02	1.21	1.23	28	970

Table A-5. Beaver Creek NW of Sydney									
Date (2006)	Stage (ft.)	Flow (ft^3/s)	Total P (mg/L)	NH_4 N (mg/L)	NO_3+NO_2-N (mg/L)	Kjeldahl N (mg/L)	Total N (mg/L)	TSS (mg/L)	Fecal Coliform #/100 ML
3/31	0.5	2.37	0.724	0.202	0.07	2.54	2.61	11	—
4/5	0.4	1.67	0.359	< 0.010	< 0.02	1.56	1.58	13	—
4/13	0.15	0.018	0.344	0.017	< 0.02	1.50	1.52	12	—
4/17	0.18	0.15	0.316	< 0.010	< 0.02	1.42	1.44	7	—
4/26	—	—	0.234	0.011	< 0.02	1.38	1.40	13	—
5/1	0.43	1.871	0.200	< 0.010	0.02	1.21	1.23	16	10
5/8	0.3	1.074	0.149	0.029	< 0.02	1.32	1.34	12	5
5/11	—	—	0.157	0.019	< 0.02	1.31	1.33	9	10
5/15	0.25	0.63	0.145	0.088	0.02	1.36	1.38	12	5
5/22	0.2	0.066	0.231	0.011	0.02	1.36	1.38	11	140
5/25	0.17	0.08	0.266	0.040	0.02	1.38	1.40	14	260
5/31	0.15	0.01	0.329	< 0.010	< 0.02	0.392	0.412	13	50
6/6	0.15	0.01	0.416	< 0.010	< 0.02	1.54	1.56	25	65
6/12	0.15	0.01	0.345	< 0.010	< 0.02	1.30	1.32	32	50
6/19	0.15	0.01	0.379	< 0.010	< 0.02	1.35	1.37	19	150

Table A-6. Beaver Creek at Montpelier									
Date (2006)	Stage (ft.)	Flow (ft^3/s)	Total P (mg/L)	NH_4 N (mg/L)	NO_3+NO_2-N (mg/L)	Kjeldahl N (mg/L)	Total N (mg/L)	TSS (mg/L)	Fecal Coliform #/100 mL
3/31	1.05	10.05	0.248	0.058	0.15	0.87	1.02	7	—
4/5	1.10	13.07	0.168	< 0.010	< 0.02	1.09	1.11	7	—
4/13	0.95	7.412	0.136	0.024	< 0.02	1.00	1.02	< 5	—
4/17	0.86	5.911	0.132	< 0.010	< 0.02	1.14	1.16	5	—
4/26	0.80	5.065	0.128	< 0.010	< 0.02	0.968	0.988	< 5	—
5/1	1.04	10.82	0.113	< 0.010	0.02	0.856	0.876	< 5	150
5/8	1.04	9.738	0.125	0.043	< 0.02	0.939	0.959	7	10
5/11	0.90	7.01	0.133	0.049	< 0.02	0.98	1.00	< 5	5
5/15	0.90	4.22	0.126	< 0.010	< 0.02	0.99	1.01	< 5	10
5/22	0.90	1.646	0.141	< 0.010	0.02	1.00	1.02	7	20
5/25	0.60	0.43	0.148	0.058	0.03	1.03	1.06	< 5	5
5/31	0.80	2.17	0.245	0.082	0.02	0.433	0.453	6	30
6/6	0.55	0.381	0.226	< 0.010	< 0.02	1.07	1.09	6	60
6/12	0.70	0.676	0.143	0.085	0.03	0.99	1.02	< 5	330
6/19	0.70	1.423	0.176	0.052	0.02	0.94	0.96	< 5	290
6/29	0.40	0.04	0.279	0.262	0.02	2.08	2.10	47	—
7/6	0.40	0.124	0.387	0.229	0.02	1.42	1.44	8	400
7/12	0.50	0.15	0.362	0.081	0.02	1.28	1.30	12	500
7/20	—	—	0.650	0.259	0.03	1.53	1.56	12	60
7/26	0.50	0.15	0.710	0.136	< 0.02	1.15	1.17	26	60
8/2	0.50	0.15	0.446	0.196	0.02	1.15	1.17	6	5
8/9	0.50	0.15	0.253	0.078	0.02	0.915	0.935	8	5
8/14	0.58	0.379	0.243	0.101	0.02	0.822	0.842	6	200
8/22	0.45	0.09	0.198	0.023	< 0.02	0.677	0.697	11	30
8/29	0.50	0.144	0.189	< 0.010	0.03	0.581	0.611	< 5	10
9/6	0.61	0.105	0.167	< 0.010	< 0.02	0.615	0.635	10	5
9/14	0.60	0.126	0.127	< 0.010	< 0.02	0.618	0.638	9	10
9/20	0.70	1.02	0.148	0.020	0.03	0.525	0.555	< 5	130
10/2	0.60	0.43	0.078	0.018	< 0.02	0.585	0.605	< 5	—
10/11	0.60	0.43	0.077	< 0.010	0.02	0.513	0.533	< 5	—
10/19	0.85	3.06	0.042	0.028	< 0.02	0.445	0.465	< 5	—
10/23	0.85	3.06	0.047	< 0.010	0.02	0.635	0.655	< 5	—
10/30	0.80	2.17	0.062	0.019	0.02	0.532	0.552	6	—

ATTACHMENT B

CORRELATIONS OF MONITORING DATA WITHIN AND BETWEEN SITES

Table B-1. Seven-Mile Coulee 5 mi. N and 6 mi. E of Jamestown – Pearson correlation matrix

		Date	Stage	Flow	Total P	NH_4-N	NO_3+NO_2-N	Organic N	Total N	TSS
Fecal Coli	r	0.3479	-0.2395	-0.2970	0.3351	0.2015	-0.0806	0.4045	0.3993	0.2386
	Prob. > r	0.244093	0.430674	0.324447	0.263106	0.509101	0.793393	0.170405	0.176472	0.432525
	n	13	13	13	13	13	13	13	13	13
TSS	r	0.0410	-0.2421	-0.0936	0.2822	0.6216	0.3793	0.4306	0.5057	
	Prob. > r	0.871536	0.333132	0.711731	0.256564	0.005886	0.120607	0.074450	0.032279	
	n	18	18	18	18	18	18	18	18	
Total N	r	0.4848	-0.5212	-0.1921	0.6536	0.5415	0.2596	0.9837		
	Prob. > r	0.041439	0.026567	0.445157	0.003266	0.020293	0.298226	< 0.000001		
	n	18	18	18	18	18	18	18		
Organic N	r	0.5818	-0.5888	-0.2994	0.7244	0.5006	0.0891			
	Prob. > r	0.011307	0.010142	0.227361	0.000674	0.034352	0.725010			
	n	18	18	18	18	18	18			
NO_3+NO_2-N	r	-0.4278	0.2716	0.5146	-0.2841	0.0760				
	Prob. > r	0.076555	0.275555	0.028885	0.253185	0.764413				
	n	18	18	18	18	18				
NH_4-N	r	0.2000	-0.2517	0.0167	0.3757					
	Prob. > r	0.426137	0.313595	0.947444	0.124421					
	n	18	18	18	18					
Total P	r	0.9477	-0.8618	-0.7133						
	Prob. > r	< 0.000001	0.000004	0.000889						
	n	18	18	18						
Flow	r	-0.7872	0.8310							
	Prob. > r	0.000106	0.000019							
	n	18	18							
Stage	r	-0.8489								
	Prob. > r	0.000008								
	n	18								

r	Correlation coefficient
Prob. > r	Probability of a correlation coefficient of the magnitude shown occurring by chance alone
n	Number of data pairs in the correlation

NOTE - significance designated by a probability < 0.01

Table B-2. Seven-Mile Coulee 7 mi East of Jamestown – Pearson correlation matrix

		Date	Stage	Flow	Total P	NH_4-N	NO_3+NO_2-N	Organic N	Total N	TSS
Fecal Coli	r	0.7247	-0.6265	-0.6645	0.7690	0.4249	0.7001	0.6245	0.7161	0.4671
	Prob. > r	0.000449	0.004106	0.001912	0.000119	0.069735	0.000846	0.004256	0.000564	0.043765
	n	19	19	19	19	19	19	19	19	19
TSS	r	0.5097	-0.6965	-0.5639	0.4089	0.3737	0.3215	0.4061	0.4492	
	Prob. > r	0.002885	0.000010	0.000777	0.020126	0.035152	0.072812	0.021104	0.009898	
	n	32	32	32	32	32	32	32	32	
Total N	r	0.4420	-0.4581	-0.5274	0.7875	0.5586	0.8600	0.9146		
	Prob. > r	0.011320	0.008381	0.001924	< 0.000001	0.000892	< 0.000001	< 0.000001		
	n	32	32	32	32	32	32	32		
Organic N	r	0.2877	-0.3940	-0.4598	0.7347	0.3759	0.6790			
	Prob. > r	0.110370	0.025665	0.008113	0.000002	0.033988	0.000019			
	n	32	32	32	32	32	32			
NO_3+NO_2-N	r	0.6047	-0.5033	-0.5803	0.8086	0.2387				
	Prob. > r	0.000246	0.003321	0.000499	< 0.000001	0.188256				
	n	32	32	32	32	32				
NH_4-N	r	0.0852	-0.1144	-0.1182	0.1823					
	Prob. > r	0.642814	0.533155	0.519406	0.318103					
	n	32	32	32	32					
Total P	r	0.5119	-0.5674	-0.6590						
	Prob. > r	0.002743	0.000708	0.000041						
	n	32	32	32						
Flow	r	-0.7646	0.9472							
	Prob. > r	< 0.000001	< 0.000001							
	n	32	32							
Stage	r	-0.7840								
	Prob. > r	< 0.000001								
	n	32								

NOTE - significance designated by a probability < 0.01

Table B-3. Buffalo Creek NW of Sharlow – Pearson correlation matrix										
		Date	Stage	Flow	Total P	NH_4-N	NO_3+NO_2-N	Organic N	Total N	TSS
Fecal Coli	r	0.3231	-0.1443	-0.0621	0.2312	0.1826	0.3311	-0.3300	-0.0498	0.4336
	Prob. > r	0.362426	0.690916	0.864735	0.520465	0.613709	0.349967	0.351808	0.891230	0.210628
	n	10	10	10	10	10	10	10	10	10
TSS	r	0.1880	0.0333	0.0309	0.2703	0.8938	0.9071	0.1111	0.6983	
	Prob. > r	0.502234	0.906148	0.913090	0.329875	0.000007	0.000003	0.693393	0.003788	
	n	15	15	15	15	15	15	15	15	
Total N	r	0.0877	0.1616	0.1606	0.4489	0.8014	0.7802	0.7306		
	Prob. > r	0.755915	0.565006	0.567378	0.093252	0.000328	0.000600	0.001976		
	n	15	15	15	15	15	15	15		
Organic N	r	0.1877	-0.0811	-0.0781	0.2601	0.1985	0.1456			
	Prob. > r	0.502908	0.773876	0.782034	0.349177	0.478227	0.604633			
	n	15	15	15	15	15	15			
NO_3+NO_2-N	r	-0.0740	0.3434	0.3392	0.4181	0.9645				
	Prob. > r	0.793284	0.210196	0.216135	0.120983	< 0.000001				
	n	15	15	15	15	15				
NH_4-N	r	0.0495	0.1965	0.1927	0.3997					
	Prob. > r	0.860997	0.482836	0.491451	0.139905					
	n	15	15	15	15					
Total P	r	-0.1212	0.3636	0.3520						
	Prob. > r	0.666926	0.182855	0.198163						
	n	15	15	15						
Flow	r	-0.8423	0.9895							
	Prob. > r	0.000081	< 0.000001							
	n	15	15							
Stage	r	-0.8652								
	Prob. > r	0.000031								
	n	15								
NOTE - significance designated by a probability < 0.01										

Table B-4. Buffalo Creek at Sydney – Pearson correlation matrix

Variable		Date	Stage	Flow	Total P	NH_4-N	NO_3+NO_2-N	Organic N	Total N	TSS
Fecal Coli	r	0.6981	-0.6676	-0.4875	0.8030	-0.3052	-0.4593	-0.2662	-0.3861	0.6518
	Prob. > r	0.054173	0.070437	0.220478	0.016394	0.462315	0.252226	0.523998	0.344819	0.079930
	n	8	8	8	8	8	8	8	8	8
TSS	r	0.5230	-0.6435	-0.5706	0.3420	0.2619	-0.2384	-0.7066	-0.6463	
	Prob. > r	0.066633	0.017647	0.041689	0.252675	0.387430	0.432840	0.006931	0.016998	
	n	13	13	13	13	13	13	13	13	
Total N	r	-0.3020	0.2066	0.1739	0.0342	0.1478	0.1438	0.9170		
	Prob. > r	0.315982	0.498227	0.569879	0.911668	0.629997	0.639365	0.000010		
	n	13	13	13	13	13	13	13		
Organic N	r	-0.2257	0.1467	0.1080	0.1139	-0.2352	-0.0313			
	Prob. > r	0.458348	0.632537	0.725481	0.710893	0.439134	0.919268			
	n	13	13	13	13	13	13			
NO_3+NO_2-N	r	-0.5822	0.6334	0.6567	0.0287	0.0999				
	Prob. > r	0.036809	0.020115	0.014752	0.925835	0.745517				
	n	13	13	13	13	13				
NH_4-N	r	0.0343	-0.0829	-0.0770	-0.2258					
	Prob. > r	0.911522	0.787629	0.802546	0.458222					
	n	13	13	13	13					
Total P	r	0.5159	-0.5128	-0.3969						
	Prob. > r	0.071104	0.073112	0.179289						
	n	13	13	13						
Flow	r	-0.8440	0.9738							
	Prob. > r	0.000286	< 0.000001							
	n	13	13							
Stage	r	-0.8683								
	Prob. > r	0.000119								
	n	13								

NOTE - significance designated by a probability < 0.01

Table B-5. Beaver Creek NW of Sydney – Pearson correlation matrix

Variable		Date	Stage	Flow	Total P	NH_4-N	NO_3+NO_2-N	Organic N	Total N	TSS
Fecal Coli	r	0.4399	-0.4961	-0.5416	0.3829	-0.0726	0.2993	0.1865	0.1775	0.0242
	Prob. > r	0.203319	0.174362	0.132081	0.274720	0.841999	0.400849	0.605978	0.623710	0.947114
	n	10	9	9	10	10	10	10	10	10
TSS	r	0.6226	-0.3041	-0.2766	0.1738	-0.2443	-0.1949	-0.0519	-0.0810	
	Prob. > r	0.013176	0.312414	0.360283	0.535613	0.380170	0.486326	0.854314	0.774206	
	n	15	13	13	15	15	15	15	15	
Total N	r	-0.5254	0.5529	0.5472	0.6363	0.7301	0.7443	0.9937		
	Prob. > r	0.044276	0.050006	0.052951	0.010767	0.002001	0.001461	< 0.000001		
	n	15	13	13	15	15	15	15		
Organic N	r	-0.5174	0.5194	0.5130	0.6068	0.6497	0.6734			
	Prob. > r	0.048219	0.068868	0.073019	0.016451	0.008755	0.005928			
	n	15	13	13	15	15	15			
NO_3+NO_2-N	r	-0.4099	0.6590	0.6430	0.6772	0.9318				
	Prob. > r	0.129191	0.014289	0.017764	0.005552	< 0.000001				
	n	15	13	13	15	15				
NH_4-N	r	-0.4072	0.5769	0.5769	0.5748					
	Prob. > r	0.131955	0.038998	0.039021	0.025000					
	n	15	13	13	15					
Total P	r	-0.2450	0.2942	0.3085						
	Prob. > r	0.378884	0.329238	0.305121						
	n	15	13	13						
Flow	r	-0.6727	0.9957							
	Prob. > r	0.011752	< 0.000001							
	n	13	13							
Stage	r	-0.6745								
	Prob. > r	0.011439								
	n	13								

NOTE - significance designated by a probability < 0.01

Table B-6. Beaver Creek at Montpelier – Pearson correlation matrix

Variable		Date	Stage	Flow	Total P	NH_4-N	NO_3+NO_2-N	Organic N	Total N	TSS
Fecal Coli	r	-0.0317	-0.2329	-0.1574	0.1266	0.2906	0.2781	0.3665	0.3844	0.0012
	Prob. > r	0.888656	0.309600	0.495602	0.574447	0.189550	0.210203	0.093395	0.077316	0.995740
	n	22	21	21	22	22	22	22	22	22
TSS	r	0.0132	-0.4149	-0.2269	0.4954	0.6084	-0.0185	0.6102	0.6530	
	Prob. > r	0.941821	0.018212	0.211701	0.003378	0.000172	0.918743	0.000163	0.000038	
	n	33	32	32	33	33	33	33	33	
Total N	r	-0.4699	-0.2052	0.0527	0.5552	0.7201	0.0646	0.9816		
	Prob. > r	0.005789	0.259999	0.774459	0.000797	0.000002	0.720969	< 0.000001		
	n	33	32	32	33	33	33	33		
Organic N	r	-0.5261	-0.1360	0.1086	0.4515	0.5853	-0.0247			
	Prob. > r	0.001665	0.457957	0.554065	0.008353	0.000346	0.891299			
	n	33	32	32	33	33	33			
NO_3+NO_2-N	r	-0.2124	0.2103	0.2364	0.0989	0.1005				
	Prob. > r	0.235376	0.247979	0.192733	0.583957	0.578070				
	n	33	32	32	33	33				
NH_4-N	r	-0.0099	-0.5197	-0.3166	0.7541					
	Prob. > r	0.956456	0.002299	0.077498	< 0.000001					
	n	33	32	32	33					
Total P	r	-0.0671	-0.4913	-0.2819						
	Prob. > r	0.710457	0.004300	0.118022						
	n	33	32	32						
Flow	r	-0.6403	0.8844							
	Prob. > r	0.000079	< 0.000001							
	n	32	32							
Stage	r	-0.5021								
	Prob. > r	0.003410								
	n	32								

NOTE - significance designated by a probability < 0.01

Table B-7. Seven Mile Coulee – correlations of total phosphorus, total nitrogen, and flow between sites							
Variables		*Date*	*Flow-Up.*	*TP-Up.*	*TN-Up.*	*Flow-Down.*	*TP-Down.*
TN-Down	r	0.5953	-0.3213	0.7025	0.8276	-0.5586	0.8455
	Prob. > r	0.009143	0.193552	0.001150	0.000022	0.015965	0.000010
TP- Down	r	0.8359	-0.6628	0.9103	0.6586	-0.7305	
	Prob. > r	0.000016	0.002718	< 0.000001	0.002961	0.000575	
Flow- Down	r	-0.7305	0.6842	-0.7519	-0.3310		
	Prob. > r	0.000576	0.001740	0.000320	0.179683		
TN-Up.	r	0.4848	-0.1921	0.6536			
	Prob. > r	0.041439	0.445157	0.003266			
TP-Up.	r	0.9477	-0.7133				
	Prob. > r	< 0.000001	0.000889				
Flow-Up.	r	-0.7872					
	Prob. > r	0.000106					
Pairwise frequency: 18							

KEY: TN = Total Nitrogen
TP = Total Phosphorus
Up. = Upstream site
Down = Downstream site

Table B-8. Buffalo Creek – correlations of total phosphorus, total nitrogen, and flow between sites

Variables		*Date*	*Flow-Sharlow*	*TP-Sharlow*	*TN-Sharlow*	*Flow-Sydney*	*TP-Sydney*
TN-Sydney	r Prob. > r n	-0.3020 0.315982 13	0.1249 0.684299 13	0.0742 0.809700 13	0.6407 0.018297 13	0.1739 0.569879 13	0.0342 0.911668 13
TP-Sydney	r Prob. > r n	0.5159 0.071104 13	-0.2296 0.450517 13	0.2408 0.427982 13	0.4209 0.152110 13	-0.3969 0.179289 13	
Flow-Sydney	r Prob. > r n	-0.8632 0.000070 14	0.9371 0.000001 14	0.1267 0.666066 14	0.0879 0.764972 14		
TN-Sharlow	r Prob. > r n	0.0877 0.755915 15	0.1606 0.567378 15	0.4489 0.093252 15			
TP-Sharlow	r Prob. > r n	-0.1212 0.666926 15	0.3520 0.198163 15				
Flow-Sharlow	r Prob. > r n	-0.8423 0.000081 15					

Table B-9. Beaver Creek – correlations of total phosphorus, total nitrogen, and flow between sites

Variables		*Date*	*Flow-Sydney*	*TP-Sydney*	*TN-Sydney*	*Flow-Montpelier*	*TP-Montpelier*
TN-Montpelier	r Prob. > r n	-0.2897 0.294925 15	0.0765 0.803878 13	0.0815 0.772804 15	0.6575 0.007722 15	0.1246 0.658252 15	-0.3736 0.170116 15
TP-Montpelier	r Prob. > r n	0.0949 0.736616 15	0.0853 0.781616 13	0.7676 0.000835 15	0.1665 0.553129 15	-0.1697 0.545448 15	
Flow-Montpelier	r Prob. > r n	-0.8288 0.000134 15	0.8377 0.000351 13	0.0620 0.826348 15	0.3556 0.193388 15		
TN-Sydney	r Prob. > r n	-0.5254 0.044276 15	0.5465 0.053311 13	0.6363 0.010767 15			
TP-Sydney	r Prob. > r n	-0.2450 0.378884 15	0.3105 0.301775 13				
Flow-Sydney	r Prob. > r n	-0.6703 0.012172 13					

Table B-10. Correlations of flow (Q), total phosphorus (TP), and total nitrogen (TN) among sites in the Seven Mile Coulee. Buffalo Creek, and Beaver Creek basins

Variable		Date	Q 7Mi1	TP 7Mi1	TN 7Mi1	Q 7Mi2	TP 7Mi2	TN 7Mi2	Q Bvr1	TP Bvr1	TN Bvr1	Q Bvr2	TP Bvr2	TN Bvr2	Q Buff1	TP Buff1	TN Buff1	Q Buff2	TP Buff2
TN Buff2	r	-0.3020	0.0869	-0.0857	0.7393	-0.0365	-0.0894	0.6667	0.0090	0.0975	0.5573	0.0918	-0.4338	0.9123	0.1249	0.0742	0.6407	0.1739	0.0342
Sydney	Prob. > r	0.315982	0.777714	0.780619	0.003877	0.905674	0.771462	0.012824	0.978987	0.751411	0.047848	0.765599	0.138589	0.000014	0.684299	0.809700	0.018297	0.569879	0.911668
	n	13	13	13	13	13	13	13	11	13	13	13	13	13	13	13	13	13	13
TP Buff2	r	0.5159	-0.1912	0.7699	0.0609	-0.4394	0.8100	0.3404	-0.3175	0.3385	-0.1812	-0.4614	0.3730	-0.2477	-0.2296	0.2408	0.4209	-0.3969	
Sydney	Prob. > r	0.071104	0.531447	0.002082	0.843247	0.132987	0.000789	0.255138	0.341432	0.257857	0.553627	0.112519	0.209382	0.414507	0.450517	0.427982	0.152110	0.179289	
	n	13	13	13	13	13	13	13	11	13	13	13	13	13	13	13	13	13	
Q Buff2	r	-0.8632	0.8500	-0.7979	0.2693	0.6961	-0.6983	0.2053	0.8448	0.3139	0.5372	0.9280	-0.0486	0.2473	0.9371	0.1267	0.0879		
Sydney	Prob. > r	0.000070	0.000118	0.000626	0.351762	0.005686	0.005479	0.481399	0.000544	0.274491	0.047592	0.000002	0.868888	0.394035	0.000001	0.666066	0.764972		
	n	14	14	14	14	14	14	14	12	14	14	14	14	14	14	14	14		
TN Buff1	r	0.0877	0.3267	0.2849	0.7754	-0.2154	0.2272	0.9206	0.1916	0.4678	0.6860	-0.0953	0.0951	0.5764	0.1606	0.4489			
NW of	Prob. > r	0.755915	0.234644	0.303329	0.000683	0.440614	0.415371	0.000001	0.530559	0.078702	0.004752	0.735390	0.736040	0.024509	0.567378	0.093252			
Sharlow	n	15	15	15	15	15	15	15	13	15	15	15	15	15	15	15			
TP Buff1	r	-0.1212	0.3416	-0.0298	0.3881	-0.1370	0.0293	0.5592	0.2786	0.7784	0.5589	0.0435	0.7609	0.1328	0.3520				
NW of	Prob. > r	0.666926	0.212687	0.915949	0.152928	0.626253	0.917425	0.030216	0.356592	0.000630	0.030313	0.877647	0.000986	0.637041	0.198163				
Sharlow	n	15	15	15	15	15	15	15	13	15	15	15	15	15	15				
Q Buff1	r	-0.8423	0.9222	-0.7146	0.1911	0.5875	-0.6067	0.2544	0.8952	0.5035	0.6338	0.8638	0.1552	0.1694					
NW of	Prob. > r	0.000081	0.000001	0.002758	0.495157	0.021282	0.016474	0.360130	0.000036	0.055675	0.011180	0.000033	0.580783	0.546052					
Sharlow	n	15	15	15	15	15	15	15	13	15	15	15	15	15					
TN Bvr2	r	-0.2897	0.1662	-0.1763	0.7352	0.1266	-0.1703	0.6144	0.0765	0.0815	0.6575	0.1246	-0.3736						
Montpelier	Prob. > r	0.294925	0.553739	0.529596	0.001791	0.652968	0.543967	0.014802	0.803878	0.772804	0.007722	0.658252	0.170116						
	n	15	15	15	15	15	15	15	13	15	15	15	15						
TP Bvr2	r	0.0949	0.1540	0.1635	0.0095	-0.2687	0.3011	0.2045	0.0853	0.7676	0.1665	-0.1697							
Montpelier	Prob. > r	0.736616	0.583798	0.560462	0.973321	0.332857	0.275406	0.464615	0.781616	0.000835	0.553129	0.545448							
	n	15	15	15	15	15	15	15	13	15	15	15							
Q Bvr2	r	-0.8288	0.7643	-0.8028	0.0598	0.7314	-0.8077	-0.0320	0.8377	0.0620	0.3556								
Montpelier	Prob. > r	0.000134	0.000907	0.000314	0.832344	0.001944	0.000271	0.909791	0.000351	0.826348	0.193388								
	n	15	15	15	15	15	15	15	13	15	15								
TN Bvr1	r	-0.5254	0.6759	-0.3606	0.6298	0.0815	-0.2974	0.7323	0.5465	0.6363									
NW of	Prob. > r	0.044276	0.005676	0.186682	0.011865	0.772838	0.281713	0.001907	0.053311	0.010767									
Sydney	n	15	15	15	15	15	15	15	13	15									
TP Bvr1	r	-0.2450	0.4518	-0.0112	0.3270	-0.1982	0.2026	0.5953	0.3105										
NW of	Prob. > r	0.378884	0.090906	0.968466	0.234226	0.478771	0.469064	0.019217	0.301775										
Sydney	n	15	15	15	15	15	15	15	13										
Q Bvr1	r	-0.6703	0.9668	-0.6360	0.2275	0.6186	-0.7109	0.2201											
NW of	Prob. > r	0.012172	< 0.000001	0.019454	0.454688	0.024200	0.006448	0.470050											
Sydney	n	13	13	13	13	13	13	13											
TN 7Mi2	r	0.5953	-0.3213	0.7025	0.8276	-0.5586	0.8455												
7 mi East	Prob. > r	0.009143	0.193552	0.001150	0.000022	0.015965	0.000010												
	n	18	18	18	18	18	18												
TP 7Mi2	r	0.8359	-0.6628	0.9103	0.6586	-0.7305													
7 mi East	Prob. > r	0.000016	0.002718	< 0.000001	0.002961	0.000575													
	n	18	18	18	18	18													
Q 7Mi2	r	-0.7305	0.6842	-0.7519	-0.3310														
7 mi East	Prob. > r	0.000576	0.001740	0.000320	0.179683														
	n	18	18	18	18														
TN 7Mi1	r	0.4848	-0.1921	0.6536															
5 mi. N &	Prob. > r	0.041439	0.445157	0.003266															
6 mi. E	n	18	18	18															

Table B-10. Correlations of flow (Q), total phosphorus (TP), and total nitrogen (TN) among sites in the Seven Mile Coulee. Buffalo Creek, and Beaver Creek basins

Variable		Date	Q 7Mi1	TP 7Mi1	TN 7Mi1	Q 7Mi2	TP 7Mi2	TN 7Mi2	Q Bvr1	TP Bvr1	TN Bvr1	Q Bvr2	TP Bvr2	TN Bvr2	Q Buff1	TP Buff1	TN Buff1	Q Buff2	TP Buff2
TP 7Mi1	r	0.9477	-0.7133																
5 mi. N &	Prob. > r	< 0.000001	0.000889																
6 mi. E	n	18	18																
Q 7Mi1	r	-0.7872																	
5 mi. N &	Prob. > r	0.000106																	
6 mi. E	n	18																	

Basin abbreviations: 7Mi = Seven Mile Coulee; Buff = Buffalo Creek; Bvr = Beaver Creek; 1 = upstream site and 2 = downstream site

NOTE – assume statistical significance if Probability of a greater r occurring by chance alone (= Prob. > r in the table) is less than 0.01