TONGUE RIVER WATERSHED

ASSESSMENT FINAL REPORT 1996 - 1999

September, 2000

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FORWARD

The Tongue River watershed is the lifeblood for northwest Sheridan County, Wyoming because it provides the water resource that drives the recreational, agricultural, urban and wildlife opportunities in this region of Wyoming. Protection of this water resource is critical to maintain the quality of life enjoyed by not only residents in the watershed, but by all Wyoming residents and citizens from throughout the United States that visit this region for the recreational, esthetic, spiritual and economic offerings provided by the watershed.

Water quality concerns have emerged over the years in that segment of the Tongue River from the Bighorn National Forest (BHNF) boundary to the Town of Ranchester. Concerns were related to suspect water quality deterioration manifest by sediment, nutrient, and bacterial inputs to the Tongue River and its tributaries. Public health and safety concerns surfaced because the Town of Dayton and the Town of Ranchester rely on the Tongue River for their domestic water supply. The Town of Ranchester received complaints from residents regarding turbidity and odor. The Ranchester Water Treatment Plant has shut down operation on occasion when the facility was unable to meet treatment standards. Moreover, the Tongue River is a Class 1 coldwater trout fishery near the BHNF boundary. This classification indicates a premium trout fishery of national importance. The quality of the fishery declines to the Town of Ranchester suggesting a declining water resource within this reach of the Tongue River.

SCCD in partnership with the Natural Resources Conservation Service (NRCS) initiated an assessment of the Tongue River watershed between the Bighorn National Forest boundary and the Town of Ranchester. SCCD and NRCS implemented the Project not only for water quality concerns, but because of the high value for resources in the watershed and to continue to address voluntary conservation and resource issues as part of an integrated conservation program. A proposal was submitted to WDEQ in 1995 and funding was received in 1996. Additional 205(j) funding was secured in 1998 to extend the watershed assessment through 1999.

In 1996, the Wyoming Department of Environmental Quality 305(b) report indicated this segment of the Tongue River was not achieving full attainment of its beneficial uses. The 1996 Wyoming Water Quality Assessment (305(b)) report listed this segment as Threatened due to fishery concerns (WDEQ, 1996). The causes responsible for this finding were listed as siltation and nutrients based on information provided by the Wyoming Game and Fish Department and the United States Geological Survey monitoring station number 06298000. The sources for these pollutants were reported as range land and pasture land.

The Little Tongue River and Smith Creek, tributaries to the Tongue River, were also listed by WDEQ in 1996 for not achieving full attainment of their beneficial uses. The Little Tongue River was listed as partially supporting aquatic life use while Smith Creek was listed as not supporting drinking water standards due to pathogens indicated by high fecal coliform bacteria levels.

SCCD conducted chemical, physical, biological and stream habitat monitoring at stations on the main stem Tongue River and major tributaries from 1996 through 1999. The Wyoming Department of Environmental Quality Water Quality Division (WDEQ), Wyoming Game and Fish Department (WGFD), United States Geological Survey (USGS), Ranchester Public Works Department (RPWD), Wyoming State Board of Control (WSBC) and Natural Resources Conservation Service (NRCS) conducted monitoring concurrent with SCCD monitoring during the same time frame. This Final Report presents historic and current monitoring data, analysis of the data from each monitoring group and provides recommendations for future monitoring direction and assessment techniques. The Watershed Plan prepared under auspices of SCCD, Tongue River Watershed Steering Committee and watershed landowners is provided as a separate document (SCCD, 2000) and may be secured by contacting SCCD.

ACKNOWLEDGEMENTS

SCCD would like to thank many individuals and agencies for their time and effort offered during this Project. Successful completion of this Project could not have occurred without their assistance and dedication.

The SCCD supervisors and associate members provided encouragement and volunteered many hours in the field. Sincere appreciation is due to Mr. Jerry Forster, Natural Resources Conservation Service (NRCS) District Conservationist and fellow NRCS personnel in the Sheridan, Wyoming office for assistance in the field. The NRCS Casper Wyoming Office provided valuable precipitation and air temperature data and expertise for hydrologic aspects including construction of discharge rating curves for discharge measurements. The Town of Dayton and Town of Ranchester, especially Mr. Harold Herman, Director of the Ranchester Public Works Department, provided valuable analytical technical assistance and extensive long term water quality data files. Special thanks go to Kurt King, WDEQ, Sheridan, for providing monitoring and assessment training to SCCD staff, technical advice, Quality Assurance and Quality Control insight and field assistance. The Wyoming Game and Fish Department in Sheridan provided fisheries data and a historical natural resource perspective for the Tongue River watershed. George Cleek, NRCS liaison with the Wyoming Department of Agriculture was a pivotal link in the watershed planning process. Sincere appreciation goes to the Tongue River watershed landowners and users, especially those that allowed access for sampling.

The Wyoming Department of Environmental Quality is acknowledged for providing the mechanism to conduct the watershed assessment and to the United States Environmental Protection Agency for providing funding through Section 205(j) of the Clean Water Act.

EXECUTIVE SUMMARY

Sheridan County Conservation District (SCCD) completed a four (4) year Tongue River Watershed Assessment Project on the Tongue River and five (5) major tributaries. The Project area located in North-Central Wyoming comprised approximately 80,000 surface acres and extended from near the Bighorn National Forest boundary to the Town of Ranchester.

The Tongue River watershed is the lifeblood for northwest Sheridan County, Wyoming because it provides the water resource that drives the recreational, agricultural, urban and wildlife opportunities in this region of Wyoming. Protection of this water resource is critical to maintain the quality of life enjoyed by not only residents in the watershed, but by all Wyoming residents and citizens from throughout the United States that visit this region for the recreational, esthetic, spiritual and economic offerings provided by the watershed.

Water quality concerns emerged over the years for the segment of the Tongue River from the Bighorn National Forest boundary to the Town of Ranchester. Concerns were related to suspect water quality deterioration manifest by sediment, nutrient, and bacterial inputs to the Tongue River and its tributaries. Public health and safety concerns surfaced because the Town of Dayton and the Town of Ranchester rely on the Tongue River for their domestic water supply. The Tongue River fishery declines from a Class 1 wild trout fishery of national importance near the Bighorn National Forest boundary to a marginal fishery at the Town of Ranchester indicating a declining water resource.

SCCD in partnership with the Natural Resources Conservation Service (NRCS) initiated an assessment of the Tongue River watershed between the Bighorn National Forest boundary and the Town of Ranchester. SCCD and NRCS implemented the Project not only for water quality concerns, but because of the high value for resources in the watershed and to continue to address voluntary conservation and resource issues as part of an integrated conservation program. In 1995, funding was requested from the United States Environmental Protection Agency through Section 205(j) funding administered by the Wyoming Department of Environmental Quality. Funding was received in 1996 and 1998 for monitoring through 1999.

This segment of the Tongue River was identified by Wyoming Department of Environmental Quality in 1996 as water quality limited and placed on the 303d list. The Little Tongue River and Smith Creek, tributaries to the Tongue River, were also identified as water quality limited.

SCCD conducted integrated chemical, physical, biological and stream habitat monitoring at multiple stations on the Tongue River and five major tributaries from 1996 through 1999. Some of the tributaries had never been sampled prior to the Project. Other tributaries had not been sampled at this scale or intensity. The Wyoming Department of Environmental Quality Water

Quality Division (WDEQ), Wyoming Game and Fish Department (WGFD), United States Geological Survey (USGS), Ranchester Public Works Department (RPWD), Natural Resources Conservation Service (NRCS) and Wyoming State Board of Control (WSBC) conducted monitoring in the watershed during the same time frame. Data collected by WDEQ after 1997 was considered PROVISIONAL for this Final Report and subject to change because data had not been subjected to internal Quality Assurance review. Macroinvertebrate data collected by USGS in 1999 was also considered PROVISIONAL and subject to change because data was not subjected to the usual USGS Quality Assurance and peer review process.

This Final Report presents historic data from as early as 1938, current monitoring data, analysis of the data from each monitoring group and provided recommendations for potential future monitoring and assessment. The Tongue River Watershed Management Plan was prepared under auspices of SCCD, Tongue River Watershed Steering Committee and watershed landowners. The Plan was provided as a separate document from this Final Report and may be secured by contacting SCCD. The Tongue River Watershed Management Plan charted the future direction for land treatments, priorities, funding mechanisms and Information and Education. The role that SCCD may play in future monitoring efforts is uncertain due to staffing limitations, limited operating budget dependent upon "soft money", unknown future funding and public support for voluntary BMP implementations and land treatments. SCCD must stretch limited resources to fulfill it's commitment not only the Tongue River watershed, but to all Sheridan County residents to promote and implement wise conservation practices.

Water pollutants affecting the Tongue River and primary tributaries were identified. Potential sources for pollutants were discussed in relation to primary land uses. However, specific sources for pollutants such as individual septic tanks, storm drains, animal feeding operation were not identified because the Project scope was geared to a watershed scale assessment. The Tongue River watershed within the Project area was a complex system due to multiple land uses and water uses. Land ownership was about 92 percent private and 8 percent State of Wyoming land. Land use in the upper watershed bordering the Bighorn National Forest was primarily wildlife habitat, recreation and seasonal livestock grazing. Land use diversifies in the middle and lower portions of the watershed. Agricultural land use predominated although wildlife habitat, tourism/recreation, urban (areas within or immediately adjacent to a town) and emerging rural subdivision development were locally significant. There are approximately 12,000 acres of irrigated hay and crop land in the Project area with approximately one-third to one-half operating at low efficiencies. Agricultural operations center around cattle and hay production enhanced by irrigation water from the Tongue River and tributaries primarily during the summer growing season. Livestock tend to be fed and wintered along the creek bottoms since these areas provide the necessary shelter and water.

Quality Assurance and Quality Control (QA/QC) evaluation of data collected during the four year Project indicated adequate data quality was provided to meet Project goals and objectives.

Recommendations were made when QA discrepancies were identified. Each water quality monitoring project reveals numerous unanswered questions. This Project was no exception. Recommendations found in this Final Report were provided to improve future water quality monitoring and assessment within the Tongue River Project area. Some recommendations, especially for water temperature and fecal coliform monitoring, may have implications to statewide water quality monitoring by Conservation Districts, WDEQ and other groups.

The Tongue River Watershed Assessment Project was initiated before Credible Data legislation was enacted in 1999 as per W.S. §35-11-103 of the Wyoming Environmental Quality Act. The SCCD monitoring program met the criteria and intent of the legislation. This was important because data collected during this Project may be used to determine attainment of designated uses for the Tongue River and tributaries and to propose stream classifications or change in stream classification when appropriate.

Water quality in the Tongue River from the Bighorn National Forest boundary to the Town of Ranchester was good to excellent with few exceptions. Land use in the Bighorn National Forest produced no significant effects for water quality and stream biological condition in the Tongue River and its primary tributaries. Nutrient concentrations (nitrate, phosphorus and ammonia) were either low or not detected, herbicides and pesticides were not detected. Turbidity, pH and dissolved oxygen were within Wyoming water quality standards. Conductivity, alkalinity, total sulfate and total chloride concentrations were relatively low for a water body of this stream order and drainage area. Total hardness concentration indicated water in the Tongue River was moderately hard to hard and reflected the predominant limestone geology in the upper watershed. USGS sampling found non-detectable or low stream bed sediment metal concentrations; brown trout fish tissue and liver samples indicated no accumulation of organic compounds. Water column metals sampling found non-detectable or low concentrations. The metals and organic sampling suggested low potential for contamination of the aquatic food chain and no fish consumption advisory. Monthly water quality sampling by USGS at the Tongue River Upper station confirmed findings from SCCD and WDEQ water quality sampling. Intensive monitoring by WDEQ at the Dayton Wastewater Treatment Plant (WWTP) found no significant amount of pollutants were entering the Tongue River from the WWTP.

Biological condition based on sampling and analysis of benthic macroinvertebrate communities was rated good at each Tongue River station indicating full support for aquatic life use and attainment of Wyoming water quality narrative biological criteria. Limited benthic macroinvertebrate sampling conducted by USGS compared favorably with SCCD and WDEQ benthic macroinvertebrate sampling despite differences in sampling method, sampling date and sampling location. The transition from a cool water benthic community at the Upper station to a warmer water benthic macroinvertebrate community at the Lower station reflected the increase in water temperature along the longitudinal gradient from the upper to lower reaches. Dewatering during the summer accelerated water temperature increase in the lower reach. Periphyton and algae samples were collected by USGS and WDEQ, but analytical results were not available for this Final Report.

In-stream and riparian habitat quality was reduced from the Tongue River Upper to Lower reaches based on qualitative habitat scoring criteria. Because habitat assessments were subjective, SCCD took a conservative approach for the interpretation of habitat data. The reduction in habitat scores between stations was due to lower scores for embeddedness (silt cover on cobble and gravel stream substrate), channel flow status, channel shape, channelization, width depth ratio and bank stability. Reduced scores for some of the habitat parameters were related not only to current land use practices and water management, but to lingering effects from the period of extensive channelization that apparently occurred in the late 1950's to early 1960's. The semi-quantitative stream substrate particle size distribution varied little between stations. The general decrease in substrate particle size observed from the Upper station to the Lower station was normal because particle size generally decreases as stream size, drainage area and stream order increase. Stream substrate composition at Tongue River stations in order of importance was cobble, coarse gravel and fine gravel. Sand and silt deposition was minimal. Sand comprised from 1 percent to 5 percent of stream substrate at Tongue River stations. Only the Upper and Lower stations had detectable silt deposition. Silt comprised about one (1) percent of total substrate at those stations.

Stream substrate embeddedness increased from the Tongue River Upper to Lower stations. Increase in embeddedness from the Upper to Lower stations was considered normal for the size (drainage area was 347 square miles at Tongue River Lower station) and stream order of the Tongue River. The increase in embeddedness and minor increase in sediment deposition observed from Tongue River upper to lower reaches was expected due to normal hydrologic processes. Increased water temperature, embeddedness and minor sediment deposition had no apparent detrimental effect on the benthic macroinvertebrate population because biological condition was rated very good and full support of aquatic life use was indicated. Despite the reduction in habitat scores and increase in embeddedness values from Tongue River Upper to Lower stations, these stations ranked high when compared to habitat scores and embeddedness values observed at other plains streams in the Northwestern Great Plains ecoregion of Wyoming. The small percent of sand and silt comprising the Tongue River stream substrate further indicated no large scale disruption in the Tongue River watershed.

Review of historic and current WGFD fishery data found game fish populations were dominated by trout species in the Tongue River upper canyon reach. Whitefish replaced trout species downstream of the canyon into the middle reach. Extensive historic channelization appeared to reduce trout habitat and trout populations downstream to the Town of Ranchester. Non-game fish populations increased in abundance in this reach. Loss of habitat due to channelization, channel modification, and elevated summer water temperature accelerated by dewatering appeared to be the primary reasons for the decline in game fish populations observed in the Tongue River over the years. Effects of channelization and channel modification continue to this day requiring stream bank stabilization projects.

Long term monitoring data sets provided by RPWD indicated a gradual, but significant decline in turbidity, water temperature and pH in the Tongue River over the years. Decline in alkalinity was also indicated in a short term two (2) year data set. Decline in pH and alkalinity could be related to anthropogenic (man caused) effects affecting other water bodies nationwide (i.e. acid rain), change in water management in Tongue River tributaries or to other unknown factors. Reduction in turbidity and water temperature were positive trends. Continued monitoring by RPWD was recommended to track the trends in pH and alkalinity because further decline may affect the aquatic biological community, fishery and the ability of the Tongue River to meet Wyoming water quality standards.

All Wyoming water quality numeric and narrative criteria were met in the Tongue River with the exception of frequent water temperature and infrequent fecal coliform bacteria exceedences in the lower reach near the Town of Ranchester. Dewatering appeared to accelerate the increase in summer water temperature. There was one fecal coliform sample that exceeded the Wyoming water quality standard during the four (4) year Project representing four (4) percent of total fecal coliform bacteria samples collected. Significant, but infrequent fecal coliform bacteria contamination may exist. Because the fecal coliform excursion occurred near the Ranchester Water Treatment Plant intake, remedial action should be pursued to ensure that all fecal coliform bacteria samples are in compliance with the Wyoming water quality standard.

Historic fecal coliform data were compared to fecal coliform data collected during this Project. There was no large difference in fecal coliform bacteria between periods in the upper reach of the Tongue River. Generally consistent and low fecal coliform bacteria levels were observed since 1976 to present. Potential wildlife and recreational sources for fecal coliform bacteria potentially affecting the upstream reach were not contributing significant levels of bacterial contamination. Livestock do not access this area because the steep-walled canyon does not provide suitable grazing pasture. Significant reductions in fecal coliform bacteria level occurred from 1985 to present in the middle reach of the Tongue River. The reduction in fecal coliform bacteria was probably due to the significant upgrade of the Dayton WWTP in the mid-1980's, continued effective operation and maintenance of the facility. Fecal coliform bacteria level in the lower Tongue River reach appeared to decline slightly over time, but large differences in the number of samples collected between periods prevented a firm conclusion.

The Tongue River will remain on the Wyoming 303d list identifying water quality limited stream segments due to exceedence of the water temperature and fecal coliform bacteria standards. However, the size of the current water quality limited segment should be reduced. The current water quality limited segment was from near the Tongue River Upper station and Bighorn National Forest boundary to the Tongue River Lower station at Ranchester. The revised water quality limited segment should be listed as from the Halfway Lane County Road near the Tongue

River Middle station located about midway between the Town of Dayton and the Town of Ranchester, to the Town of Ranchester. Reduction in size of the water quality limited segment was justified because no water quality problems were identified at or upstream of the Tongue River Middle station. Impairments will be listed as water temperature and fecal coliform bacteria. Being retained on the 303d list will require remedial action probably in the form of BMP implementation and voluntary conservation land treatments in concert with water management modification to restore water quality. SCCD prepared the Tongue River Watershed Management Plan (SCCD, 2000) under the auspices of the Tongue River Watershed Steering Committee (TRWSC) and Tongue River watershed landowners with assistance from NRCS. The management plan and TRWSC will guide future prioritization and implementation of voluntary land treatments, land management changes and monitoring activity within the Project area to bring affected water bodies back into compliance with Wyoming water quality standards. The Watershed Plan will delay implementation of Total Maximum Daily Loads (TMDL's) for both water temperature and fecal coliform.

Water temperature naturally increases along the longitudinal gradient in the Tongue River during the warmer summer months. Dewatering accelerated the increase in water temperature and resulted in loss of habitat by restricting trout to reaches further upstream. However, after accounting for these factors and evaluation of credible historic and current chemical, physical and biological data, it was evident that the Tongue River Lower station was sited in the transition zone between a cold water system (WDEQ Class 2 cold water) and a warm water system (WDEQ Class 2 warm water). The entire length of the Tongue River to the Montana border is currently a Class 2 cold water, water body. SCCD proposed that reclassification of the Tongue River from Class 2 cold water to Class 2 warm water was warranted. The Interstate 90 Bridge was proposed as a possible point of division between cold water and warm water stream classes. SCCD may consider submittal of a formal petition to WDEQ to initiate the reclassification process at a later date. Data and findings contained in this Final Report should provide adequate justification for initiation of the proposed reclassification. The proposed reclassification will not change the current status for placement of the Tongue River Lower segment on the Wyoming 303d list, but will provide more appropriate water quality goals for the downstream segments.

Water quality in tributaries was poorer than water quality in the Tongue River. Each tributary exceeded one or more Wyoming water quality standards and will be placed on the Wyoming 303d list. Smith Creek and Little Tongue River were previously on the 303d list and will remain. Columbus Creek, Wolf Creek and Five Mile Creek will be new additions to the 303d list.

Smith Creek will be listed for exceedence of the fecal coliform bacteria standard, the turbidity standard and water temperature standard. The water quality limited length of stream was identified as the segment from the Smith Creek Upper station to the Smith Creek Lower station because the impairments were occurring somewhere between the two stations.
Little Tongue River will be listed for exceedence of the fecal coliform bacteria standard, the water

temperature standard and narrative biological criteria standard. The water quality limited length of stream was identified as the segment from the Little Tongue River Upper station to the Little Tongue River Lower station because the impairments were occurring somewhere between the two stations. The Little Tongue River Upper station exceeded the narrative biological criteria standard based on WDEQ benthic macroinvertebrate sampling in 1993. SCCD analysis confirmed the WDEQ finding.

Columbus Creek will be listed for exceedence of the fecal coliform bacteria standard, water temperature standard, turbidity standard and narrative biological criteria standard. The water quality limited length of stream was identified as the segment from the Columbus Creek Upper station to the Columbus Creek Lower station because the impairments were occurring somewhere between the two stations. Water quality upstream of the Upper station was good with the exception of a single high fecal coliform bacteria sample representing four (4) percent of total samples. SCCD proposed that the Columbus Creek segment upstream of this station not be placed on the 303d list due to the single sample exceedence. Rather, SCCD proposed to continue fecal coliform bacteria monitoring to determine if significant bacterial contamination persisted.

Wolf Creek will be listed for exceedence of the fecal coliform bacteria standard, water temperature standard and turbidity standard. The water quality limited stream segment was identified as from the Wolf Creek Upper station to the Wolf Creek Lower station because the impairments were occurring somewhere between the two stations. The EPA secondary drinking water standard for total sulfate was exceeded based on a single WDEQ sample collected in 1995 at the Wolf Creek - Berry station. However, the EPA secondary drinking water standard was not enforceable and as such, will not require a potential TMDL.

Five Mile Creek exhibited the poorest water quality of any stream assessed during this Project. Five Mile Creek will be placed on the 303d list for exceedence of the fecal coliform bacteria standard, water temperature standard, turbidity standard and narrative standard for biological criteria. The EPA secondary drinking water standard for sulfate was exceeded, but this standard was not enforceable and will not require a potential TMDL. The sulfate concentration may pose a seasonal health risk to young livestock and animals especially if they are not acclimated to higher sulfate water. The water quality limited length of stream was identified as the entire Five Mile Creek drainage including the Five Mile Ditch and both irrigation storage reservoirs because the impairments were occurring somewhere upstream of the Five Mile Creek Lower station.

Five Mile Creek was currently not classified by WDEQ, but assumed the classification of the Tongue River (Class 2 cold water) due to the “tributary rule”. Five Mile Creek functions as an irrigation water supply conduit. SCCD proposed that Five Mile Creek be classified as a Class 3 water body. Because Five Mile Creek was currently not classified, SCCD believes notification and reference to this Final Report should provide sufficient documentation to justify the proposed classification. The Class 3 determination will not change the status for placement of Five Mile

Creek on the Wyoming 303d list.

Chemical, physical, biological and habitat attributes were ranked by station to assist prioritization of voluntary land treatments and management activity to improve water quality. Five Mile Creek had the poorest water quality followed by Columbus Creek, Smith Creek, Little Tongue River and Wolf Creek. The Tongue River stations rated highest for water quality. Site ranking for biological condition based on benthic macroinvertebrates closely agreed with the site ranking for water quality. Close agreement between water quality and benthic macroinvertebrate rankings suggested that macroinvertebrate sampling alone could provide a good estimate for water quality at a fraction of the cost. The percent contribution of benthic oligochaetes (worms) to the total benthic macroinvertebrate community was a statistically significant and reliable predictor for identification of significant fecal coliform bacteria contamination. Certain worm taxa including *Ophidonais serpentina*, *Eiseniella tetraedra*, *Nais variabilis* and Lumbricina may present additional predictive power because these organisms occurred most frequently at stations exceeding the Wyoming water quality standard for fecal coliform bacteria. No *Tubifex tubifex* worms were identified from samples. *T. tubifex* is significantly involved in the whirling disease life cycle caused by a parasite (*Myxobolus cerebralis*) that penetrates the head and spinal cartilage of fingerling trout. Whirling disease may eventually cause death in trout and the absence of this worm indicated low probability for the occurrence of whirling disease in the Tongue River watershed within the Project area.. These associations further indicated the importance of benthic macroinvertebrates as cost-effective water quality indicators.

Comparability between the habitat assessment ranking and both water quality and benthic macroinvertebrate rankings was not good. The subjective nature of the habitat assessment and annual variability in flow dependent habitat parameters appeared to be important factors related to the lack of comparability between the habitat assessment and the water quality and biological condition rankings.

Water quantity reduction and water temperature increase observed at tributaries affected mainstem Tongue River water resources. However, cumulative total discharge from tributaries comprised a relatively small proportion of total discharge in the Tongue River. With the exception of Smith Creek and Five Mile Creek, each tributary exhibited a reduction in stream discharge from Upper to Lower stations. Reduction in discharge was most apparent during the summer irrigation months. Reduction in tributary discharge reduced the quantity of pollutants entering the Tongue River. The Little Tongue River contributed an estimated 6.2 percent of the Tongue River discharge. Smith Creek comprised an estimated 1.3 percent, Columbus Creek 1.3 percent, Wolf Creek 8.9 percent and Five Mile Creek an estimated 1.6 percent of the total Tongue River discharge. The proportionally small percentage attributed to Five Mile Creek was due to diversion of Columbus Creek water into the Five Mile Creek watershed. Accordingly, diversion from Columbus Creek into Five Mile Creek reduced the amount of discharge from Columbus Creek to the Tongue River. It was noted that discharge data measured during this Project was usually from April through

September and may not reflect total annual discharge characteristics for the tributaries.

Water management and irrigation practices appeared to greatly influence water quality, aquatic benthic communities and fish populations more in tributaries than in the Tongue River. The proportion of irrigation return comprising total tributary discharge appeared high especially for Smith Creek, Columbus Creek and Wolf Creek. Dewatering, admixture of ambient water with irrigation return water and variable stream discharge related to irrigation demand appeared to result in the lack of consistent and expected associations between discharge and certain water quality parameters. The apparent repeated use and reuse of water was a complicating factor in determining the fate of pollutants in the tributaries. These factors may be responsible for the lack of consistent associations between fecal coliform bacteria and temperature, discharge and turbidity at the regulated Lower tributary stations. Irrigation return entering the Tongue River did not appear to have a significant impact on Tongue River water quality and water quantity because primary points for return water were located downstream of the Project area.

The majority of pollutants affecting tributaries were from apparent non-point sources. Water quality and fecal coliform bacteria levels changed significantly from the Upper tributary stations to the Lower tributary stations. Accordingly, primary land use and water management changed significantly from the Upper tributary to Lower tributary stations.

Fecal coliform bacteria levels were generally low at the Tongue River Upper station and at each of the Upper tributary stations. With the exception of the Columbus Creek Upper station (one daily exceedence), there were no exceedences of the Wyoming water quality standard for fecal coliform bacteria during the four year Project. Primary land use in the watershed at and upstream of these stations included wildlife, recreation and seasonal livestock grazing. This observation indicted that wildlife, recreation and limited seasonal livestock grazing land use had no significant effect on fecal coliform bacteria levels.

Fecal coliform bacteria levels increased significantly at the Tongue River Lower station and each tributary station. Each station exceeded the Wyoming water quality standard for fecal coliform bacteria. Agricultural land uses including irrigated hayland, dryland pasture and livestock grazing (more intensive, some year around grazing) predominated areas between the Upper and Lower tributary stations although wildlife habitat, recreation, rural residential and urban land use were locally important. It was not possible to separate the potential influence of agricultural land uses from the potential influence by wildlife, recreation, and other land uses on fecal coliform bacteria levels at the Lower stations. Ancillary effects related to irrigation water delivery and return may promote fecal coliform bacteria contamination by transporting bacteria, contributing sediment and creating variable discharges resulting in the instability of stream bottom sediment suspected of harboring bacteria and resuspension of fecal coliform bacteria. Although wildlife land use was not an important source of fecal coliform bacteria at the Upper tributary stations, change in the stream channel morphology from the higher gradient Upper stations in the foothills to the lower gradient and meandering Lower stations in the plains provided better habitat for increased utilization by waterfowl and small mammals. Thus, the role that waterfowl may exert on fecal coliform bacteria levels further complicated the search for fecal bacteria sources.

Although livestock grazing was suspected as a potential source for significant bacterial contamination at some of the Lower tributary stations, certain best management practices may be implemented to ensure livestock grazing has no significant effect on bacteria levels. Likewise, suspect urban, recreational, rural residential and agricultural land use practices should be re-evaluated throughout the Tongue River watershed within the Project area.

Identification of fecal coliform bacteria sources is elusive because of the usual interaction of wildlife, livestock and occasionally humans through urban, rural residential and normally limited high use recreation concentration. Because wildlife and livestock have more widespread distribution throughout the Tongue River watershed, they represent the primary potential sources for fecal coliform bacteria. Identification of potential sources is even more difficult in urban areas affected by storm drain effluent. Recent advances in biotechnology have allowed water quality investigators to more readily discern sources of fecal contamination through DNA testing. DNA testing is relatively expensive and time consuming and results may be inconclusive about 20 percent to 60 percent of the time. Reliability for identification of fecal bacteria sources increases as the reference source material database increases for the watershed under study. Although expensive in the short term, DNA testing may realize long term benefits and cost savings by more effectively directing water quality improvement funds to areas suspect of fecal contamination. SCCD and other monitoring groups may explore use of DNA testing for future monitoring in the Project area or for statewide monitoring.

Considerable analysis of fecal coliform bacteria data was conducted because each tributary and the Tongue River Lower station exceeded the Wyoming water quality standard. Regression analyses were conducted to determine the relationship between fecal coliform bacteria level, certain water quality parameters and select benthic macroinvertebrate community metrics.

With few exceptions, there were no consistent statistically significant associations between fecal coliform bacteria level and discharge, temperature and turbidity at the Tongue River Upper station and at the Upper tributary stations. These stations normally exhibited lower fecal coliform levels and with the exception of a single high fecal coliform bacteria sample at Columbus Creek Upper, none exceeded Wyoming water quality standards. There was an infrequent statistically significant relationship between fecal coliform and discharge, water temperature and turbidity.

Turbidity appeared to be the primary physical factor that was routinely significantly associated with high fecal coliform bacteria levels at Lower tributary stations and the Tongue River Lower station. However, the association was not consistent at all stations indicating that merely reducing turbidity would not always result in reduction in fecal coliform levels. Discharge, and then temperature, occasionally exhibited statistical significance with fecal coliform bacteria levels usually at the Lower tributary stations where discharge was highly regulated by irrigation demand. There appeared to be more interaction between turbidity, discharge and temperature with fecal coliform bacteria levels at the more highly regulated Lower tributary stations than at the Upper tributary stations that were not regulated by irrigation demand. Some of the conflicting "noise" present in the fecal coliform bacteria - water quality chemical and physical relationships at the Lower tributary stations sited in urban settings may be due to potential fecal coliform contamination from urban sources during low stream discharge in addition to suspected fecal coliform contamination from upstream wildlife and agricultural related land use.

The association between turbidity and fecal coliform bacteria level may be related in part to sediment deposition. Sediment may harbor bacteria for a considerable length of time.
The usual significant relationship between fecal coliform bacteria and turbidity suggested a strong link to deposition of stream bed sediment. The statistically significant association between increase in percent of Oligochaeta (worms associated with sediment and organic pollution) in the benthic community and increase in fecal coliform bacteria contamination added more evidence to suggest a link between fecal bacteria in sediment with fecal coliform bacteria detected in the water column.

Sampling frequency influenced the ability to reliably detect significant fecal coliform bacteria contamination. SCCD found that a single instantaneous monthly grab sample for fecal coliform would miss significant fecal coliform bacteria contamination on average, about forty-eight (48) percent of the time. However, the greater the level of fecal coliform contamination, the fewer number of daily samples were generally needed to detect significant fecal coliform contamination with confidence. At stations with high geometric mean fecal coliform bacteria levels greater than 500 per 100ml, samples collected on one to two different days would generally be sufficient to detect significant fecal coliform bacteria levels (when using the WDEQ standard of 400 per 100ml based on a single daily sample). When fecal coliform bacteria levels were lower (geometric mean from 200 per 100ml to 300 per 100ml), the minimum number of separate daily samples collected must be increased from three (3) to five (5) per 30 day period to reliably detect significant fecal coliform contamination. The single daily sample for fecal coliform collected monthly by SCCD had a probability of about 50 percent of missing significant fecal coliform levels when in fact significant bacteria probably existed.

Sampling season had a significant effect on fecal coliform bacteria level. SCCD evaluation of WDEQ fecal coliform bacteria data collected from the adjacent Goose Creek watershed found a significant difference ($P<0.01$) in fecal coliform bacteria level between the Recreation Season (May 1 to September 30) and Non-Recreation Season. Fecal coliform bacteria levels were significantly higher at each station during the Recreation Season than during the Non-Recreation season. The greatest difference observed at a single station was a 31-fold decrease in fecal coliform bacteria during the Non-Recreation Season when compared to fecal coliform bacteria levels during the Recreation Season. Several stations exhibited >15-fold decreases in fecal coliform bacteria during the Non-Recreation Season.

Based on these findings, SCCD will modify fecal coliform bacteria sampling frequency for future watershed scale and routine water quality sampling. Sampling will occur during the Recreation Season and at a minimum frequency of five (5) samples each on separate days during a 30 day period within the Recreation Season (May 1 through September 30). Sampling for fecal coliform bacteria outside the Recreation Season may be required to identify sources for fecal coliform, but the data should be relegated to an secondary role for public health and safety concerns. Other Conservation Districts and monitoring groups in Wyoming may consider adopting this sampling frequency to standardize fecal coliform bacteria monitoring results statewide.

Analysis of historic and current water temperature data found that routine instantaneous water temperature measurements were insufficient to detect maximum daily water temperature. Maximum daily summer water temperature in the Tongue River was generally recorded between 1700 hours (5:00 pm) and 2000 hours (8:00 pm) and minimum daily water temperature generally occurred from 0800 hours (8:00 am) to 1000 hours (10:00 am). The difference between maximum and minimum daily summer water temperatures routinely ranged from 5^{o}C to 7^{o}C. The SCCD sampling design and routine water temperature measurements by other monitoring groups in the watershed missed the maximum daily water temperature. SCCD sampling generally occurred during the morning through early afternoon hours when lower water temperatures persisted. Instantaneous daily water temperature measured by SCCD and others during this Project usually more closely approximated the lower minimum daily water temperature instead of maximum daily water temperatures needed to evaluate potential effects on cold water fish species and determine compliance with the Wyoming temperature standard. This finding indicated that water temperatures recorded in the Tongue River and tributaries could be conservatively adjusted upward by from 5^{o}C to 7^{o}C to provide a better estimate of maximum daily water temperature. Continuous water temperature recorders or thermistors should be purchased and installed at stations suspected of approaching the Wyoming water temperature standard.

The TRWSC will prioritize voluntary water quality improvement activity after consultation with SCCD, landowners, WDEQ and EPA. Water bodies with confirmed fecal coliform bacteria standard violations may receive the highest priority because they represent immediate public health and safety concerns. Water bodies with turbidity, water temperature, sulfate and narrative biological criteria exceedences may receive secondary priority. Other local important watershed resource concerns (i.e. roads) and willingness of landowners to apply voluntary land treatments should be closely factored into the prioritization process. Improvement in water quality will play a major role in improvement of aquatic resources and fisheries.

Successful planning must include the entire watershed and the majority of landowners and land users within the Project area. Water management in the upper watershed affects water users in the lower watershed. Land use and water management practices appeared to be indirectly responsible for some water temperature, turbidity and narrative biological criteria standard violations at the Tongue River lower reach and lower tributary stations. The role that water management practice had on fecal coliform bacteria standard violations was less clear. The Tongue River Watershed Management Plan listed this topic as a watershed concern.

Numerous recommendations were proposed throughout this Final Report. Additional water quality and benthic macroinvertebrate monitoring will be required at some time because the Tongue River Lower station and each tributary within the Project area will be placed on the Wyoming 303d list identifying water quality limited stream segments. Monitoring will be required to determine when water quality in these water bodies is improved to meet Wyoming water quality standards. Future monitoring may be directed toward the identification of those specific segments within each impaired tributary to better identify potential sources of significant pollution and effectively target resources to improve water quality. Monitoring to identify segments with significant pollutants and the potential sources of pollutants will require a more complex and intensive sampling design than the basic upstream and downstream design used during this Project. A project of this scope would require significant additional resources currently beyond those available to SCCD. Local support from Sheridan County and its residents will be instrumental in order for the District to accept future significant monitoring responsibilities in the Tongue River watershed in addition to fulfilling it's prior commitment to land and water conservation for all Sheridan County residents.

It is possible that future monitoring will be funded primarily through Section 319 of the Clean Water Act administered by WDEQ through EPA funding. Section 319 projects include a combination of voluntary BMP implementations, land treatments and appropriate land management changes in concert with an emphasis on intensive "implementation monitoring" to determine if BMP's and on the ground changes are effective by reducing water pollutants. Intensive implementation monitoring will require more resources, QA/QC oversight, time and coordination between the Project Sponsors, land owners and funding agencies.

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1 INTRODUCTION

1.1 STATEMENT OF NEED

There are water quality concerns for that portion of the Tongue River from the Bighorn National Forest (BHNF) boundary to the Town of Ranchester (Figure 5-1). Concerns were related to suspect water quality deterioration manifest by sediment, nutrient, and bacterial inputs to the Tongue River and its tributaries. Public health and safety concerns emerged because the Town of Dayton and the Town of Ranchester rely on the Tongue River for their domestic water supply. As of 1998, the Town of Dayton and Town of Ranchester served total populations of 650 and 675 individuals, respectively (Wyoming Water Development Commission, 2000). The Town of Ranchester has received complaints from residents regarding turbidity and odor. Seasonal water quality changes in the Tongue River have caused the Ranchester Water Treatment Plant to modify operations when the facility was unable to meet treatment standards.

Because of these concerns, in 1995, SCCD in partnership with the Natural Resources Conservation Service (NRCS) explored the need for an assessment of the Tongue River watershed between the Bighorn National Forest boundary and the Town of Ranchester. SCCD and NRCS felt an assessment was important not only for water quality concerns, but because of the high value for resources in the watershed and to continue to address voluntary conservation and resource issues as part of an integrated conservation program.

The Tongue River is classified by the Wyoming Department of Environmental Quality (WDEQ) as a Class 2 coldwater water body (WDEQ, 1998). This classification designates the beneficial uses applicable for the Tongue River including:

- Agriculture;
- Protection and propagation of fish and wildlife;
- Industry;
- Human Consumption;
- Recreation; and
- Scenic Value

In addition, EPA requires states to report on beneficial use attainment for Aquatic Life.

In 1996, the WDEQ Wyoming Water Quality Assessment 305(b) report indicated this segment of the Tongue River was not achieving full attainment of it's beneficial uses (WDEQ, 1996). The

1996 report listed this segment as Threatened due to fishery concerns. The causes responsible for this finding were listed as siltation and nutrients based on information provided by the Wyoming Game and Fish Department (WGFD) and the United States Geological Survey (USGS) monitoring station number 06298000. The sources for these pollutants were reported as range land and pasture land. This reach was identified by WDEQ as WYTR10090101-007-3 and assigned a medium priority for future statewide assessment.

The Tongue River is classified by WGFD as a Class 1 cold water trout fishery upstream from the BHNF boundary (WGFD, 1991). This classification indicated a trout fishery of national importance. WGFD currently manages this reach as a wild trout fishery and it receives no supplemental stocking. The quality of the fishery appears to decline from the BHNF boundary to the Town of Ranchester indicating a declining water resource within this segment.

The 1996 305(b) report listed the Little Tongue River segment from near the BHNF boundary to it's confluence with the Tongue River in Dayton as water quality impaired. This segment was identified by WDEQ as WYTR10090101-022-2 and assigned a low priority for future statewide assessment.

The entire length of Smith Creek from its headwaters in the BHNF to confluence with the Tongue River in Dayton was listed in the 1996 305(b) report as water quality limited. This segment was identified as WYTR10090101-100-1. WDEQ assigned a medium priority to Smith Creek for future statewide assessment.

There was sufficient information to indicate the Tongue River, Little Tongue River and Smith Creek were water quality limited. This observation suggested that the other primary Tongue River tributaries (Columbus Creek, Wolf Creek, Five Mile Creek) may have water quality problems. However, potential sources and magnitude of water quality pollutants were unknown due to limited historic sampling throughout the watershed.

SCCD submitted a proposal in 1995 for funding from the United States Environmental Protection Agency (EPA) through Section 205(j) funding administered by the WDEQ. Funding was received in 1996. Additional 205(j) funding was secured in 1998 to extend the watershed assessment through 1999. Important elements of the assessment included water quality sampling, data analysis and evaluation, information and education outreach and formation of the Tongue River Watershed Steering Committee (TRWSC). The TRWSC is an oversight committee consisting of a representative from the Town of Ranchester, Town of Dayton, a SCCD board member, the SCCD District Manager and the NRCS District Conservationist. Attempts were made to include a representative from each sub-drainage within the Project area. The role of the steering committee was to provide information and education, explain the assessment project to the public, review project results, and develop a Watershed Plan. Landowner involvement was a critical component in TRWSC planning.

2 GOALS, OBJECTIVES AND TASKS

The Project goals were the same for the 1996 205(j) assessment project and the 1998 205(j) assessment project. The 1998 project was a continuation of monitoring and assessment initiated in 1996. Minor changes were made to certain objectives and tasks in 1998 to fine tune monitoring and assessment based on evaluation of data collected in 1996 and 1997. For example, fecal coliform bacteria sampling frequency increased in 1999 to more accurately estimate fecal coliform bacteria concentrations during the Recreation Season (defined by WDEQ as the period from May 1 through September 30) to allow comparison with the Wyoming water quality standard for fecal coliform bacteria. Dissolved oxygen measurements were initiated in 1999 to determine attainment with the Wyoming water quality standard for this physical parameter (WDEQ, 1998).

The goals and objectives for the Tongue River watershed project included:

2.1 GOAL 1

Was to provide project administration consistent with approved project management. This Goal was completed as planned.

2.1.1 OBJECTIVE 1

Was to provide oversite and administration as the lead agency. This Objective was completed as planned.

2.1.1.1 TASK 1

Was to conduct project administration including ordering supplies, making payments, preparation of reports, submitting reimbursement applications and day-to-day management responsibilities to ensure completion of the project. This Task was completed as planned.

2.2 GOAL 2

Was to determine the major types of nonpoint source impairments occurring in the Tongue River watershed Project area. This Goal was completed as planned and results may be found in Section 8 and Section 9 of this Final Report.

2.2.1 OBJECTIVE 1

Was to develop the list of sampling parameters to be analyzed in the watershed and a sampling and analysis plan by which sampling for analyses would proceed. This Objective was completed as planned. See Section 6 for the list of sampling parameters and sampling methods employed during this Project. See Section 7 for the Quality Assurance and Quality Control program.

2.2.1.1 TASK 2

Was to compile and evaluate available data in the Tongue River watershed Project area. This task comprised three primary efforts

A. Evaluation of water quality data obtained from the Wyoming Water Resource Center, the Bighorn National Forest and a historical water quality data review;

B. Utilize local contacts to ensure awareness of potentially useful data. Contacts may include the Wyoming Game and Fish Department, United States Forest Service, United States Geological Survey, Wyoming Department of Environmental Quality, Ranchester Water Treatment Plant, and Tongue River High School students; and

C. Review all available data and information to determine which water quality parameters were likely to cause concerns.

This Task was completed as planned. See Section 5.1 for a description of historic chemical, physical and biological data compiled within the Project area, Figure 5-1 for the approximate locations of historic monitoring stations and Appendices A, C, E, J and K for the historical data.

2.2.1.2 TASK 3

Was to provide public education and obtain public input in the target watershed from agricultural producers, recreational land users, and urban community members. This task had two primary efforts:

A. Education through tours, newsletters, and personal contact of landowners within the watershed and

B. Obtain additional input through Conservation District Board meetings and TRWSC meetings.

This Task was completed as planned. SCCD personnel have conducted numerous information and education activities for public groups, schools and local radio talk shows. The TRWSC was formed and has met numerous times for preparation of the Tongue River Watershed Plan (SCCD, 2000). TRWSC has held several public meetings to obtain public input and landowner participation has been encouraging.

2.2.2 OBJECTIVE 2

Was to perform sample analyses and interpret data collected.

This Objective was completed as planned. See Section 8 for results of sample analyses and Section 8 and Section 9 for interpretation of the data.

2.2.2.1 TASK 4

Was to monitor water quality and perform analyses.

This Task was completed as planned. See Section 8 for results of water quality monitoring and analysis of samples.

2.2.2.2 TASK 5

Was to assess the relative health of the riparian areas to determine effects on the water quality within the Project area. WGFD conducted a concurrent inventory of landscape and habitat factors on the entire Tongue River Drainage using multi-layer remote sensing Geographic Information System (GIS) computer models. The University of Wyoming also conducted a Master of Science (M.S.) graduate level water quality project on the North Tongue River watershed and a Doctor of Philosophy (Ph.D) graduate level project to develop an ecosystem-based assessment of the North Tongue River fishery on the BHNF. Both these projects could provide information related to assessment of nonpoint source impairments within the Project area.

This task was completed as planned. See Section 8 for habitat assessment results and determination of relative riparian health at main stem Tongue River and tributary stations.

WGFD completed the GIS project for vegetation types and relative composition for each vegetation type. The GIS layer has been presented to SCCD.

The University of Wyoming M.S. thesis was completed by Felbeck (1999). The thesis evaluated potential sediment sources and estimated the percent sediment contribution from each source to the North Tongue River. The study was valuable in that it provided information to assist land managers and users to chart future management of the North Tongue River in the BHNF. SCCD analysis of the water quality data presented by Felbeck, although important at the scale of the North Tongue River watershed, was not directly applicable to the Tongue River within the SCCD

Project area located several miles downstream of Felbeck's study area. It appeared that water quality observed in the North Tongue River was greatly transformed as it flowed downstream to the SCCD Project area (starting at the BHNF boundary in the Tongue River canyon). The transformation in water quality appeared to be due to the influence of South Tongue River and other tributary water entering the Tongue River within the BHNF. Once the Tongue River entered the upper Tongue River canyon and flowed approximately eight (8) stream miles through the isolated canyon, water quality appeared to improve since natural stream cleansing processes were allowed to function because anthropogenic, potential negative land use influence and significant pollutant sources were absent. Water quality in the Tongue River as it exited the lower canyon may be characterized as good to excellent (See Section 9.1). Thus, the Felbeck (1999) data set was not included in this Final Report because of the observed transformation in water quality to the SCCD Project area. The Ph.D level thesis has not been completed to date of this Final Report.

2.3 GOAL 3

Was to develop a Watershed Plan to address identified nonpoint source pollution concerns within the Tongue River project area.

The Tongue River Watershed Management Plan was completed as planned (see SCCD, 2000).

2.3.1 OBJECTIVE 3

Was to develop a prioritized list of cost-effective management and structural practices.

This objective was completed in the Tongue River Watershed Management Plan (see SCCD, 2000).

2.3.1.1 TASK 6

Was to interpret data and identify concerns/opportunities to improve the watershed.

This task was completed as planned. See Section 8 and Section 9 in this Final Report and the Tongue River Watershed Management Plan (SCCD, 2000).

2.3.1.2 TASK 7

Was to develop a Watershed Plan to address high priority areas of concern that may require additional efforts to remediate identified water quality problems. The Watershed Plan would provide discussion for the implementation of future projects requiring additional technical and financial assistance to address concerns identified through this 205(j) watershed assessment.

Typical improvements may include irrigation improvements, relocation of livestock facilities, filter strips, improved grazing management in riparian areas, streambank stabilization, and nutrient/pesticide management. Other Best Management Practices (BMP's) would be identified to address resource concerns.

This task was completed and is addressed in the Tongue River Watershed Management Plan (see SCCD, 2000).

3 DESCRIPTION OF PROJECT AREA

3.1 TONGUE RIVER AND MAJOR TRIBUTARIES

3.1.1 TONGUE RIVER

The Tongue River forms at the junction of the North Tongue River and the South Tongue River in the Big Horn Mountains. The North Tongue River and the South Tongue River are WDEQ Class 1 water bodies (WDEQ, 1998). This classification indicated that these streams were among the highest quality water bodies in Wyoming and no further water quality degradation by point source discharges other than from dams would be allowed (WDEQ, 1998). The WDEQ stream classification changes to Class 2 after the confluence of the North and South Tongue Rivers. The river flows east where it enters the steep walled Tongue River Canyon. Access to the river in the canyon segment is limited to a pack trail and recreation is the primary land use. It is in this reach downstream to near the lower canyon mouth that was classified by WGFD as a Class 1 trout fishery (WGFD, 1991). It is near the mouth of the canyon where the SCCD Project begins; the Project area extends from near the BHNF boundary in the canyon downstream to the Town of Ranchester.

An instream flow water right was issued for this reach by the State of Wyoming Engineers office in 1990. This was only the third stream in Wyoming at that time approved for an instream flow water right. The instream flow right is for 60 cubic feet per second (cfs) from July through March, 80 cfs in April and 180 cfs during May and June. There are no dams on the mainstem Tongue River from its headwaters to the Wyoming state line where it enters the state of Montana. The Tongue River Reservoir is sited in Montana near the Wyoming state line and provides excellent recreational opportunities and a warm water fishery of regional importance.

The Hydrologic Unit Code (HUC) for the Tongue River and each major tributary in the Project area is 10090100. Predominant geology in the canyon section is plutonic rocks, quartz diorite to quartz monzonite (USGS, 1985) indicating low erosive potential. The river has been classified as a Reference Stream reach by WDEQ indicating that this reach has been minimally affected by human activity (Hughes, 1995). As such, the upper reach in the canyon serves as a suitable reference or control site for comparison to downstream Tongue River sites because the Reference classification exhibits water quality and biological conditions most natural and attainable for streams in this foothills region of Wyoming (EPA, 1996).

After the river exits the canyon, it enters a transition zone from the Big Horn Mountain foothills to the Great Plains. The river transforms from a higher gradient and confined “B” type channel in the canyon to a lower gradient, meandering “C” type channel in the plains (Rosgen 1996). Moreover, the river exits the Middle Rockies Ecoregion and enters the Great Plains Ecoregion (Omernik and Gallant, 1987). Because ecoregions are regions of relative homogeneity (similar to one another) with respect to ecological systems (Hughes, 1995), the change from one ecoregion to another indicated that normal changes in environmental, ecological and water quality characteristics were expected along the longitudinal gradient of the Tongue River.

The predominant geology in the plains is alluvium and colluvium comprised of clay, silt, sand and gravel present in flood plains, fans, terraces and slopes (USGS, 1985). The meandering character of the river combined with these geological characteristics provide naturally greater potential for clay and silt introduction and deposition in the river. Because of the greater natural potential of siltation in the river, it is even more important for land users to practice wise soil and irrigation conservation practices and employ Best Management Practices (BMP’S) where appropriate. Disruption of the river channel by channelization and stream bank modification may drastically alter hydrologic, physical and biological (e.g. fishery) processes.

Soils in the Tongue River canyon area are dominated by the Tolman-Cloud Peak-Stanley association indicating shallow, moderately deep and very deep soils and areas of rock outcrop present in mountainous areas (NRCS, 1998). Soil type from the canyon to near the Town of Dayton is dominated by the Trimad-Trivar-Abac association characterized by shallow and very deep soils on hills, terraces and alluvial fans adjacent to mountainous areas. The soil type changes to the Worfka-Samday-Parmleed association from near Dayton to the Town of Ranchester. This association is also characterized by shallow and very deep soils on hills, terraces and alluvial fans adjacent to mountainous areas.

There are no impoundments on the main stem Tongue River. There are no diversions from the Tongue River prior to the lower canyon mouth. Water is first diverted from the Tongue River at the Highline Ditch just upstream of USGS gage station 06298000. Other significant diversions downstream include the South Side located near the XL Ranch and the Tongue River No. 1 located about ½ mile upstream of the Town of Dayton. The Hanover Ditch is another large diversion located near the Highway 14/16 bridge in Dayton. The Hanover Ditch later splits into the OZ Ditch and Mikado Ditch. The York Ditch is present downstream of Dayton in the vicinity of the Dayton Wastewater Treatment Facility. Water in the main stem Tongue River is not over appropriated whereas some of the primary tributaries within the Project area are over appropriated. The dominant use for Tongue River water is for agricultural use. Municipalities use a proportionately small amount of water when compared to agricultural diversions. The Town of Dayton normally uses an average of about 152,000 gallons per day (gpd) or 0.235 cubic feet per second (cfs) per day with peak usage of about 470,000 gpd or 0.727 cfs per day during summer months (WWDC, 2000). The Town of Ranchester uses an average of about 203,000 gpd or 0.314 cfs per day with peak usage of about 684,000 gpd or 1.058 cfs per day during summer months (WWDC, 2000).

Significant irrigation return enters the Tongue River downstream of the Town of Ranchester outside the Project area. Certain tributaries entering the Tongue River within the Project area were believed to contain flow consisting primarily of irrigation return water during the irrigation season from about May into September.

Primary land use in the lower canyon area is wildlife habitat and recreation with private summer and year around residences located intermittently along it's length. After exiting the canyon, primary land use changes to irrigated hayland, dryland pasture, wildlife habitat, livestock grazing, recreation and limited gravel and sand mining. A change to urban land use occurs as the river enters the Town of Dayton, then reverts back to agricultural related land use and wildlife habitat as the Tongue River flows downstream. The Dayton Wastewater Treatment Facility discharges treated effluent directly to the Tongue River about one to two miles downstream of Dayton. Agricultural land use and wildlife habitat dominates the mainstem Tongue River until it enters the Town of Ranchester which marks the lower end of the Project area. Land use in Ranchester is urban, recreation and wildlife habitat.

3.1.2 LITTLE TONGUE RIVER

The headwaters for the Little Tongue River are in the BHNF near Black Mountain at an elevation of about 8,200 feet. The stream disappears underground as it traverses the face of the mountain in the vicinity of a rock slide called the Fallen City. The stream surfaces in the lower foothills on the Horseshoe Ranch which is located within the Project area. Dye studies suggest a portion of underground stream flow discharges in the Tongue River Canyon to the north.

The WDEQ 1996 Wyoming Water Quality Assessment listed the Little Tongue River as partially supporting aquatic life use (WDEQ, 1996). The causes believed to be responsible for this finding were listed as siltation and flow alteration based on information provided by WDEQ. The source for siltation was reported as pasture land and flow alteration was due to low stream discharge possibly related to water diversion for irrigation.

The stream is a 4^{th} order water body (Strahler, 1957) and drains an area of about 26.2 square miles up to its confluence with the Tongue River in the Town of Dayton. The predominant geology of the watershed within the Project area is Bearpaw shale comprised of dark greenish-gray shale containing thin gray sandstone partings (USGS, 1985). The entire stream is placed in the Middle Rockies Ecoregion although the lower reaches near the Town of Dayton approach the Northwestern Great Plains (Omernik and Gallant, 1987). WGFD has classified the Little Tongue River within the project area as a Class 4 trout fishery. This indicated the stream was a low production trout water, a fishery frequently of local importance, but generally incapable of sustaining substantial fishing pressure (WGFD, 1991).

Soils in the upper Little Tongue River watershed are dominated by the Tolman-Cloud

Peak-Stanley association indicating shallow, moderately deep and very deep soils and areas of rock outcrop present in mountainous areas (NRCS, 1998). The remainder of the watershed downstream to the Town of Dayton is dominated by the Trimad-Trivar-Abac association characterized by shallow and very deep soils on hills, terraces and alluvial fans adjacent to mountainous areas.

There are no dams on the main stem of the Little Tongue River although flows are diverted for use primarily by a golf course and for agricultural use. The Frisbee Ditch may divert up to 12 cubic feet per second during periods of spring runoff. Primary landuse in the upper drainage within the project area is recreational (golf course), irrigated hayland, wildlife habitat and limited livestock grazing. Landuse in the middle portion of the drainage include irrigated hayland, pasture land, wildlife habitat, recreation and livestock grazing. Landuse in the lower drainage in Dayton is primarily urban. Considerable channelization (straightening) of the stream bank has occurred in Dayton.

3.1.3 SMITH CREEK

The headwaters for Smith Creek are found in the BHNF at about 7,600 feet. This is the smallest tributary to the Tongue River within the Project area with a drainage area of about 11.6 square miles at the confluence with the Tongue River in the Town of Dayton.

The WDEQ 1996 Wyoming Water Quality Assessment listed Smith Creek as non supporting for drinking water use due to pathogens (based on fecal coliform bacteria sampling), siltation, nutrients and habitat alteration. The sources for these impairments were reported as pasture land, streambank alteration and removal of riparian vegetation. The source of information leading to this finding was WDEQ. WDEQ apparently identified water quality impairments at a confined animal feeding operation in response to a citizen complaint.

The stream is a 3rd order water body (Strahler, 1957) and is a Class 2 coldwater stream (WDEQ, 1998). The predominant geology in the upper Portion of the watershed within the Project area is Madison limestone comprised of blue-gray, massive limestone and dolomite underlain by gray cherty limestone and dolomite (USGS, 1985). The preponderance of limestone in the drainage should naturally result in higher stream pH and Total Dissolved Solids (TDS). The lower portion of the drainage near the confluence with the Tongue River is Bearpaw shale comprised of dark greenish-gray shale containing thin gray sandstone partings (USGS, 1985). The upper segment of the stream is placed in the Middle Rockies ecoregion while the lower reach near the Town of Dayton approaches the Northwestern Great Plains ecoregion (Omernik and Gallant, 1987). WGFD classified Smith Creek as a Class 5 trout fishery within the Project area. This indicated the stream was very low production trout water, often incapable of sustaining a trout fishery (WGFD, 1991).

Soils in the upper Smith Creek watershed downstream to near County Road 116 are dominated by the Tolman-Cloud Peak-Stanley association indicating shallow, moderately deep and very deep soils and areas of rock outcrop present in mountainous areas (NRCS, 1998). Soil type downstream to about two miles upstream from the Town of Dayton is dominated by the Trimad-Trivar-Abac association characterized by shallow and very deep soils on hills, terraces and alluvial fans adjacent to mountainous areas. The soil type then changes to the Norbert-Savage-Savar association downstream to Dayton. This association is also characterized by shallow and very deep soils on hills, terraces and alluvial fans adjacent to mountainous areas.

There are no major impoundments on the main stem of Smith Creek although stream discharge is highly regulated by diversions for primarily agricultural use. The Powers Pipeline, Mock No. 2, Scott Pipeline-Huntington & Smith, Owens No. 1 and the Davis Supply Ditch are primary Smith Creek irrigation water conduits serving irrigators (WSBC, 1998). Stream surveys published by the WGFD in 1958 stated that the lower portion of Smith Creek was unsuitable for game fish due to low flows caused by irrigations diversions (WGFD, 1958). The report added that trout habitat and trout spawning facilities were good on the Glenn Mock Ranch (in the upper watershed) while fish food production was poor.

Primary landuse in the upper Smith Creek drainage within the Project area are wildlife habitat, recreation, limited seasonal livestock grazing, limited irrigated hayland, and pasture land. A Confined Animal Feeding Operation (CAFO) was relocated off Smith Creek in the mid to latter 1990's to the White Tail drainage south of Smith Creek. Rural subdivision development is present in the middle portion of the watershed. Other land use in the middle portion of the drainage include irrigated hayland, wildlife habitat, dry land pasture and livestock grazing. Landuse in the lower drainage is agricultural, wildlife habitat, recreation and urban in the Town of Dayton. Considerable channelization (straightening) of the stream bank has occurred in Dayton.

3.1.4 COLUMBUS CREEK

Columbus Creek heads in the BHNF at an elevation of about 7,900 feet. It is the second largest tributary to the Tongue River within the Project area with a drainage area of about 17.9 square miles near it’s confluence with the Tongue River near Halfway Lane (located about halfway between the Town of Dayton and the Town of Ranchester).

Columbus Creek was not listed by WDEQ as water quality impaired although citizen complaints have been reported in the vicinity of a CAFO located upstream of Highway 14.

The stream is a 3rd order water body (Strahler, 1957) and is a Class 2 cold water stream (WDEQ, 1998). The predominant geology in the upper portion of the watershed within the Project area is Madison limestone comprised of blue-gray, massive limestone and dolomite underlain by gray cherty limestone and dolomite (USGS, 1985). The lower portion of the drainage near the confluence with the Tongue River is the Fort Union Formation, Tullock Member comprised of soft gray sandstone, gray and brown carbonaceous shale and thin coal beds. The upper segment of the stream is placed in the Middle Rockies Ecoregion foothills while the lower reach is in the Northwestern Great Plains Ecoregion (Omernik and Gallant, 1987). WGFD classified Columbus Creek as a Class 3 trout fishery within the Project area. This indicated the stream was an important trout water and fishery of regional importance (WGFD, 1991).

Soils in the upper Columbus Creek watershed within the Project area downstream to near the County Road 140 crossing are dominated by the Tolman-Cloud Peak-Stanley association indicating shallow, moderately deep and very deep soils and areas of rock outcrop present in mountainous areas (NRCS, 1998). Soil type then changes a short distance downstream to the Trimad-Trivar-Abac association characterized by shallow and very deep soils on hills, terraces and alluvial fans adjacent to mountainous areas. The soil type again changes to the Norbert-Savage-Savar association, similar in characterization to the Trimad-Trivar-Abac association. Soil type then shifts to the Worfka-Samday-Parmleed association and then again to the Haverdad-Zigweid-Nuncho association near the Highway 14 crossing. The Haverdad-Zigweid-Nuncho association was also identified in the lower Wolf Creek flood plain and was characterized by very deep soils on flood plains, low terraces, and alluvial fans (NRCS, 1998). This soil type indicated the presence of increased amounts of soil available for transport to the water column during high discharge periods or riparian and channel disturbance.

There are no major impoundments on the mainstem of Columbus Creek although the stream is highly regulated because nearly all stream discharge flow may be diverted during the irrigation season for agricultural use. Water is diverted from Columbus Creek into the Five Mile Ditch. An average 3,260 acre feet of water are diverted to Five Mile Ditch annually based on records maintained by the Wyoming State Board of Control from 1989 to 1998. Consequently, discharge in lower Columbus Creek during the latter portion of the irrigation season is greatly reduced and believed to be comprised primarily by irrigation return or groundwater recharge from upstream irrigated hayfields. Stream surveys conducted by WGFD in 1958 stated that the lower portion of Columbus Creek from Mock's Ranch to the mouth was not suitable for trout as a large irrigation reservoir on the Bear Claw Ranch and irrigation diversions deplete the stream flow (WGFD, 1958). The report added that the upper section of the stream (probably in the foothills) had adequate fish shelter and fish food production was good. Trout spawning facilities were very good.

Primary landuse in the upper drainage within the Project area is livestock grazing, wildlife habitat, limited seasonal livestock grazing and recreation. Landuse in the middle and lower portions of the drainage include livestock grazing, irrigated hayland, confined feeding operation, pasture land, limited irrigated crop land, wildlife habitat and recreation.

3.1.5 WOLF CREEK

The headwaters for Wolf Creek are in the BHNF at an elevation of about 8,800 feet. This is the largest tributary to the Tongue River within the Project area with a drainage area of about 72.4 square miles near its confluence with the Tongue River near the Town of Ranchester.

Wolf Creek was not listed as water quality impaired by WDEQ although complaints related to livestock feeding operations have been received. The stream is a 4th order water body (Strahler, 1957) and is a Class 2 coldwater stream throughout its length (WDEQ, 1998). The predominant geology in the upper portion of the watershed within the Project area is a mixture of the Fort Union Formation and Tullock Member comprised of soft gray sandstone, gray and brown carbonaceous shale and thin coal beds and alluvium and colluvium comprised of clay, silt, sand and gravel in flood plains, fans and terraces and slopes. Geology in the lower portion of the drainage near the confluence with the Tongue River is undivided surficial deposits of mostly alluvium, colluvium, and glacial landslide deposits (USGS, 1985). The upper portions of the stream are placed in the Middle Rockies Ecoregion while the lower reaches near the Town of Ranchester are in the Northwestern Great Plains Ecoregion (Omernik and Gallant 1987). WGFD classified Wolf Creek as a Class 3 trout fishery within the Project area. This indicated the stream was an important trout water and fisheries of regional importance (WGFD, 1991).

Soils in the upper watershed near the Project boundary downstream to just below the Soldier Creek Road are dominated by the Tolman-Cloud Peak-Stanley association indicating shallow, moderately deep and very deep soils and areas of rock outcrop present in mountainous areas (NRCS, 1998). Soil type downstream to the Town of Ranchester is dominated by the Bidman-Parmleed-Shingle association characterized by shallow and very deep soils on hills, terraces and alluvial fans adjacent to mountainous areas. Within the lower half of Wolf Creek is a relatively narrow band soil type within the immediate flood plain identified as the Haverdad-Zigweid-Nuncho association. This soil type is characterized by very deep soils on flood plains, low terraces, and alluvial fans (NRCS, 1998).

There are no major impoundments on the mainstem of Wolf Creek although stream flows are highly regulated by diversion primarily for agricultural use. Several irrigation supply ditches are routinely monitored by WSBC because Wolf Creek is over appropriated (water rights exceed the total amount of water in Wolf Creek). Major ditches monitored by WSBC include Hardin & Campbell, West Wolf, East Wolf, Nichols & Oberich, Shields, Dye & Shields, Gibbons, Old Reliable, Garrard, Decker and Grinnell (WSBC, 2000). One landowner has apparently elected to leave a portion of appropriated water in Wolf Creek to enhance fisheries.

Stream surveys published by the WGFD in 1958 stated that Wolf Creek had fair spawning facilities toward the mouth (near the confluence with the Tongue River) and excellent spawning areas near the canyon section (near the upper boundary of Wolf Creek within the Project area).

Primary landuse in the upper Wolf Creek drainage within the Project area include wildlife habitat, recreation and limited livestock grazing. Primary landuse in the middle and lower portions of the watershed include irrigated hayland, pasture land, some year around livestock grazing, wildlife habitat and recreation. Urban landuse is evident near the Town of Ranchester.

3.1.6. FIVE MILE CREEK

Five Mile Creek although termed a Creek, is primarily a conduit to deliver irrigation water for agricultural landuse. The Creek receives the majority of flow from diversion of Columbus Creek via the Five Mile Ditch. A few springs exist in the drainage, but they would not provide sufficient discharge to allow maximum agricultural development without diversion from Columbus Creek. The first water rights appropriated for the Five Mile Ditch date back to August 16, 1882 when several individuals and a company were granted rights. Water diverted from Columbus Creek is stored in irrigation reservoirs for release during the irrigation season.

The headwaters for Five Mile Creek are difficult to identify, but appear to consist of a single spring or series of springs. The entire drainage is contained within the Project area and consists of about 15.2 square miles up at the confluence with the Tongue River in the Town of Ranchester.

Five Mile Creek was not listed as water quality impaired by WDEQ. The stream is a 4^{th} order water body (Strahler, 1957) and was not classified by WDEQ (WDEQ, 1998). Although not classified, Five Mile Creek assumes the classification of the Tongue River (Class 2 cold water) due to the "tributary rule". The tributary rule states that "...any unlisted water shall have the same classification as the first listed water to which it is a tributary" (i.e. Tongue River) (WDEQ, 1998).

The predominant geology in the drainage is the Fort Union Formation, Lebo Member comprised of dark-gray clay shale and concretionary sandstone (USGS 1985). The entire watershed is placed in the Northwestern Great Plains Ecoregion (Omernik and Gallant, 1987). WGFD classified Five Mile Creek as a Class 5 trout fishery. This indicated the stream was very low production trout water, often incapable of sustaining a trout fishery (WGFD, 1991).

Soils in the upper Five Mile Creek watershed are dominated by the Norbert-Savage-Savar association characterized by shallow and very deep soils on hills, terraces and alluvial fans adjacent to mountains. Soil type then shifts to the Worfka-Samday-Parmleed association and then again to the Haverdad-Zigweid-Nuncho association near the Town of Ranchester. The Haverdad-Zigweid-Nuncho association was also identified in the lower Wolf Creek area and lower Columbus Creek drainage. This soil type is characterized by very deep soils on flood plains, low terraces, and alluvial fans (NRCS, 1998) and indicated the presence of increased amounts of soil available for transport to the water column during high discharge periods and riparian and channel disturbance.
There were two impoundments significantly influencing Five Mile Creek. One impoundment in

Wagner Draw receives and stores water diverted from Columbus Creek for use during the irrigation season. Located downstream is Five Mile Creek Reservoir, the largest impoundment on Five Mile Creek. It also functions to store water for irrigation use. The irrigation season may begin as early as May and continue through August and into mid-September. Primary landuse in the Five Mile Creek drainage is irrigated hayland, cropland, pasture land, livestock grazing and wildlife habitat although urban and recreational land use occur in the lower reach in the Town of Ranchester.

3.2 LAND USES

The land surface within the Project area is approximately 80,000 acres with about 8 percent in state ownership, including the Amsden Creek Big Game Winter range administered by WGFD. The remaining 92 percent is privately owned.

The land use in the BHNF in which the Tongue River and all tributaries originate, with the exception of Five Mile Creek, include recreation, wildlife habitat, logging and seasonal livestock grazing. Land use within the Project area as indicated in Section 3.1 is diverse and dominated by irrigated cropland, irrigated hayland, dryland pasture, livestock grazing, recreation and wildlife habitat. Urbanization occurs in the Towns of Dayton and Ranchester. A golf course, emerging rural subdivisions, significant tourist/recreation industry and limited sand and gravel mining operations are additional land uses. The area provides outstanding year-round habitat for small and big game, furbearers, waterfowl, game birds and songbirds. Prime wildlife habitat is concentrated along stream bottoms and brushy draws where riparian zones were intact.

The mainstem Tongue River and major tributaries contain numerous small to very large ranches. Status for domestic wastewater treatment at ranches and rural subdivisions was unknown. Agriculture related land use dominates. Agricultural operations center around cattle and hay production enhanced by irrigation water from the Tongue River and tributaries during the summer growing season. There are approximately 12,000 acres of irrigated hay and crop land in the Project area with approximately one-third to one-half operating at low efficiencies. Livestock tend to be fed and wintered along the creek bottoms since these areas provide the necessary shelter and water.

3.3 POINT SOURCE DISCHARGES

There are three permitted facilities with point source discharges in the Project area. Each has a National Pollutant Discharge Elimination System (NPDES) permit issued through WDEQ. Two of the permits are issued to feedlots which have historically generated water quality complaints.

A. The Padlock Ranch feedlot (Permit Number WY-0022462) is located adjacent to

Columbus Creek in the lower watershed about 1 to 2 miles upstream of Highway 14. It has a capacity of around 9,000 animals and has been in operation for several years. The NPDES permit for the feedlot allows no discharge except during chronic or catastrophic storm events which may cause an overflow of wastewater storage lagoons or in the event of precipitation or snowmelt runoff events which exceed the 25 year, 24 hour event. The permit allows the operator to remove wastewater from storage treatment lagoons for use by spray irrigation onto adjacent fields. Should the facility discharge, the operator is required to immediately notify WDEQ.

B. The Bear Claw Cattle Company feedlot (NPDES Permit Number WY-0035831) was relocated in 1995 and 1996 from Smith Creek south to the Whitetail Creek drainage. A complaint to WDEQ in the mid 1990's led to the relocation of the feedlot to the White Tail Creek watershed. The feedlot site on Smith Creek was remediated. The permit indicated that the feedlot has a capacity of about 400 head per year. The NPDES permit allows no discharge except during chronic or catastrophic storm events cause an overflow from facilities designed, constructed and operated to contain all process generated waste waters plus the runoff from a 25 year - 24 hour precipitation event (3.3 inches). The facility is required to immediately notify WDEQ in the event of a discharge.

C. The last NPDES permitted facility in the project area is the Town of Dayton Wastewater Treatment Facility (WWTF) (Permit Number WY-0020435). The WWTF treats wastewater from the Town of Dayton. The system consists of a two cell aerated lagoon with ultraviolet light disinfection before discharging directly to the mainstem Tongue River. There is also a second discharge point consisting of groundwater from the WWTF french drain system. The WWTF received funding to significantly upgrade the treatment system around 1986 and 1987. Further WWTF upgrade and repair of lagoon liners occurred in 1998.

4 STREAM CLASSIFICATION AND STANDARDS

4.1 STREAM CLASSIFICATIONS

The Tongue River, Little Tongue River, Smith Creek, Columbus Creek, and Wolf Creek within the Project area are Class 2 cold water streams (WDEQ,1998; Chapter 1, Water Quality Rules and Regulations). Five Mile Creek was not classified. However, it is a Class 2 coldwater stream as indicated in Section 3.1.6. The Class 2 designation indicated these water bodies were:

1. Presently supporting game fish; or

2. Have the hydrologic and natural water quality potential to support game fish; or

3. Include nursery areas or food sources for game fish.

4.2 BENEFICIAL USES

The Tongue River and tributaries are Class 2 water bodies. As Class 2 water bodies, all Wyoming beneficial uses apply to each including:

1. Agriculture;
2. Protection and propagation of fish and wildlife;
3. Industry;
4. Human Consumption;
5. Recreation; and
6. Scenic Value

In addition, EPA requires states to report on beneficial use attainment for Aquatic Life.

4.3 WATER QUALITY STANDARDS

Wyoming surface waters designated as Class 2 water bodies are protected through application of narrative (descriptive) and numeric water quality standards described in WDEQ Water Quality Rules and Regulations, Chapter 1 (WDEQ, 1998). All Aquatic Life use and Human Health water quality criteria found in Appendix B of Chapter 1 apply. WDEQ (2000) proposed revisions to water quality rules and regulation as part of the required triennial review after initiation of this Project in 1996. It was uncertain how the revised rules and regulations may affect findings contained in this Final Report because they have not been finalized.

Table 4-1 lists water quality parameters, reference for the water quality standard and a brief description of the narrative or numeric water quality standard applicable to the parameter. Standards for eighty-seven (87) organic priority pollutants and fifteen (15) organic non-priority pollutants are referenced as a group in Table 4-1, but are not listed individually. These organic pollutants include numerous pesticides, herbicides, solvents and other compounds. Please see Appendix B in WDEQ Water Quality Rules and Regulations, Chapter 1 (WDEQ, 1998) for the specific organic pollutant and associated standard.

Included in Table 4-1 are lists of additional chemical, biological and habitat parameters for which there are no established Wyoming surface water quality numeric standards. These parameters were included since they provided additional information for use in determining attainment of beneficial uses applicable to the water bodies within the Project area. Recommended referenced standards are provided for each. These parameters and rationale for their use in the Project monitoring plan are discussed in detail in Section 6.0.

TABLE 4-1. Numeric and Narrative Quality Standards for Wyoming Surface Waters Applicable for Class 2 Waters in the Tongue River 205(j) Project Area (From WDEQ, 1998)

NUMERIC STANDARDS		
Parameter	**Reference**	**Standard / Description**
Antimony	Section 18; Appendix B	Human Health: 14 ug/l
Arsenic	Section 18; Appendix B	Human Health: .018 ug/l; Acute Aquatic Life: 360 ug/l
Asbestos	Section 18; Appendix B	Human Health: 30000 fibers/L
Beryllium	Section 18; Appendix B	Human Health: .0077 ug/l
Cadmium	Section 18; Appendix B	Human Health: 10 ug/l; Acute Aquatic Life: 3.9 ug/l (calculated)
Chromium (III)	Section 18; Appendix B	Human Health: 50 ug/l; Acute Aquatic Life: 1700 ug/l (calculated)
Chromium (VI)	Section 18; Appendix B	Human Health: 50 ug/l; Acute Aquatic Life: 16 ug/l
Copper	Section 18; Appendix B	Human Health: 1000 ug/l; Acute Aquatic Life: 18 ug/l (calculated)
Total Cyanide	Section 18; Appendix B	Human Health: 200 ug/l; Acute Aquatic Life: 22 ug/l
Lead	Section 18; Appendix B	Human Health: 50 ug/l; Acute Aquatic Life: 82 ug/l (calculated)
Mercury	Section 18; Appendix B	Human Health: .144 ug/l; Acute Aquatic Life: 2.4 ug/l
Nickel	Section 18; Appendix B	Human Health: 610 ug/l; Acute Aquatic Life: 1400 ug/l (calculated)
Selenium	Section 18; Appendix B	Human Health: 10 ug/l; Acute Aquatic Life: 20 ug/l
Silver	Section 18; Appendix B	Human Health: 50 ug/l; Acute Aquatic Life: 4.1 ug/l (calculated)
Thallium	Section 18; Appendix B	Human Health: 13 ug/l
Zinc	Section 18; Appendix B	Human Health: 5000 ug/l; Acute Aquatic Life: 120 ug/l (calculated)
Aluminum (pH 6.5-9.0)	Section 18; Appendix B	Acute Aquatic Life: 750 ug/l
Ammonia	Sections 18 and 21	See Appendix C (WDEQ, 1998)

TABLE 4-1. (Con't)

Barium	Section 18; Appendix B	Human Health: 1000 ug/l
Chloride	Section 18; Appendix B	Acute Aquatic Life: 860000 ug/l
Chlorine	Section 18; Appendix B	Acute Aquatic Life: 19 ug/l
Dissolved Gases	Sections 18 and 30; Appendix B	Chronic Aquatic Life: 100%; Section 30: 110% saturation below man-made dams
Dissolved Oxygen	Sections 18 and 30	Appendix D: 5.0 mg/l for fish early life; 4.0 mg/l other life stages
Fecal Coliform	Section 27	200 groups / 100ml (Recreation Season, 5 samples w/in 30 days); 400 groups / 100ml in 10 percent of samples
Iron	Section 18; Appendix B	Acute Aquatic Life: 19 ug/l
Manganese	Section 18; Appendix B	Human Health: 50 ug/l
Nitrates (as N)	Section 18; Appendix B	Human Health: 1000 ug/l
Oil and Grease	Section 29	10 mg/l; no sheen or visible deposits allowed
pH	Sections 18 and 26; Appendix B	Chronic Aquatic Life: 6.5-9.0 standard units
Sulfide (S^{2-}, HS^{-})	Section 18; Appendix B	Chronic Aquatic Life: 2 ug/l
Radium 226	Section 22	60 pCi/l
Temperature	Section 25	No change greater than 2 degrees F (1.1 degrees C); Maximum temperature considered to be 78 degrees F (25.6 degrees C)
Turbidity	Section 23	No increase greater than 10 NTU due to discharge of substances
Organics, priority	Section 18	Human Health and Aquatic Life, Appendix B: Standards for 87 organic priority pollutants are listed
Organics, non-priority	Section 18	Human Health and Aquatic Life, Appendix B: Standards for 15 organic non-priority pollutants are listed

TABLE 4-1. (Con't)

NARRATIVE STANDARDS		
Parameter	**Reference**	**Standard / Description**
Settleable Solids	Section 15	Shall not be present to degrade aquatic life habitat or adversely affect other water uses
Floating and Suspended Solids	Section 16	Shall not be present to degrade aquatic life habitat or adversely affect other water uses
Taste, Odor, Color	Section 17	Shall not contain substances that produce taste, odor and color in fish, skin, clothing vessels, structures, water supplies
Macroinver-tebrates	Barbour et al. (1994); Stribling et al. (2000); Section 32 (proposed, WDEQ (2000)	Barbour et al. (1994): WBCI total score ≥35 Middle Rockies; Stribling et al. (2000): WSII Middle Rockies: Score <70 based on 25th percentile of reference; WSII NW Great Plains: Score <57 based on 25th percentile of reference; WDEQ (2000) proposed narrative biological criteria
ADDITIONAL PARAMETERS AND RECOMMENDED STANDARDS		
Total Phosphorus	EPA (1977); USGS (1999)	EPA: Should not exceed 0.05 mg/L for a stream entering a lake or reservoir (i.e. Tongue River Reservoir); USGS: National background level in undisturbed watersheds is 0.10 mg/l
Sulfate	WDEQ (1993)	Groundwater: 200 mg/L agriculture; 250 mg/L drinking water; 3000 mg/L livestock; 250 mg/L EPA secondary drinking water
Alkalinity	EPA (1986)	Minimum 20 mg/L
Total Suspended Solids (TSS)	None	No recommended standard for use attainability.
Hardness	Sawyer (1960) *in* EPA (1986)	Concentrations greater than 300 mg/L may be considered unsuitable for industrial use
Habitat	King (1993); Stribling et al. (2000)	Habitat condition no less than 50 percent of reference; total habitat score >100 to qualify as reference

5 HISTORIC AND CURRENT DATA SOURCES

5.1 HISTORICAL DATA AND DATA SOURCES

Collection, compilation and evaluation of historical data provided a historical perspective for water quality within the Project area. Historical data played an important role in the development of an effective monitoring and assessment plan. Historical data was used to develop a cost-effective monitoring plan by providing information to:

1. Identify gaps in previous monitoring, sampling parameters, sampling frequency and sampling locations;

2. Select representative sampling stations;

3. Select proper sampling parameters;

4. Allow comparison of current data collected during the Project to historic data; and

5. Assist development of post-project monitoring recommendations.

Historical data for purposes of this project were defined as data that were greater than five years old from the start of this Project. Because the Tongue River Watershed Assessment Project was initiated in 1996, data collected before 1991 was considered historic data.

The following sources were contacted for historical data within the Project area:

1. Wyoming Department of Environmental Quality (WDEQ)
2. United States Geological Survey (USGS)
3. Wyoming Game and Fish Department (WGFD)
4. City of Dayton Public Works Department (DPWD)
5. City of Ranchester Public Works Department (RPWD)
6. United States Environmental Protection Agency (STORET) database
7. Natural Resources Conservation Service (NRCS)
8. Wyoming State Engineers Office, Wyoming State Board of Control (WSBC)
9. Wyoming Water Resources Database (WWR)
10. United States Forest Service (USFS)

Table 5-1 lists historic sampling stations, the name of the sample station, agency conducting data collection, data type and other descriptive information. Table 5-2 described the acronyms used in Table 5-1 and Table 5-3. Figure 5-1 shows the general location of the historical sampling stations within the Project area. Appendices A, C, E, J and K contain the historical data.

5.2 EVALUATION OF HISTORICAL DATA

Historic environmental data was obtained from several sources. When possible, files and publications were obtained directly from the agency responsible for data collection to secure original or first-hand data sets. Some data files obtained by SCCD were found to be corrupt and could not be used with confidence. For example, some data presented in the University of Wyoming Water Resources Database (WWR) were problematic. One consistent problem included mis-labeling of reporting units for WDEQ data collected after 1982 (i.e. Chloride and sulfate values were reported as dissolved instead of total as actually collected). The reported location of several sampling stations appeared inaccurate both in the latitude-longitude and section, township, range. Data qualifiers were absent which could have improved the quality of the data base. The disclaimer at the beginning of the WWR data base should be closely read before using data. Because of these findings, SCCD used data from the WWR data base after data could be confirmed by comparison to original or first-hand data sets.

The USGS and EPA STORET data bases were determined to contain high quality data with minor (<.001 percent of all data evaluated) exceptions. The minor exceptions included omission of less than (<) or greater than (>) data qualifiers (in older data sets) when a value was greater than or less than the detection limit reported for the specific parameter. When identified, SCCD attached these qualifiers to the data after the analytical method was researched. Additionally, data reported as 0.00 were rejected for some reported USGS metal parameters when no qualifier was attached. Historic water quality data sets are presented in Appendix A of this Final Report.

Long-term monitoring stations within the Project area provided both historic and current data. USGS Station Number 06298000 recorded discharge data since about 1918. The NRCS Burgess Junction meteorological station Number WY07E33S collected precipitation and temperature data since at least 1982. The Town of Ranchester Water Treatment Plant has collected daily turbidity measurements at the Tongue River raw water intake since 1983, daily temperature and pH measurements since 1993 and daily alkalinity measurements since 1998.

5.3 CURRENT DATA COLLECTION BY OTHER INVESTIGATORS

USGS, WDEQ, WGFD, NRCS, RBPU and WSBC collected monitoring data within the Project area concurrent with SCCD (see Appendices A, B, C, D, F, I and J). This data provided a valuable source of information for use by SCCD to meet Project goals and objectives. Consequently, much of the data collected by these agencies will be referred to in upcoming Sections of this Final Report. The monitoring stations used for collection of current chemical, physical, biological and habitat data are presented in Table 5.3 and cross referenced to Figure 5-2. A brief description of current monitoring efforts by other agencies within the Project area is described herein.

5.3.1 USGS Data

USGS initiated the Upper Yellowstone Basin National Water Quality Assessment (NAWQA) study in 1998. The NAWQA study design placed one monitoring station at the Tongue River gage Station No. 06298000. This was the same station used by SCCD for monitoring during the Project. The station was identified by SCCD as Tongue River Upper. USGS collected whole body brown trout fish tissue organic samples (Appendix Table D-2), liver trace metals from brown trout (Appendix Table D-1), bed sediment trace metals (Appendix Table D-3) and bed sediment organics (Appendix Table D-4). Benthic macroinvertebrate samples were collected in 1999 (Appendix Table F-40 and Appendix Table G-3). Benthic macroinvertebrate sample results were considered PROVISIONAL at the time of this Final Report because data had not been finalized. SCCD adjusted the USGS macroinvertebrate data to the same taxonomic Level of Identification used by SCCD and WDEQ (see Section 6.5.4.1, Table 6-4). The taxonomic Level of Identification must be standardized to allow reliable comparison between data sets. For example, USGS reported the larvae, pupae and adults for *Optioservus* separately whereas SCCD and WDEQ combined larvae, pupae and adults into a single taxon. USGS water quality sampling was initiated in January, 1999 (Appendix Table B-26).

5.3.2 WDEQ Data

WDEQ established a long-term Reference station in the Tongue River canyon in 1993 (Site ID MRC 24). Water quality, benthic macroinvertebrates and habitat quality were sampled annually usually in late September or early October. Annual periphyton sampling was initiated in 1998, but results of sample analyses were not available for this Final Report. Because the Tongue River, Little Tongue River and Smith Creek were listed by WDEQ in 1996 as impaired water bodies, monitoring stations were established by WDEQ in 1996 at these and other water bodies within the Project area for annual assessment. Additional intensive sampling occurred in 1998 at Tongue River stations upstream and downstream of the Dayton WWTF. Five sample events occurred within a 30-day period in October and November, 1998.

SCCD and WDEQ coordinated placement of monitoring stations, sampling parameters, field and analytical methods, and sampling frequency to avoid duplication and ensure data would be comparable and usable by each. It should be noted that some duplication in effort was desired to establish comparability between results obtained by one monitoring group with results obtained by another monitoring group (see Section 7.6.5). Close coordination between SCCD and WDEQ allowed each to draw upon the expertise offered by one another. Data collected by WDEQ was presented in Appendices B, F, G and I. It should be noted that data collected by WDEQ in 1998 and 1999 were considered PROVISIONAL because it had not undergone Quality Assurance evaluation nor released prior to completion of this Final Report.

5.3.3 WGFD Data

WGFD collected current fish population data at stations on the Tongue River at the IXL Ranch in 1991, in Ranchester during 1993 and 1994, the Little Tongue River at the Little Tongue River Ranch in 1997 and Wolf Creek at Berry's in 1997. Results of current and historic fish sampling since 1959 comprised 34 individual data sets. Fishery data are presented in Appendix C. WGFD conducted historic continuous water temperature monitoring at the Tongue River canyon in 1988 and current continuous water temperature monitoring on the Tongue River at Ranchester in 1994. These data sets presented in Appendix E provided valuable insight into the thermal dynamics of the lower Tongue River reach during summer, low flow periods.

5.3.4 NRCS Data

NRCS collected daily precipitation and air temperature data at the Burgess Junction meteorological station WY07E33S since at least 1982. Although this station was located outside the Project area in the BHNF and upper Tongue River watershed, it provided excellent information for daily precipitation and temperature which together, could track the timing and magnitude for water yield within the Project area. The timing and magnitude of water yield may affect chemical, physical, biological and habitat characteristics of water bodies within the watershed. NRCS data is presented in Appendix J.

5.3.5 WSBC

WSBC, District II is responsible for tracking water quantity and water use information within the Tongue River drainage. WSBC records quantity of water at several irrigation diversions and ditches using a combination of calibrated recorders and flumes. The data collected by WSBC was not included in this Final Report, but may be accessed by reference to the Annual Hydrographers Report published by WSBC (see WSBC, 1998).

Water quantity diverted from the Tongue River was not regularly recorded by WSBC. Other than USGS gage station 06298000, the nearest continuous discharge recorder was operated by the Big Horn Coal Mine located about ½ to 3/4 mile downstream of the Interstate 90 bridge crossing. Water quantity was closely tracked by WSBC during the irrigation season (May through September) at Little Tongue River, Smith Creek, Wolf Creek and Five Mile Creek because these waters are near or above maximum appropriation.

5.2.6 RPWD

RPWD collected daily samples for temperature, pH, turbidity and alkalinity to provide information for the Town of Ranchester Water Treatment Plant operations. Samples were drawn directly from the raw water intake line prior to treatment generally between the hours of 0730 AM and 0900 AM. Daily turbidity samples have been measured since 1982 (Appendix Table A-19), daily water temperature (Appendix Table A-20) and pH (Appendix Table A-21) have been measured since 1993 and daily alkalinity has been measured since 1998 (Appendix Table A-22). It was rare to find a continuous quality long-term and well maintained water quality record such as this during the historic data search. The Town of Ranchester should be commended for their commitment to provide quality service to the residents of Ranchester.

SCCD contacted the Town of Dayton Water Treatment Plant to procure their daily operational water quality data record. The data could not be used for this Project because samples were drawn from a large submerged stilling basin and results were not representative of ambient Tongue River water.

TABLE 5-1. Site Descriptors for Monitoring Stations Providing Historic Data Greater Than (>) 5 Years Old Within the Tongue River 205j Project Area, Sheridan County, Wyoming (**Note**: See Table 5-2 for Description of Agency[a], Data Type[b] and Geology[c] Acronyms)

Descriptor	Tongue River	Tongue River	Tongue River	Tongue River
Station Name	5 Miles West of Dayton	Canyon Mouth	Campground @ USGS 6-2974.80	West of Dayton
Agency [a]	WGFD	WGFD	USFS	WWRC
Year(s)	1938	1959;69;79;89	1968-70;73;76	1976
Data Type Collected [b]	P	F	C;P;B	C;P
Figure 5-1 Station No.	1	1	1	2
Appendix Table	A-1	C-1,2,3,4	A-2	A-3
Hydrologic Unit Code	10090100	10090100	10090100	10090100
NRCS Small Watershed Code	000	000	000	000
USGS Quad Map	Dayton South	Dayton South	Dayton South	Dayton South
Ecoregion	Middle Rockies	Middle Rockies	Middle Rockies	Middle Rockies
Landform	Foothill	Foothill	Foothill	Foothill
DEQ Classification	2	2	2	2
Strahler Order	5	5	5	5
Drainage Area (mi^2)	Unknown	Unknown	Unknown	Unknown
Elevation (ft)	Unknown	Unknown	4210	Unknown
Section	10	10	10	11
Township	56	56	56	56
Range	87	87	87	87
Latitude	Unknown	Unknown	Unknown	Unknown
Longitude	Unknown	Unknown	Unknown	Unknown
Geology [c]	WVG	WVG	WVG	WVG
Dam Present?	No	No	No	No

TABLE 5-1. Con’t

Descriptor	Tongue River	Tongue River	Tongue River	Tongue River
Station Name	USGS #0629800	USGS #0629800	Dayton WTP Intake	Adamsons - Stations 4, 5, 5A
Agency [a]	USGS	USGS	WDEQ	WGFD
Year(s)	1975,76,77	1966 through 81;87,88	1983-90	1969;81
Data Type Collected [b]	PER	C;P	C;P;B	F
Figure 5-1 Station No.	2	2	3	4
Appendix Table	C-5	A-4	A-5	C-6 through 10
Hydrologic Unit Code	10090100	10090100	10090100	10090100
NRCS Small Watershed Code	000	000	000	000
USGS Quad Map	Dayton South	Dayton South	Dayton South	Dayton South
Ecoregion	Middle Rockies	Middle Rockies	Middle Rockies	Middle Rockies
Landform	Foothill	Foothill	Foothill	Foothill
DEQ Classification	2	2	2	2
Strahler Order	5	5	5	5
Drainage Area (mi^2)	204	204	Unknown	Unknown
Elevation (ft)	4060	4060	Unknown	Unknown
Section	11	11	1	Unknown
Township	56	56	56	Unknown
Range	87	87	87	87
Latitude	$44^0$50'58"	$44^0$50'58"	Unknown	Unknown
Longitude	$107^0$18'14"	$107^0$18'14"	Unknown	Unknown
Geology [c]	WVG	WVG	MD	Unknown
Dam Present?	No	No	No	No

TABLE 5-1. Con't

Descriptor	Tongue River	Tongue River	Tongue River	Tongue River
Station Name	IXL Ranch	Dayton WWTF	At Dayton	Dayton WWTF
Agency [a]	WGFD	WDEQ	WWRC	WWRC
Year(s)	1979	1985,89	1976,77	1977
Data Type Collected [b]	F	B	C;P	C;P
Figure 5-1 Station No.	4	6	5	6
Appendix Table	C-12	A-6	A-7	A-8,9,10
Hydrologic Unit Code	10090100	10090100	10090100	10090100
NRCS Small Watershed Code	000	000	000	000
USGS Quad Map	Dayton South	Dayton South	Dayton South	Dayton South
Ecoregion	Middle Rockies	Middle Rockies	Middle Rockies	Middle Rockies
Landform	Foothill	Foothill	Foothill	Foothill
DEQ Classification	2	2	2	2
Strahler Order	5	5	5	5
Drainage Area (mi^2)	Unknown	241	Unknown	241
Elevation (ft)	Unknown	3870	Unknown	3870
Section	1	28	Unknown	28
Township	56	57	57	57
Range	87	87	87	87
Latitude	Unknown	44^{0}53'02"	Unknown	44^{0}53'02"
Longitude	Unknown	107^{0}14'21"	Unknown	107^{0}14'21"
Geology [c]	MD	QA	QA	QA
Dam Present?	No	No	No	No

TABLE 5-1. Con't

Descriptor	Tongue River	Tongue River	Tongue River	Tongue River
Station Name	County Road 71	Halfway Bridge Bearclaw Ranch	Ranchester WTP Intake	Ranchester City Park
Agency [a]	WDEQ	WGFD	WDEQ	WWRC
Year(s)	1985	1962	1967-71;73;85;83-90	1976
Data Type Collected [b]	B	F	C;P;B	C:P
Figure 5-1 Station No.	7	7	8	8
Appendix Table	A-11	C-13	A-12,13,14	A-15
Hydrologic Unit Code	10090100	10090100	10090100	10090100
NRCS Small Watershed Code	000	000	000	000
USGS Quad Map	Ranchester	Ranchester	Ranchester	Ranchester
Ecoregion	Northwestern Great Plains	Northwestern Great Plains	Northwestern Great Plains	Northwestern Great Plains
Landform	Plains	Plains	Plains	Plains
DEQ Classification	2	2	2	2
Strahler Order	5	5	5	5
Drainage Area (mi^2)	264	Unknown	347	347
Elevation (ft)	3810	Unknown	3750	3750
Section	26	Unknown	19	19
Township	57	Unknown	57	57
Range	86	86	85	85
Latitude	$44^0$53'26"	Unknown	$44^0$54'25"	$44^0$54'25"
Longitude	$107^0$12'38"	Unknown	$107^0$09'55"	$107^0$09'55"
Geology [c]	QA	QA	QA	QA
Dam Present?	No	No	No	No

TABLE 5-1. Con’t

Descriptor	Little Tongue River	Little Tongue River	Smith Creek	Wolf Creek
Station Name	Station 06298500	Leonard Grahams Stations 1, 2, 3	Glen Mock Ranch	Near Eaton’s Stations 1, 2, 2A, 3
Agency [a]	USGS	WGFD	WGFD	WGFD
Year(s)	1971;85	1972,73,81,82,84	1959	1959
Data Type Collected [b]	C;P	F	F	F
Figure 5-1 Station No.	9	10	11	13
Appendix Table	A-16	C-17 through C-21	C-22	C-23 through 26
Hydrologic Unit Code	10090100	10090100	10090100	10090100
NRCS Small Watershed Code	030	030	040	040
USGS Quad Map	Dayton South	Dayton South	Dayton North	Wolf
Ecoregion	Middle Rockies	Middle Rockies	Middle Rockies	Middle Rockies
Landform	Foothills	Foothills	Foothills	Foothills
DEQ Classification	2	2	2	2
Strahler Order	4	4	4	4
Drainage Area (mi^2)	25.1	Unknown	Unknown	Unknown
Elevation (ft)	4420	Unknown	Unknown	Unknown
Section	24	28	21	27? & 33?
Township	56	56	57	56
Range	87	87	87	86
Latitude	$44^0$48'38"	Unknown	Unknown	Unknown
Longitude	$107^0$17'02"	Unknown	Unknown	Unknown
Geology [c]	MD	QU	Unknown	MD
Dam Present?	No	No	No	No

TABLE 5-1. Con’t

Descriptor	Wolf Creek	Wolf Creek	Wolf Creek	Wolf Creek
Station Name	Joe Patterson Ranch	Wolf Ranch Stations 2,2A	Near Bighorn N.F. Boundary	Station #06299500
Agency [a]	WGFD	WGFD	USFS	USGS
Year(s)	1967,68,69	1972,82	1972,73,74	1985
Data Type Collected [b]	F	F	C;P	C
Figure 5-1 Station No.	16	14	12	13
Appendix Table	C-27,28,29	C-30 through 33	A-17	A-18
Hydrologic Unit Code	10090100	10090100	10090100	10090100
NRCS Small Watershed Code	040	040	040	040
USGS Quad Map	Wolf	Wolf	Wolf	Wolf
Ecoregion	Middle Rockies	Middle Rockies	Middle Rockies	Middle Rockies
Landform	Foothill	Foothill	Foothills	Foothills
DEQ Classification	2	2	2	2
Strahler Order	4	4	4	4
Drainage Area (mi^2)	Unknown	Unknown	Unknown	37.8
Elevation (ft)	Unknown	Unknown	4750	4525
Section	Unknown	15 & 33	5	5
Township	Unknown	56	55	55
Range	Unknown	86	86	86
Latitude	Unknown	Unknown	Unknown	$44^0$46'21"
Longitude	Unknown	Unknown	Unknown	$107^0$14'01"
Geology [c]	Unknown	QU	MD	MD
Dam Present?	No	No	No	No

TABLE 5-2. Description of Acronyms Used in Table 5-1 and Table 5-3 for Agency[a], Data Type[b] and Geology[c] Descriptors

Agency	
WGFD = Wyoming Game and Fish Department	USFS = United States Forest Service
WWRC = Wyoming Water Resources Center	USGS = United States Geological Survey
WDEQ = Wyoming Department Environmental Quality	SCCD = Sheridan County Conservation District
RPWD = Ranchester Public Works Department	
Data Type Collected	
C = Water Chemical	P = Water Physical
B = Bacteria	F = Fish Population
PER = Periphyton	PES = Organochlorine Pesticides
HER = Chlorinated Herbicides	H = Habitat
M = Benthic Macroinvertebrates	BSO = Bed Sediment Organics
BSM = Bed Sediment Trace Metals	FTM = Brown trout liver trace metals
FTO = Brown trout fish tissue organics	
Geology (after USGS, 1985)	
KFB = Bearpaw shale - dark greenish-gray shale containing thin gray sandstone partings.	
MD = Madison limestone: blue-gray, massive limestone and dolomite underlain by gray cherty limestone and dolomite.	
QA = Alluvium and colluvium: clay, silt, sand, and gravel in flood plains, fans, terraces and slopes.	
QU = Undivided surficial deposits; mostly alluvium, colluvium, and glacial landslide deposits.	
TFL = Fort Union Formation - Lebo Member; dark-gray clay shale and concretionary sandstone.	
TFT = Fort Union Formation, Tullock Member: soft gray sandstone, gray and brown carbonaceous shale and thin coal beds.	
WVG = Plutonic rocks; quartz diorite to quartz monzonite.	

FIGURE 5-1 PAGE HERE

FIGURE 5-2 PAGE HERE

TABLE 5-3. Site Descriptors for Monitoring Stations Providing Current Data Less Than (<) 5 Years Old Within the Tongue River 205j Project Area, Sheridan County, Wyoming (**Note**: See Table 5-2 for Description of Agency[a], Data Type[b] and Geology[c] Acronyms)

Descriptor	Tongue River	Tongue River	Tongue River	Tongue River
Station Name	Upper @ Canyon (ID #MRC 24)	Upper (@ USGS #0629800)	USGS #0629800	IXL Ranch
Agency [a]	WDEQ	SCCD	USGS	WGFD
Year(s)	1993-99	1996-99	1998-99	1991
Data Type Collected [b]	C;P;B;M;H;PE	C;P;B;PES;HER	C;P;MFTO;FTM: M;BSM;BSO	F
Figure 5-2 Station No.	1	2	2	3
Appendix Table	B-1;F	B-2	D-1-4;B-26;F-40	C-11
Hydrologic Unit Code	10090100	10090100	10090100	10090100
NRCS Small Watershed Code	000	000	000	000
USGS Quad Map	Dayton South	Dayton South	Dayton South	Dayton South
Ecoregion	Middle Rockies	Middle Rockies	Middle Rockies	Middle Rockies
Landform	Foothill	Foothill	Foothill	Foothill
DEQ Class	2	2	2	2
Strahler Order	5	5	5	5
Drainage Area (mi^2)	202	204	204	Unknown
Elevation (ft)	4120	4060	4060	Unknown
Section	10	11	11	1
Township	56	56	56	56
Range	87	87	87	87
Latitude	$44^0$50'44"	$44^0$50'58"	$44^0$50'58"	Unknown
Longitude	$107^0$19'48"	$107^0$18'14"	$107^0$18'14"	Unknown
Geology [c]	WVG	WVG	WVG	MD
Dam Present?	No	No	No	No

TABLE 5-3. Con’t

Descriptor	Tongue River	Tongue River	Tongue River	Tongue River
Station Name	Above Dayton WWTF (ID# NGP 37)	Below Dayton WWTF (ID# NGP 39)	Middle	Middle (ID# NGPI 5)
Agency [a]	WDEQ	WDEQ	SCCD	WDEQ
Year(s)	1998	1998	1996-99	1996-99
Data Type Collected [b]	C;P;B;M;H	C;P;B;M;H	C;P;B;M;H;PES; HER	C;P;B;M;H
Figure 5-2 Station No.	4	4	5	5
Appendix Table	B-3;F	B-4;F	B-5;F	B-6;F
Hydrologic Unit Code	10090100	10090100	10090100	10090100
NRCS Small Watershed Code	000	000	000	000
USGS Quad Map	Dayton South	Dayton South	Ranchester	Ranchester
Ecoregion	Northwestern Great Plains	Northwestern Great Plains	Northwestern Great Plains	Northwestern Great Plains
Landform	Plains	Plains	Plains	Plains
DEQ Class	2	2	2	2
Strahler Order	5	5	5	5
Drainage Area (mi^2)	241	245	264	264
Elevation (ft)	3870	3860	3810	3810
Section	28	27	26	26
Township	57	57	57	57
Range	87	87	86	86
Latitude	$44^0$53'02"	$44^0$52'59"	$44^0$53'26"	$44^0$53'26"
Longitude	$107^0$14'21"	$107^0$14'05"	$107^0$12'38"	$107^0$12'38"
Geology [c]	QA	QA	QA	QA
Dam Present?	No	No	No	No

TABLE 5-3. Con't

Descriptor	Tongue River	Tongue River	Tongue River	Tongue River
Station Name	Lower (at Ranchester)	Lower (ID# NGPI 4)	Conner Battlefield Ranchester	Ranchester WTP Intake
Agency [a]	SCCD	WDEQ	WGFD	RPWD
Year(s)	1996-99	1996-99	1993-94	1982-99
Data Type Collected [b]	C;P;B;M;H;PES; HER	C;P;B;M;H;PE	F	P
Figure 5-2 Station No.	6	6	6	6
Appendix Table	B-7;F	B-8;F	C-14;C-15	A-19;A-20
Hydrologic Unit Code	10090100	10090100	10090100	10090100
NRCS Small Watershed Code	000	000	000	000
USGS Quad Map	Ranchester	Ranchester	Ranchester	Ranchester
Ecoregion	Northwestern Great Plains	Northwestern Great Plains	Northwestern Great Plains	Northwestern Great Plains
Landform	Plains	Plains	Plains	Plains
DEQ Class	2	2	2	2
Strahler Order	5	5	5	5
Drainage Area (mi^2)	347	347	347	347
Elevation (ft)	3750	3750	3750	3750
Section	19	19	19	19
Township	57	57	57	57
Range	85	85	85	85
Latitude	$44^0$54'25"	$44^0$54'25"	$44^0$54'25"	$44^0$54'25"
Longitude	$107^0$09'55"	$107^0$09'55"	$107^0$09'55"	$107^0$09'55"
Geology [c]	QA	QA	QA	QA
Dam Present?	No	No	No	No

TABLE 5-3. Con’t

Descriptor	Tongue River	Little Tongue	Little Tongue	Little Tongue
Station Name	Conner Battlefield Ranchester	Upper	Upper (ID# MRC 30)	Little Tongue River Ranch
Agency [a]	WGFD	SCCD	WDEQ	WGFD
Year(s)	1993	1996-99	1993	1997
Data Type Collected [b]	P	C;P;B	C;P;M;H	F
Figure 5-2 Station No.	6	8	7	9
Appendix Table	E-2	B-9	B-11;F	C-16
Hydrologic Unit Code	10090100	10090100	10090100	10090100
NRCS Small Watershed Code	000	030	030	030
USGS Quad Map	Ranchester	Dayton South	Dayton South	Dayton South
Ecoregion	Northwestern Great Plains	Middle Rockies	Middle Rockies	Middle Rockies
Landform	Plains	Foothills	Foothills	Foothills
DEQ Class	2	2	2	2
Strahler Order	5	4	2	4
Drainage Area (mi^2)	347	12.8	4.2	Unknown
Elevation (ft)	3750	4420	4480	4170
Section	19	24	24	7
Township	57	56	56	56
Range	85	87	87	88
Latitude	44^{0}54'25"	44^{0}48'38"	44^{0}48'33"	Unknown
Longitude	107^{0}09'55"	107^{0}17'02"	107^{0}17'21"	Unknown
Geology [c]	QA	MD	MD	KFB
Dam Present?	No	No	No	No

TABLE 5-3. Con't

Descriptor	Little Tongue	Little Tongue	Smith Creek	Smith Creek
Station Name	Lower	Lower (ID# MRCI 23)	Upper	Lower
Agency [a]	SCCD	WDEQ	SCCD	SCCD
Year(s)	1996-99	1996-99	1996-99	1996-99
Data Type Collected [b]	C;P;B;M;H	C;P;B;M;H	C;P;B	C;P;B;M;H
Figure 5-2 Station No.	10	10	11	12
Appendix Table	B-10;F	B-12;F	B-13	B-14
Hydrologic Unit Code	10090100	10090100	10090100	10090100
NRCS Small Watershed Code	030	030	040	040
USGS Quad Map	Dayton North	Dayton North	Dayton North	Dayton North
Ecoregion	Middle Rockies	Middle Rockies	Middle Rockies	Northwestern Great Plains
Landform	Foothills	Foothills	Foothills	Plains
DEQ Classification	2	2	2	2
Strahler Order	4	4	3	3
Drainage Area (mi^2)	26.2	26.2	3.7	11.6
Elevation (ft)	3890	3890	4880	3885
Section	32	32	20	32
Township	57	57	57	57
Range	86	86	87	86
Latitude	$44^0$52'37"	$44^0$52'37"	$44^0$53'41"	$44^0$52'41"
Longitude	$107^0$15'54"	$107^0$15'54"	$107^0$22'26"	$107^0$16'03"
Geology [c]	KFB	KFB	MD	KFB
Dam Present?	No	No	No	No

TABLE 5-3. Con't

Descriptor	Smith Creek	Columbus Creek	Columbus Creek	Columbus Creek
Station Name	Lower (ID# NGPI 7)	Upper	Upper (ID# MRC 10)	Lower
Agency [a]	WDEQ	SCCD	WDEQ	SCCD
Year(s)	1996-99	1996-99	1993	1996-99
Data Type Collected [b]	C;P;B;M;H	C;P;B	C;P;M;H	C;P;B;M;H
Figure 5-2 Station No.	12	13	13	14
Appendix Table	B-15	B-16	B-18	B-17
Hydrologic Unit Code	10090100	10090100	10090100	10090100
NRCS Small Watershed Code	040	040	040	040
USGS Quad Map	Dayton North	Columbus Peak	Columbus Peak	Ranchester
Ecoregion	Northwestern Great Plains	Middle Rockies	Middle Rockies	Northwestern Great Plains
Landform	Plains	Foothill	Foothill	Plains
DEQ Classification	2	2	2	2
Strahler Order	3	3	3	3
Drainage Area (mi^2)	11.6	9.0	9.0	17.9
Elevation (ft)	3885	4880	4880	3869
Section	32	17	17	28
Township	57	57	57	57
Range	86	87	87	86
Latitude	$44^0$52'41"	$44^0$54'41"	$44^0$54'41"	$44^0$53'35"
Longitude	$107^0$16'03"	$107^0$23'39"	$107^0$23'39"	$107^0$14'10"
Geology [c]	KFB	MD	MD	TFT
Dam Present?	No	No	No	No

TABLE 5-3. Con’t

Descriptor	Columbus Creek	Wolf Creek	Wolf Creek	Wolf Creek
Station Name	Lower (ID# NGPI 8)	Upper	Upper (Berry’s ID# NGPI 25)	Berry’s nr.road ID#4116971008
Agency [a]	WDEQ	SCCD	WDEQ	WGFD
Year(s)	1996-99	1996-99	1995	1997
Data Type Collected [b]	C;P;B;M;H	C;P;B	C;P;M;H	F
Figure 5-2 Station No.	14	15	17	16
Appendix Table	B-19	B-20	B-22	C-35
Hydrologic Unit Code	10090100	10090100	10090100	10090100
NRCS Small Watershed Code	040	050	050	050
USGS Quad Map	Ranchester	Wolf	Wolf	Wolf
Ecoregion	Northwestern Great Plains	Middle Rockies	Northwestern Great Plains	Northwestern Great Plains
Landform	Plains	Foothill	Plains	Plains
DEQ Classification	2	2	2	2
Strahler Order	3	4	4	4
Drainage Area (mi^2)	17.9	37.8	54.9	Unknown
Elevation (ft)	3869	4525	4000	4116
Section	28	4	11	15
Township	57	55	56	56
Range	86	86	86	86
Latitude	$44^0$53'35"	$44^0$46'21"	$44^0$50'33"	Unknown
Longitude	$107^0$14'10"	$107^0$14'01"	$107^0$11'21"	Unknown
Geology [c]	TFT	MD	QA	QA
Dam Present?	No	No	No	No

TABLE 5-3. Con't

Descriptor	Wolf Creek	Wolf Creek	Five Mile Creek	Five Mile Creek
Station Name	Lower	Lower (ID# NGPI 6)	Lower	Lower (ID# NGPI 9)
Agency [a]	SCCD	WDEQ	SCCD	WDEQ
Year(s)	1996-99	1996-99	1996-99	1996-99
Data Type Collected [b]	C;P;B;M;H; PES;HER	C;P;B;M;H	C;P;B;M;H; PES;HER	C;P;B;M;H
Figure 5-2 Station No.	18	18	19	19
Appendix Table	B-21;H-1	B-23	B-24;H-1	B-25
Hydrologic Unit Code	10090100	10090100	10090100	10090100
NRCS Small Watershed Code	050	050	081	081
USGS Quad Map	Ranchester	Ranchester	Ranchester	Ranchester
Ecoregion	Northwestern Great Plains	Northwestern Great Plains	Northwestern Great Plains	Northwestern Great Plains
Landform	Plains	Plains	Plains	Plains
DEQ Classification	2	2	2	2
Strahler Order	4	4	4	4
Drainage Area (mi^2)	72.4	72.4	15.2	15.2
Elevation (ft)	3775	3775	3773	3773
Section	19	19	19	19
Township	57	57	57	57
Range	85	85	85	85
Latitude	$44^0$53'54"	$44^0$53'54"	$44^0$54'23"	$44^0$54'23"
Longitude	$107^0$10'18"	$107^0$10'18"	$107^0$10'08"	$107^0$10'08"
Geology [c]	QA	QA	TFL	TFL
Dam Present?	No	No	No	No

6 MONITORING AND ASSESSMENT PLAN

6.1 MONITORING DESIGN

A primary goal of the Project was to determine the major types of nonpoint source impairments occurring in the Tongue River watershed. A monitoring design was developed by SCCD in close consultation with WDEQ in order to meet this goal. The monitoring design described the sampling stations, sampling parameters, frequency for sampling and the methods for analysis and interpretation of data. The design was a component of the total monitoring program that functioned to provide the information required to meet Project goals and objectives. The monitoring program was designed to be cost effective, easy to implement, provide credible data, and result in realization of Project goals through sound interpretation and analysis of data.

In 1999, the Wyoming Legislature enacted Credible Data legislation as per W.S. §35-11-103 of the Wyoming Environmental Quality Act. The statute defines Credible Data as scientifically valid chemical, physical and biological monitoring data collected under an accepted sampling and analysis plan, including quality control, quality assurance procedures and available historical data. Only credible data may be used to determine attainment of designated uses for a water body or assign classification of water body segments. Designated uses for the Tongue River and tributaries in the Project area were identified in Section 4.2.

Although the Tongue River Watershed Assessment Project was initiated before Credible Data legislation was enacted, the SCCD monitoring program met the criteria and intent of the legislation. This was important because data collected during this Project may be used to determine attainment of designated uses for the Tongue River and tributaries and to propose stream classifications or change in stream classification when appropriate.

6.1.1 Pre-Survey

A pre-survey or study was conducted prior to development of the Project monitoring design (Mendenhall et al. 1971; Green 1979; Mason et al. 1989). The pre-survey provided information to examine magnitude, spatial and temporal variability of target water quality parameters and to determine where data gaps may exist. The SCCD historical data search served this purpose and revealed significant data gaps. Considerable data existed for the Tongue River upper and lower reaches within the Project area. Little data was available for the middle reach of the Tongue River. No historical water quality data was located for Smith Creek, Columbus Creek and Five Mile Creek. The Little Tongue River had limited historic water quality data. No significant water quality sampling had been conducted on Wolf Creek since 1974 when USFS collected samples near the BHNF boundary. The paucity of historic bacteria data for Tongue River tributaries was identified and considered by SCCD as a monitoring priority due to potential public health and safety concerns.

6.1.2 Types of Monitoring Designs Employed

The monitoring design for the Project incorporated four types of monitoring into a multi-disciplinary chemical, physical, biological and habitat monitoring program. Each monitoring type provides certain types of information. The four types of monitoring include:

1. Baseline monitoring
2. Long term trend monitoring
3. Above and below monitoring with discharge
4. Below only monitoring

Baseline monitoring involved initial data collection at a specified frequency and fixed location. This monitoring type occurred at Little Tongue River, Columbus Creek, Smith Creek, Wolf Creek lower reaches and Five Mile Creek because these water bodies had no or little previous water quality data. Baseline data described the current water quality and stream conditions.

Baseline monitoring over a period of years evolves into **long term trend monitoring**. Trend monitoring continues over many years and is used to identify temporal (seasonal or annual) water quality variability within the watershed and assist in determination of water quality change. This type of monitoring occurred within the Project area at the upper Tongue River canyon USGS station 06298000 where substantial, although intermittent historic data was collected. WDEQ established a long term trend monitoring Reference Stream station upstream of the USGS station that has been assessed annually since 1993. RPWD conducted long term trend monitoring for turbidity, water temperature and pH at the Water Treatment Plant in Ranchester

Above and below monitoring with discharge measurement was used to identify general areas of pollutant sources (MacDonald et al., 1991) and when used in conjunction with discharge measurements was fairly specific for detection of water quality change related to change in land use and water use (Spooner et al., 1985). An upper control station and at least one downstream station was established on each primary tributary (with the exception of Five Mile Creek) to evaluate water quality change. Three monitoring stations were established on the Tongue River. Water quality data from the upstream control location was compared to water quality data from downstream locations to detect water quality change.

Accurate discharge measurements were critical to the above and below monitoring design since many chemical and physical water quality parameters were directly affected by change in discharge. This was evident during evaluation of historical USGS data collected at the Tongue River gage station No. 06298000 where highest suspended sediment concentrations occurred during periods of highest annual discharge. Moreover, Total Dissolved Solids (TDS) were associated with discharge. TDS concentration decreased with increasing stream discharge. Good discharge data were required to partition discharge dependent water quality parameters according to discharge measured during the Project.

Below only monitoring consisted of monitoring at a single fixed site located at the lower end of a water body. This was not the preferred monitoring method for this Project since comparisons could not be made to a control location. Although long term monitoring will be required to detect water quality change in absence of a control location, the single lower station may provide adequate data to determine compliance with most numeric Wyoming water quality standards. Despite this disadvantage, the lack of a well defined headwater, significant Columbus Creek diversions and monitoring budget constraints necessitated below only monitoring at a single station on lower Five Mile Creek.

6.2 Sampling Stations

Sampling stations were selected in consultation with WDEQ after evaluation of historical sampling stations, historical data, anticipated monitoring within the Project area (e.g. USGS NAWQA), monitoring budget and access. The monitoring budget allowed for sampling at thirteen (13) stations within the Project area. Table 5-2 listed the sampling stations and Figure 5-2 illustrated the location of the sampling stations.

Three sampling stations were established on the mainstem Tongue River. Two stations were established on primary tributaries to the Tongue River including the Little Tongue River, Smith Creek, Columbus Creek, and Wolf Creek. A minimum of two sampling stations were needed to detect cursory water quality change as the water bodies flowed through the Project area. Increasing the number of sampling stations at each tributary would have increased the ability to detect water quality change and identify potential sources of water pollutants, but the Project monitoring budget limited the total number of sample stations. Only one sampling station was established on Five Mile Creek because it's headwaters were difficult to identify due to dominance of Columbus Creek water diverted into the drainage.

Upper monitoring stations were sited in or near the foothills of the Bighorn Mountains in the Middle Rockies Ecoregion and lower stations were sited either in the lower foothills of the Middle Rockies ecoregion or in the Northwestern Great Plains ecoregion (Omernik and Gallant, 1987).

6.2.1 Tongue River

Three (3) sampling stations were located on the mainstem Tongue River; the Upper (Figure 5-2, Site Number 2), Middle (Figure 5-2, Site Number 5) and Lower (Figure 5-2, Site Number 6).

6.2.1.1 Tongue River Upper

The **Tongue River Upper** station was located at USGS station 06298000 at an elevation of 4,060 feet. The station was accessed by taking County Road 92 (also known as the Tongue Canyon Road) west, southwest from the Town of Dayton to the gage station located on the north bank, south of the County road. This station was located about one mile downstream from the WDEQ long-term Reference Stream station identified as Tongue River - Upper (MRC 24). Figure 6-1 illustrates the character of the Tongue River at the WDEQ monitoring station.

Primary land use near this station was recreation, wildlife habitat and limited summer and year around residences. County Road 92 ends near the WDEQ canyon monitoring station. Access upstream is limited to a pack trail. This station served as the reference station for comparison to water quality change identified at downstream Tongue River monitoring stations.

USGS conducted historic water quality sampling at this station from 1966 through 1981, 1987 and 1988. Discharge has been measured daily since 1940. USGS initiated bed sediment metals and organics, fish tissue, fish liver and fish population sampling in 1998 as part of the Yellowstone NAWQA project. Monthly water chemistry sampling was initiated January, 1999 and annual macroinvertebrate and periphyton sampling occurred in 1999. The USGS water chemistry data (Appendix Table B-26), macroinvertebrate data (Appendix Table F, Page F-40 and Appendix Table G-3), brown trout liver trace metals data (Appendix Table D-1), brown trout whole body fish tissue organics data (Appendix Table D-2), bed sediment trace metals data (Appendix Table D-3) and stream bed sediment organics data (Appendix Table D-4) were available for this Final Report. USGS periphyton and fish population data were not available.

6.2.1.2 Tongue River Middle

The **Tongue River Middle** station was located at the Halfway Lane County Road bridge at an elevation of 3810 feet. WDEQ also established a monitoring station in 1996 identified as Tongue River - Middle (station ID NGPI 5). WDEQ and SCCD sampled benthic macroinvertebrates at the first riffle upstream of the Halfway Lane County Road bridge. Water samples were collected just downstream of the bridge. Figures 6-2 and 6-3 show general characteristics for this stream reach. Primary land uses in order of importance include irrigated hayland, livestock grazing, wildlife habitat and recreation.

The majority of historical sampling occurred upstream of the SCCD station during the 1970's and

1980's in the vicinity of the Town of Dayton Waste Water Treatment Facility (WWTF). Historic sampling was conducted by WDEQ and WWRC. WDEQ conducted current additional water quality, bacteriological, macroinvertebrate and stream habitat sampling in the fall, 1998 at stations upstream and downstream of the Dayton WWTF. The WDEQ upstream station was identified as Above Dayton WWTF (Figure 5-2, Site Number 4), and downstream station identified as Below Dayton WWTF; (Figure 5-2, Site Number 4). The Dayton WWTF is located about 1 mile upstream of the SCCD Tongue River - Middle station. Historic stream channelization was apparent in this segment.

6.2.1.3 Tongue River Lower

The **Tongue River Lower** station was located near the Ranchester Water Treatment Plant (WTP) immediately upstream of the raw water intake structure at the foot bridge at an elevation of about 3,750 feet. WDEQ established a sampling site in 1996 about 1/4 to 1/3 mile upstream. This WDEQ site was identified as Tongue River - Lower (station ID NGPI 4) and was located immediately upstream of the County Road 67 bridge. SCCD used the WDEQ station for macroinvertebrate sampling and habitat assessment to allow comparison to data collected by WDEQ. However, all water quality sampling occurred at the station near the Ranchester WTP intake. Figure 6-4 illustrates stream reach characteristics at the joint SCCD/WDEQ monitoring station.

WGFD conducted fish population sampling in 1993 and 1994 at a station identified as the Connor Battlefield located adjacent to the Ranchester WTP intake. The fishery data is presented in Appendix C, Tables C-14 and C-15. The RPWD collected daily raw water samples at the Tongue River WTP intake from 1982 through 1999. Temperature, ph, turbidity and alkalinity samples were collected and data are presented in Appendix A, Tables A-19 through A-22.

Urban, recreation and wildlife were the primary land uses at the station. Primary land use upstream of the Lower sampling station in order of importance included irrigated hayland, livestock grazing, wildlife habitat, rural residential and recreation.

6.2.2 Little Tongue River

Two monitoring stations were established on Little Tongue River. The stations were identified as the Upper and Lower.

6.2.2.1 Little Tongue River Upper

The **Little Tongue River Upper** station was located at the USGS station 06298500 at an elevation of 4,480 feet (Figure 5-2, Site Number 8). The station was located on the Horseshoe Ranch at the Horseshoe Ranch Golf Course. It may be accessed off Highway 14 south, southwest of the Town of Dayton by entering the golf course entrance and proceeding to the USGS gage station. This station was located about 1/4 to 1/3 mile downstream from the WDEQ reference stream station established in 1993 identified as Little Tongue River - Upper (MRC 30) (Figure 5-2, Site Number 7). Figure 6-5 illustrates the stream reach near the SCCD monitoring station.

Primary land use near this station was recreation (golf course), wildlife habitat, limited horse grazing and dryland pasture. This station served as the reference station for comparison to the Little Tongue River Lower station.

USGS conducted limited historic one day water quality sampling on August 29, 1971 and October 18, 1985 (Appendix Table A-16). WGFD conducted historic fish population monitoring at Leonard Graham's. Sampling results are presented in Appendix C, Tables C-17 through C-21. WGFD conducted current fish population monitoring at the Little Tongue River Ranch in 1997 (Figure 5-2, Site Number 9). Fishery data are presented in Appendix C, Table C-16.

6.2.2.2 Little Tongue River Lower

The **Little Tongue River Lower** station was located in the Town of Dayton about 300 to 400 yards upstream of the confluence with the Tongue River. Elevation was 3890 feet. Figure 5-2, Site Number 10, identified the general location of this station and Figure 6-6 illustrated the stream reach habitat, especially the extensive historic stream channelization (straightening). The drainage area at this station was 26.2 square miles compared to the drainage area of 12.8 square miles at the Upper station.

Primary land use at this station in order of importance was urban, recreation and wildlife habitat. Irrigated hayland, dryland pasture, wildlife habitat, livestock grazing and recreation land use are present upstream of the Dayton town limits.

WDEQ established a monitoring station in 1996 at the SCCD monitoring station. The WDEQ station was identified as Little Tongue River - Lower (station ID MRCI 23).

6.2.3 Smith Creek

Two monitoring stations were established on Smith Creek. The stations were identified as the Upper and Lower.

6.2.3.1 Smith Creek Upper

The **Smith Creek Upper** station was located upstream of the last bridge crossing on County Road 116 west, northwest of the Town of Dayton (Figure 5-2, Site Number 11). Figure 6-7 illustrates the foothills character for the stream reach situated at an elevation of 4880 feet. Drainage area upstream was 3.7 square miles.

Primary land use near this station was wildlife habitat, recreation and seasonal livestock grazing. This station served as the reference station for comparison to the Smith Creek - Lower station.

SCCD sampling represented the first known water quality collection in the Smith Creek watershed. WDEQ may have conducted limited water quality sampling in the 1990's but data could not be located for insertion into this Final Report. WGFD sampled fish populations in 1959 at a station identified as the Glen Mock Ranch. The fishery data is presented in Appendix C, Table C-22.

6.2.3.2 Smith Creek Lower

The **Smith Creek Lower** station was located in the Town of Dayton about 150 to 200 yards above the confluence with the Tongue River and about 30 yards downstream from County Road 92 (Tongue River Canyon Road) bridge crossing. The station was located downstream of the bridge crossing due to access limitations. Elevation was 3885 feet and the primary land use was urban. Rural subdivision development, irrigated hayland, dryland pasture, wildlife habitat and livestock grazing were additional land uses in the watershed upstream of this station.

Figure 5-2, Site Number 12, identified the general location for this station and Figure 6-8 illustrated the stream reach habitat, especially the extensive historic stream channelization (straightening). The drainage area at this station was 11.6 square miles making it the smallest tributary monitored during this Project.

WDEQ established a monitoring station in 1996 at the SCCD monitoring station. The WDEQ station was identified as Smith Creek - Lower (station ID NGPI 7).

6.2.4 Columbus Creek

Two monitoring stations were established on Columbus Creek. The stations were identified as the Upper and Lower.

6.2.4.1 Columbus Creek Upper

The **Columbus Creek Upper** station was located upstream of the ford across Columbus Creek on County Road 140. The route on County Road 116 south from the Parkman Road provided easiest access. Figure 5-2, Site Number 13 shows the general location of the monitoring station and Figure 6-9 illustrated the foothill character for the stream reach situated at an elevation of 4880 feet. Drainage area upstream was about 9.0 square miles.
Primary land use near this station included wildlife habitat, limited livestock grazing and

recreation. A summer home is upstream of the station, but was not believed to impact the stream. A large irrigation diversion (Five Mile Creek Ditch) downstream transfers water north into the Five Mile Creek drainage. This station served as the reference station for comparison to the Columbus Creek Lower station and as a general reference to the Five Mile Creek Lower station.

WDEQ established a monitoring station in 1993 at the SCCD monitoring station. The WDEQ station was identified as Columbus Creek - Upper (station ID MRC 10). WDEQ has not sampled the station since 1993.

6.2.4.2 Columbus Creek Lower

The **Columbus Creek Lower** station was located just downstream of the Highway 14 bridge crossing. The station was sited downstream of the highway crossing due to access limitations. Elevation was about 3869 feet and the primary land use upstream was a confined animal feeding operation, irrigated hayland, livestock grazing and wildlife habitat.

Figure 5-2, Site Number 14, identified the general location for this station and Figure 6-10 illustrates the stream reach habitat characterized by an entrenched F Type channel and channelization below the highway crossing. The drainage area at this station was about 17.9 square miles.

WDEQ established a monitoring station in 1996 at this monitoring station. The WDEQ station was identified as Columbus Creek - Lower (station ID NGPI 8).

6.2.5 Wolf Creek

Two monitoring stations were established on Wolf Creek. The stations were identified as the Upper and Lower.

6.2.5.1 Wolf Creek Upper

The **Wolf Creek Upper** station was located at the USGS gage station identified as Wolf Creek at Wolf, station number 06299500. Discharge has been measured since 1945 usually on a seasonal basis from April through September. Figure 5-2, Site Number 15 shows the general location of the monitoring station and Figure 6-11 illustrated the foothills character of the stream reach and B channel type situated at an elevation of 4525 feet. Drainage area was about 37.8 square miles.

Primary land use near this station included recreation, wildlife habitat and limited seasonal livestock grazing. Access upstream of this station is limited to a pack trail and few anthropogenic effects were apparent. This station served as the reference station for comparison to the Wolf Creek Lower station.

6.2.5.2 Wolf Creek Lower

The **Wolf Creek Lower** station was located just downstream of the County Road 67 (also known as the Wolf Creek Road) bridge crossing. The station was sited downstream of the highway crossing due to access limitations. Elevation was about 3775 feet and the primary land use upstream was irrigated hayland, livestock grazing, wildlife habitat and recreation.

Figure 5-2, Site Number 18, identified the general location of this station and Figure 6-12 illustrates the stream reach habitat characterized by a C Type channel upstream and entrenched F Type channel downstream of the station. The drainage area at this station was about 72.4 square miles making it the largest tributary the Tongue River within the Project area.

WDEQ established a monitoring station in 1996 at this monitoring station. The WDEQ station was identified as Wolf Creek - Lower (station ID NGPI 6). WGFD conducted fish population sampling in 1997 at a station upstream near the Soldier Creek Road. Results of sampling are presented in Appendix C, Table C-34. WDEQ established a monitoring station in 1995 about one (1) mile downstream of the WGFD fish sampling station. This station was identified as Wolf Creek - Upper (Berry's) (Station ID NGPI 25). Figure 5-2, Site Number 17 identified the general location of the monitoring station.

The stream channel at Wolf Creek Lower has evolved into a meandering C Type channel commonly found in the Wyoming plains as compared to the B Type channel observed at the SCCD Wolf Creek Upper foothill station. Other differences at the Lower station when compared to the Wolf Creek - Upper station included increased water demand for irrigation, increased irrigated hayland acreage, presence of irrigation returns and increased livestock grazing. Figures 6-13 and 6-14 illustrated results of stream habitat improvement in this vicinity related to changes in livestock grazing management that occurred after 1993.

6.2.6 Five Mile Creek Lower

A single monitoring station identified as Five Mile Creek Lower was established downstream of the Highway 14 crossing in the Town of Ranchester at a Park. This station was relocated about 100 yards upstream of Highway 14 in 1999 because the initial station was impounded by a beaver pond and representative samples could not be collected. Descriptive data for this station presented in Table 5-3 represented the station that was established in 1999. Figure 5-2, Site Number 19 shows the general location of the monitoring station and Figure 6-15 shows representative stream reach habitat. The reach was classified as an entrenched meandering F Type channel due to historic down cutting and was situated at an elevation of 3773 feet. Drainage area was about 15.2 square miles, but this value was inconsequential because the majority of water in Five Mile Creek originated from diversion of Columbus Creek water via the Five Mile Ditch.

Two reservoirs are present upstream for storage of irrigation water.

Primary land use upstream includes irrigated hayland, livestock grazing, wildlife habitat and recreation. Land use in the immediate vicinity of the monitoring station was urban, wildlife habitat, recreation and grazing by horses.

WDEQ established a monitoring station in 1996 at the SCCD station and subsequently relocated the station in 1999 along with SCCD due to beaver activity. The WDEQ station was identified as Five Mile Creek - Lower (station ID NGPI 9).

6.3 Sampling Parameters

Sampling parameters were selected after review of historical data and consultation with WDEQ to coordinate concurrent monitoring efforts within the Project area. Table 6-1 lists chemical, physical, bacteriological, biological, habitat and discharge sampling parameters, sampling agency, reporting unit, minimum detection limit, sample container, preservation, holding time, analytical method and analytical method reference.

6.3.1 Field Water Chemistry and Physical Parameters

6.3.1.1 Temperature

Water temperature affects growth, distribution and survival of aquatic organisms including trout. These organisms are cold-blooded and thus assume the temperature of the water in which they reside. Water temperature in the Project area is affected by seasonal changes in air temperature, solar radiation, discharge and other factors. Physical factors may affect stream water temperature through loss of vegetative cover caused by disruption of the riparian zone, reduction in stream discharge due to water withdrawal by diversion and irrigation returns. Cold water is diverted from the Tongue River and tributaries and routed through irrigation supply systems for delivery to crop land. Water from Columbus Creek is diverted to irrigation reservoirs in the Five Mile Creek watershed for later use in the summer. Both practices can increase stream water temperatures during summer.

High summer water temperature is most critical to trout. Trout are mobile and may migrate to cooler upstream reaches. However, low stream discharge and low head diversion structures may prevent trout movement and result in death when lethal temperatures of 25.6 degrees C (78 degrees F) are attained (Garside and Tate, 1958). EPA (1986) stated that the upper tolerance limit for a balanced benthic macroinvertebrate population structure was approximately 32 degrees C.

TABLE 6-1. Standard Field and Laboratory Methods for Chemical, Physical, Biological and Habitat Sampling Conducted by Sheridan County Conservation District, Wyoming Department of Environmental Quality and Ranchester Public Works Department at Tongue River 205j Project Stations, 1993 Through 1999

Parameter	Sampling Agency	Reporting Unit	Minimum Detection Limit	Sample Container	Preservation	Holding Time	Method / Reference
Temperature	SCCD;WDEQ; RPWD	C^0	0.1	None	None	Analyze in Field	170.1 / EPA 1983
pH	SCCD;WDEQ; RPWD	S.U.	0.1	None	None	Analyze In Field	150.1 / EPA 1983
Conductivity	SCCD;WDEQ	umhos/cm	5	None	None	Analyze In Field	120.1 / EPA 1983
Dissolved Oxygen	SCCD;WDEQ	Mg/L	0.1	None	None	Analyze In Field	360.1 / EPA 1983
Turbidity	SCCD;WDEQ	NTU	.05 To 100	Plastic or Glass	Ice	48 Hours	180.1 / EPA 1983
T. Suspended Solids	WDEQ	Mg/l	2	Plastic or Glass	Ice	7 Days	160.2 / EPA 1983
Alkalinity	WDEQ;RPWD	Mg/l	1	Plastic or Glass	Ice	14 Days	310.1 / EPA 1983
Total Sulfate	WDEQ	Mg/l	10	Plastic or Glass	Ice	28 Days	375.2 / EPA 1983
Total Chloride	WDEQ	Mg/l	5	Plastic or Glass	Ice	28 Days	325.2 / EPA 1983
Total Nitrate	SCCD;WDEQ	Mg/l	0.1	Plastic or Glass	Ice; 5 ml 1+1H2SO4	28 Days	353.2 / EPA 1983
Total Phosphorus	SCCD	Mg/l	0.02	Plastic or Glass	Ice; 5 ml 1+1H2SO4	28 Days	200.7 / EPA 1994
Total Phosphorus	WDEQ	Mg/l	0.1	Plastic or Glass	Ice; 5 ml 1+1H2SO4	28 Days	365.3 / EPA 1983
Total Ammonia	WDEQ	Mg/l	0.1	Plastic or Glass	Ice; 5 ml 1+1H2SO4	28 Days	350.3 / EPA 1983

TABLE 6-1.   Con't

Parameter	Sampling Agency	Reporting Unit	Minimum Detection Limit	Sample Container	Preservation	Holding Time	Method / Reference
Total Hardness	WDEQ	Mg/l	10	Plastic or Glass	Ice; 5 ml 1+1HNO3	6 Months	130.1 / EPA 1983
Fecal Coliform	SCCD;WDEQ	No./100ml	1 to 10	Sterile Plastic or Glass	Ice	6 Hours	Membrane Filter /EPA 1978
BOD	WDEQ	Mg/L	1	Sterile Plastic or Glass	Ice	48 Hours	405.1 / EPA 1983
Organochlorine Pesticides (Various)	SCCD	Mg/l	.0004	Glass	Ice	7 Days	EPA Method 8081
Chlorinated Herbicides (Various)	SCCD	Mg/l	.0004	Glass	Ice	7 Days	EPA Method 8150
Benthic Macroinvertebrates	SCCD;WDEQ	Metrics	Not Applicable	Plastic	Isopropyl Alcohol and Formalin	None	King 1993
Habitat Assessment	SCCD;WDEQ	Parameters	Not Applicable	None Required	None Required	None	King 1993
Periphyton	WDEQ	Unknown	Not Applicable	Plastic	Formalin and Lugol's	None	Modified from Porter et al. 1993
Discharge	SCCD;WDEQ; USGS	Cubic Feet per Second (CFS)	1 CFS	None Required	None Required	None	Calibrated Staff Gage NRCS and USGS Internal Methods
Ambient Air Temperature	NRCS	C^0	0.1	None Required	None Required	None	NRCS Internal Methods
Precipitation	NRCS	Inches	0.1	None Required	None Required	None	NRCS Internal Methods

Wyoming surface water quality standards for Class 2 waters prohibit temperature increases which change natural water temperatures to levels which are deemed harmful to existing coldwater fish life, which is considered to be 78 degrees F (25.6 degrees C) (WDEQ, 1998). Prohibited are activities which cause temperature changes in excess of 4 degrees F (2.2 degrees C) from ambient water temperatures (WDEQ, 1998).

Review of historical temperature data indicated that instantaneous grab samples for water temperature normally collected during water quality monitoring were insufficient to detect maximum daily stream temperature critical to trout. The review of historic continuous surface water temperature data collected by WGFD at an upper Tongue River station in 1988 (Appendix Table E-1) and at a Tongue River station in Ranchester (Appendix Table E-2) clearly illustrated the need for continuous recording thermometers to detect thermal trends affecting trout. Detailed discussion of this data set and implications for routine water temperature monitoring conducted by SCCD and WDEQ is found in Section 8.5.2.

The WGFD data set was not discovered by SCCD until after the 1998 monitoring season began. The monitoring budget did not allow for purchase of continuous recording thermometers or thermisters. It was recommended that future monitoring at the mainstem Tongue River Middle and Lower Stations and each major tributary Lower station include continuous temperature recorders (Section 10).

Should Wyoming quality standards for water temperature be exceeded, management changes may be implemented to mitigate the problem. Water conservation and improved irrigation management combined with riparian management to promote cover and shading may result in more consistent stream discharge and lower water temperature benefitting trout and aquatic organism populations.

6.3.1.2 pH

The pH of water is a standard measurement conducted for water quality monitoring. Values for pH range from 0 to 14 standard units (SU). The pH of pure water at 24 degrees C (75.2 degrees F) is 7.0 SU which is neutral. Water greater than 7.0 SU is considered basic and water with a pH below 7.0 SU is considered acidic. The pH for most mountain streams in northeast Wyoming ranges from near neutral to slightly basic while plains streams are usually basic. Streams coursing through limestone formations common within the upper Tongue River and tributary watersheds should normally have pH values greater than 7.0 SU.

Daily fluctuations in stream pH are common and may be quite pronounced when considerable in stream plant growth is present. The pH usually rises during daylight hours in response to plant photosynthesis which reduces the buffering capacity of water. Reduction in pH normally occurs during the night when plant photosynthesis is reduced. Some tributary streams in the Tongue

River watershed Project area contain rooted aquatic plants thus, variable pH readings may be expected dependent upon the time of day that pH is measured.

The pH of water contained in irrigation storage reservoirs present in the Five Mile Creek drainage may produce significant amounts of algae (microscopic plants) during the warmer summer season. Water released from these reservoirs may have high pH values and potentially affect the receiving stream.

EPA has set a pH range from 6.5 SU to 9.0 SU to protect aquatic life (EPA, 1986). The Wyoming water quality standard limits pH from 6.5 SU to 9.0 SU (WDEQ, 1998).

6.3.1.3 Conductivity

The primary purpose for measurement of conductivity is to provide an estimate for the relative concentration of Total Dissolved Solids (TDS). TDS is a measure of the amount of total substances that are dissolved in water and although not entirely correct, has also been referred to as salinity. Conductivity is not directly proportional to the TDS concentration; however, the higher the concentration of dissolved substances present in water, the higher the conductivity measurement. Thus, conductivity is a reliable, inexpensive estimator of TDS. Conductivity is measured in the field whereas determination of TDS concentration requires a more expensive laboratory analysis.

TDS may pollute streams due to irrigation delivery system seepage (Riggle and Kysar, 1985) and poor quality irrigation return flow (MacDonald et al., 1991). High conductivity can negatively affect aquatic organisms. King (1990) reported that aquatic organisms in several northeast Wyoming plains ponds were affected when conductivities were greater than 6,900 umhos/cm. EPA (1988a) found that high conductivity and chloride concentrations resulted in lower diversity of stream macroinvertebrate taxa. Lower diversity of stream macroinvertebrates used as a food source for stream fish may negatively affect fish populations.
There were no Wyoming surface water standards for conductivity or TDS since these parameters generally pose no significant threat to surface water supplies, beneficial use, fisheries and aquatic organisms. However, quality standards are established for Wyoming groundwater such that TDS concentrations for domestic, agriculture, or livestock use shall not exceed 500 mg/l, 2000 mg/l, or 5000 mg/l, respectively (WDEQ, 1993).

6.3.1.4 Dissolved Oxygen

Dissolved oxygen (DO) is the amount of free oxygen available to fish and aquatic organisms. A minimum of 4 milligrams per liter (mg/l) is required for maintenance and survival of most aquatic organisms. One mg/l is equivalent to one part per million (ppm). Trout and other coldwater fish generally require a minimum of 5 mg/l DO.

Temperature and DO are inversely related in that as the water temperature rises, the DO concentration decreases. Moreover, elevation and DO are inversely related. As elevation increases, DO decreases. DO depletion rarely occurs in shallow, well mixed, aerated streams (Hynes, 1970) typified by water bodies in the Tongue River Project area. Low DO was not expected to occur in the Tongue River Project area streams.

Wyoming surface water quality standards for DO in Class 2 water bodies were designed to protect both the early life stages for coldwater fish (eggs, larvae and juveniles) and other life stages (adults). A 1 day minimum DO concentration of 5.0 mg/l was set for early life stages and a minimum 1 day minimum DO concentration of 4.0 mg/l was set to protect adult coldwater fish.

6.3.1.5 Discharge

Discharge is the measure of the amount of water flowing in a water body and is usually expressed as Cubic Feet per Second (cfs). Discharge is an important physical parameter measured during water quality monitoring because it may affect the concentration and quantity of pollutants. For example, in most Wyoming streams TSS, turbidity, nitrate and phosphorus will normally increase with increasing stream discharge while conductivity, chlorides, sulfates and other ions will normally decrease with increasing stream discharge. Discharge may be used to estimate the load, or amount, of a pollutant by combining measured stream discharge with the concentration of a pollutant. Estimate of pollutant loads assist to evaluate pollutant response to variable temporal and spatial stream discharge and provide information for sources of pollutants.

Adequate discharge must be present to fill the stream channel or critical habitat for fish and aquatic organisms is lost. Water quality may be sufficient to support aquatic populations, but without sufficient water, fish and organisms may be stressed or death may occur resulting in non support for the Wyoming beneficial use for the protection and propagation of fish and wildlife (see Section 4.2). Corning (1969) found that productive trout streams were transformed into non productive water bodies due to extreme water fluctuation. The primary causative factor was a 94% loss in surface water area resulting from stream discharge reduction during the summer months.

There were no Wyoming or U.S. EPA standards established for discharge. However, in stream flow rights may be granted through the State of Wyoming Engineer to establish minimum discharge for a water body (see Section 3.1.1, Tongue River in stream flow).

6.3.1.6 Precipitation and Air Temperature

Precipitation and temperature are essential components in watershed scale monitoring projects. Both may be used to estimate the timing and magnitude for water yield (discharge) within the Project area. Hydrologic processes are controlled by precipitation and air temperature because accumulated snowpack and runoff are largely determined by this interaction. Water yield will affect chemical, physical, biological and habitat characteristics for water bodies within the watershed. Precipitation and temperature must be factored into water quality data analyses because observed water quality change among years may be related to normal annual fluctuation in meteorological conditions rather than anthropogenic (man caused) effects.

6.3.1.7 Habitat Assessment

Evaluation of stream habitat is a necessary component of the total water quality monitoring program. Disruption of upland, riparian and in stream habitat can adversely affect stream water quality and biological communities. Good habitat quality is key to good fish populations and healthy aquatic biological communities. Soil compaction, loss of ground cover and eroding stream banks can result in increased discharge, erosion, sedimentation and water temperature. Trout spawning and rearing habitat may be lost and macroinvertebrate populations which serve as food for trout may be reduced.

There were no numeric standards for habitat quality in Wyoming water quality standards. However, Section 15 (Settleable Solids) and Section 16 (Floating and Suspended Solids) in Chapter 1 of the Wyoming standards refer to narrative (non-numeric) standards for Settleable Solids, Floating and Suspended Solids that shall not be present in quantities which could result in significant aesthetic degradation, significant degradation of habitat for aquatic life, or adversely affect other beneficial uses.

In addition for use to address narrative Wyoming water quality standards, the habitat assessment may be used to determine if change in benthic macroinvertebrate populations was due to change in water quality or to change in habitat quality. General habitat quality will also be compared between the Upper and Lower stations for the Tongue River and tributaries.

Habitat Assessment data collected during the Project will be compared to habitat assessment data collected from Reference Stream reaches identified during statewide WDEQ Reference Stream Project monitoring at similar stream types in the Northwestern Great Plains ecoregion and Middle Rockies ecoregion of Wyoming.

6.3.2 Laboratory Analyzed Water Chemistry Parameters

6.3.2.1 Turbidity

Turbidity is a common parameter measured in water quality monitoring studies since analysis of samples is inexpensive and results may be used as an indicator of suspended sediment concentration. Turbidity is based on a comparison of the intensity of light scattered by a water sample with the intensity of light scattered by a standard reference solution under the same conditions (American Public Health Association, 1975).

A strong correlation may exist between turbidity and suspended sediment. The higher the turbidity value, the higher the suspended sediment concentration. High turbidity may be caused by substances other than sediment. Presence of natural water color due to high mineral content (i.e. sulfates, chlorides), or to significant amounts of algae entrained in water may affect turbidity values. However, no significant natural water color or high concentration of algae were expected in the Project area with the possible exception of Five Mile Creek where summer water release from Five Mile Reservoir may contain algae.

The Wyoming water quality standard for turbidity in Class 2 waters which are cold water fisheries states that the discharge of substances attributable to or influenced by the activities of man shall not be present in quantities which would result in a turbidity increase of more than 10 nephelometric turbidity units (NTU's). Each water body in the Project area has been designated as Class 2 cold water. In all Class 3 waters and Class 2 waters which are warm water fisheries, the discharge of substances attributable to or influenced by the activities of man shall not be present in quantities which would result in a turbidity increase of more than 15 NTU's (WDEQ, 1998).

6.3.2.2 Total Suspended Solids

Total suspended solids (TSS) is the measure of suspended solid material in the water column. The majority of TSS present in streams within the Project area will be comprised of sediment. This is a valuable indicator parameter because it may be used to track and identify sources contributing sediment to a water body. TSS is highly variable and is generally correlated to stream discharge. Because of this variability, large numbers of samples may be required to adequately estimate mean daily, monthly or annual TSS concentration. SCCD did not collect TSS samples during this Project because the monitoring budget did not allow for collection of an adequate number of samples. WDEQ collected TSS samples annually at their monitoring stations.

There was no Wyoming water quality standard for TSS. However, narrative standards in Section 15 and Section 16 of the Wyoming water quality standards addressed effects due to sediment deposition. Section 15 states that in all Wyoming surface waters, substances attributable to or influenced by the activities of man that will settle to form sludge, bank or bottom deposits shall not be present in quantities which could result in significant aesthetic degradation, significant degradation of habitat for aquatic life or adversely affect public water supplies, agricultural or industrial water use, plant life or wildlife (WDEQ, 1998). Section 16 stated that in all Wyoming surface waters, floating and suspended solids attributable to or influenced by the activities of man shall not be present in quantities which could result in significant aesthetic degradation, significant degradation of habitat for aquatic life or adversely affect public water supplies, agricultural or industrial water use, plant life or wildlife (WDEQ, 1998).

6.3.2.3 Alkalinity

Alkalinity is the sum total of components in the water that tend to elevate the pH of the water above a value of about 4.5 SU. It is a measure of the buffering capacity of water, and since pH has a direct effect on organisms as well as an indirect effect on the toxicity of certain other pollutants in the water, the buffering capacity is important to water quality (EPA, 1986). The pH is also used in the evaluation and control of water and waste water treatment processes.

Dissolved substances such as carbonates, bicarbonates, phosphates, hydroxides (USEPA, 1986), borates and silicates (APHA, 1975) can increase stream alkalinity. Stream water high in alkalinity can maintain ambient pH when exposed to acidic water better than water low in alkalinity. Alkalinity is important for primary production (bacteria and algae) in streams which directly affect benthic macroinvertebrate populations that serve as food for fish. Generally, as alkalinity increases, stream productivity and density (total number of organisms) increases.

SCCD did not collect TSS samples during this Project. WDEQ collected alkalinity samples annually at their monitoring stations and RPWD collected daily alkalinity samples at the WTP since 1998.

There was no Wyoming water quality standard for alkalinity. Naturally occurring maximum alkalinity levels up to approximately 400 mg/l as calcium carbonate ($CaCo_3$) are not considered a problem to human health. Without adequate alkalinity levels, a water body may experience dramatic shifts in pH which can disrupt fish and other aquatic life. EPA (1986) suggested a minimum of 20 mg/l alkalinity was required for adequate productivity in streams.

6.3.2.4 Total Sulfate

Sulfate is a potential significant pollutant in Wyoming streams. It is naturally present in waters in concentrations ranging from a few to several thousand mg/l (APHA, 1975). Higher sulfate content is expected in groundwater close to sodium chloride and other chloride salt deposits in sedimentary rocks. Drinking water high in sulfate (greater than 600 mg/l) may have laxative effects on individuals. Water high in sulfate consumed by livestock may cause the "blind staggers" and eventual death. Increased sulfate concentration in streams is a good indicator of anthropogenic (caused by man) effects because irrigation return, industrial, oil field produced water and other point source discharge effluents may artificially elevate ambient levels.

Increase in sulfate appears to negatively affect aquatic life and benthic macroinvertebrates. Winget and Mangum (1979) studying streams in the Great Basin, found that as sulfate levels increased, macroinvertebrate community diversity decreased. They indicated that a sulfate concentration below 150 mg/l was optimal for macroinvertebrates.

Wyoming has not established a surface water quality standard for sulfate. However, sulfate limits for Wyoming groundwater are 250 mg/l, 200 mg/l and 3000 mg/l for domestic, agricultural, and livestock use, respectively (WDEQ, 1993). EPA has recommended a secondary drinking water standard at 250 mg/L. The secondary drinking water standard was not an enforceable standard, but should be a goal for consideration of public health.

6.3.2.5 Total Chloride

Chloride naturally occurs in streams and is a principal component of salt (NaCl). Wyoming mountain and foothill streams generally contain low chloride concentrations (generally <25 mg/l). Streams draining from sedimentary deposits high in salts may result in higher chloride levels. Stream chloride levels may increase due to oil and gas produced water, industrial and municipal effluent and irrigation return. Water impounded by reservoirs may increase chloride and sulfate concentration by a process termed evaporative concentration. Water held in reservoirs may evaporate, but chloride and sulfate are left resulting in higher chloride and sulfate levels that may be discharged to receiving waters.

Plants are more sensitive than humans to high chloride content. Thus, the Wyoming groundwater standard sets chloride content at 250 mg/l for domestic use, 100 mg/l for agricultural/irrigation water and 2000 mg/l for livestock use (WDEQ, 1993). The Wyoming surface water quality and U.S. EPA standard for chloride is 860 mg/l for protection of aquatic life (WDEQ, 1998).

Aquatic life is sensitive to chlorides at higher concentrations. O'Neil et al. (1989) studying effects of coalbed methane produced water, found that chloride concentrations at or below 565 mg/l produced no significant effects to the benthic macroinvertebrate community structure in study streams. Chloride values above 565 mg/l showed defined impairment to the community. Birge et al. (1985) found that benthic macroinvertebrate community structure was negatively affected by increasing chloride concentration. They recommended that the average chloride concentration should not exceed 600 mg/l over thirty consecutive days and a maximum instantaneous (one time sample) should not exceed 1,200 mg/l.

6.3.2.6 Total Nitrate Nitrogen

Nitrate nitrogen (NO_2 + NO_3-N) in streams may originate from several possible sources including the atmosphere, plant debris, animal waste and sewage, nitrogen based fertilizers and some industrial wastes. Nitrate is considered to be one of the primary nutrients (along with phosphorus) associated with Nonpoint Source (NPS) pollution. Nitrate is the end product of the decomposition of decomposed organic material such as sewage and excrement. Bacteria acts on organic material changing it to ammonia (NH_3), then nitrite (NO_2) and finally nitrate (NO_3).

Wyoming has adopted the EPA drinking water human health standard of 10 mg/l for Class 2 surface waters (WDEQ, 1998). The EPA standard of 10 mg/l for drinking water supplies was to protect against toxic infant methemoglobinemia (blue baby syndrome) characterized by a bluish color of the skin (EPA, 1986). EPA has not established surface water standards for nitrates since concentrations required for toxicity to cold or warmwater fish rarely occur in natural waters (EPA, 1986). High concentrations of nitrate in livestock drinking water has resulted in abnormally high mortality rates in baby pigs and calves and abortion in brood animals. USGS (1999) reported that national background concentrations of nitrate from streams in undeveloped areas (reference-like areas) was about 0.6 mg/L. However, they cautioned that the overall national background levels were higher than those concentrations measured from relatively undeveloped areas.

Nitrate generally has no direct effect on aquatic organisms. Indirect effects are manifest by stimulation of bacteria, periphyton, algae and in stream macrophyte (submerged and rooted plants) growth which in turn, may stimulate benthic macroinvertebrate and fish production. The benthic macroinvertebrate community structure may shift due to increased abundance of periphyton and algae used as food or refuge by different taxa. Thus, evaluation of the benthic macroinvertebrate community change can indicate nitrate pollution.

6.3.2.7 Total Phosphorus

Phosphorus and nitrate are the two most common nutrients associated with NPS pollution. Phosphorus is an essential element for plant growth. However, generally low levels of phosphorus (>0.2 mg/l) can stimulate primary production (bacteria, periphyton, algae) and plant growth when in the presence of sunlight. Strict control of phosphorus is required in watersheds draining to lakes and reservoirs because aquatic organisms and plants rapidly assimilate phosphorus resulting in potential nuisance algae and plant populations creating unfit conditions for human recreation and problematic filter clogging algal forms in municipal water treatment plants. Bacterial breakdown of dense growth of algae and plants consumes dissolved oxygen often resulting in oxygen depletion in lakes and reservoirs stressing or killing fish and aquatic organisms.

Naturally occurring phosphorus enters streams primarily by soil erosion and sediment transport. Additional phosphorus may enter streams through municipal and industrial point discharges, runoff containing animal wastes and phosphate fertilizes. Phosphorus creates less problems in streams than in lakes and reservoirs since phosphorus is accumulated in bottom sediments. Phosphorus is difficult to eliminate from standing water bodies because they serve as sediment traps and generally cannot be flushed of bottom sediments.

Wyoming has not established surface water quality standards for phosphorus because problems associated with this pollutant are generally site-specific due to localized sources of phosphorus affecting individual water bodies. U.S. EPA (1977) recommended that total phosphorus concentration should not exceed 0.05 mg/l in a stream that enters a lake or reservoir (e.g. Tongue River Reservoir) to prevent development of nuisance algal and plant populations. Mackenthun (1973) suggested a target phosphorus level of less than 0.10 mg/l for streams that did not directly enter lakes or reservoirs. Recent information provided by USGS (1999) from nationwide NAWQA monitoring and assessment reported that national background concentrations for total phosphorus from streams in undeveloped (reference - like) areas was about 0.10 mg/L. USGS indicated that waters with concentrations of total phosphorus greater than the national background concentration were considered to have been affected by human activity. They found that enrichment of streams with nutrients generally occurred in small watersheds and regions dominated by agricultural or urban land use.

The natural background level in relatively undisturbed watersheds (0.10 mg/l) presented by USGS (1999) conflicted with the EPA recommended standard (0.05 mg/l) because the national background (reference) concentration found by USGS was two-fold greater than the EPA recommended standard. This observation indicated that in order to meet the recommended EPA standard for total phosphorus, a water body would have to reduce its total phosphorus concentration by 50 percent below that of natural background. Because this goal was not attainable, SCCD adopted the finding by USGS as the recommended standard for interpretation of total phosphorus data collected during this Project. The recommended standard was not an enforceable standard.

6.3.2.8 Ammonia

Ammonia is a byproduct of the decomposition of organic material and by the hydrolysis of urea (found in urine). It is toxic to aquatic organisms in low concentration. U.S. EPA (1986) cited chronic (long term) mortality in trout when ammonia concentration ranged from 0.083 to 1.090 mg/l and from 0.140 to 4.60 mg/l for non-trout species.

Ammonia is generally unstable in water and in most stream systems quickly converts to nitrite and then to nitrate. Thus, it provides evidence of localized pollutant sources when identified in streams. SCCD did not sample for ammonia during this Project. WDEQ sampled for ammonia only in 1998 in conjunction with intensive sampling in the vicinity of the Dayton WWTF.

Seemingly harmless changes in pH and temperature can greatly affect the toxicity of ammonia to aquatic organisms and fish. The toxicity of ammonia to aquatic organisms is increased by increasing water pH. For example, a total ammonia concentration that would have virtually no lethal effect on fish at a pH of 7 could become acutely toxic if the pH were raised to 8. Decreasing water temperature generally increases the toxicity of ammonia to fish.
The Wyoming water quality standard for ammonia is variable because of the interaction between pH and temperature. However, an upper limit of 0.26 mg/l for ammonia based on a single

sample exposure should protect trout and coldwater aquatic life from mortality (WDEQ, 1998; *in* Appendix C). The Wyoming groundwater standard for ammonia for domestic use is 0.50 mg/l (WDEQ, 1993). USGS (1999) reported that national background concentration for total ammonia from streams in undeveloped areas was about 0.10 mg/L.

6.3.2.9 Total Hardness

Hardness is related to the concentration of metals (metallic ions) and is usually equivalent to the concentration of calcium carbonate ($CaCo_3$). Hardness may be used as an indicator to determine suitability of water for industrial use (i.e. Wyoming beneficial use for Industry). The maximum acceptable hardness concentration for industrial use varies according the type of industry. Table 6.2 shows the maximum hardness levels accepted by industry as a raw water source (after EPA, 1986).

TABLE 6-2. Maximum Hardness Levels Accepted by Industry

Industry	**Maximum Concentration (mg/l) as $CaCo_3$**
Electric utilities	5,000
Textile	120
Pulp and paper	475
Chemical	1,000
Petroleum	900
Primary metals	1,000

A commonly used classification for hardness is presented in Table 6.3 (*in* EPA, 1986; after Sawyer, 1960).

TABLE 6.-3. Classification of Water by Hardness Content (mg/l as $CaCo_3$).

Concentration	**Description**
0 - 75	Soft
75 - 150	Moderately Hard
150 - 300	Hard
300 +	Very Hard

Water that comes into contact with natural limestone formations is the primary source for hardness in streams. Municipal and industrial (especially subsurface mines) point source effluents, storm drain discharge, and to a lessor extent, runoff from agricultural areas, may elevate hardness concentration.

Wyoming and U.S. EPA have not established water quality standards for hardness. Because hardness in water can be removed with treatment by such processes as softening or ion exchange systems, a standard for industrial use or for public water supply is not practical. Moreover, the effects of hardness on fish and aquatic life appear to be related to the specific ions causing the hardness (i.e. calcium, magnesium, manganese) rather than the hardness itself (EPA, 1986).

6.3.2.10 Pesticides and Herbicides

Pesticides and herbicides may enter surface water bodies through surface runoff, ground water discharge or direct application through accidental spillage or haphazard aerial and ground application. Once in water, many of these man-made compounds may persist and pose human health and safety risks. Pesticides and herbicides may work their way into the aquatic food chain by benthic and terrestrial organism uptake, consumption of the organisms by fish, and accumulation in fish tissue consumed by wildlife and humans. Contamination of drinking water supplies is a major concern because many of these compounds may be carcinogenic at low concentration. Because Tongue River is a popular recreational fishery and drinking water source for the Town of Dayton and the Town of Ranchester, SCCD sampled for select herbicides and pesticides once in 1996. USGS sampled for numerous pesticides and herbicides in fish tissue and bed sediment at USGS station 06298000 (SCCD Tongue River Upper station) in 1998 as part of the Yellowstone NAWQA.

WDEQ and EPA have established drinking water standards for numerous pesticides and herbicides. The list of standards for individual pesticides and herbicides is extensive and is not presented in this Final Report. However, the reader may refer to Appendix B in Wyoming Surface Water Quality Standards (WDEQ, 1998) for standards applicable to many of these compounds.

6.3.3 Laboratory Analyzed Biological Parameters

6.3.3.1 Fecal Coliform Bacteria

Fecal coliform bacteria are present in the digestive tract of humans and all mammals. Sampling for fecal coliform bacteria may be considered as one of the most important tests conducted in water quality monitoring programs because of public health and safety concern. Cholera, typhoid fever, bacterial dysentery, infectious hepatitis and cryptosporidiosis are some of the well known diseases that spread through contact with fecal contaminated water. Eye, ear, nose and throat infections may also result from contact with contaminated water.

Presence of fecal coliform bacteria in water indicates that the water is contaminated with fecal material and the possible presence of pathogenic organisms harmful to humans. Animals may be carriers of these pathogens as well as humans. Because of this, domestic sewage from wastewater treatment systems and runoff from land may contaminate water with human pathogens.

Escherichia coli (*E. coli*) is a species of fecal coliform bacterium commonly identified as an indicator of fecal contamination. This species comprises many different strains of which the vast majority are not pathogenic to humans (Hinton, 1985). However, particular strains of *E. coli* (i.e. *E. coli* 0157:H7) and other verotoxic strains may be responsible for haemorraghic colitis (severe diahhrea) and haemolytic uraemic syndrome (kidney failure) in humans which may be fatal if left untreated.

The fecal coliform bacteria standard for Wyoming Class 2 water bodies is comprised of two parts:

1. During the entire year, fecal coliform concentrations shall not exceed a geometric mean of 200 fecal coliform groups per 100 milliliters (based on a minimum of not less than 5 samples obtained during separate 24 hour periods for any 30 day period), nor shall 10 percent of the samples exceed 400 groups per 100 milliliters during any 30 day period in any Class 4 water and at all public water supply intakes (e.g. Town of Dayton and Town of Ranchester Water Treatment Plant Intakes).

2. During the recreation season, (May 1, through September 30) fecal coliform concentrations shall not exceed a geometric mean of 200 fecal coliform groups per 100 milliliters (based on a minimum of not less than 5 samples obtained during separate 24 hour periods for any 30 day period), nor shall 10 percent of the samples exceed 400 groups per 100 milliliters during any 30 day period in all Wyoming surface waters.

6.3.3.2 Biochemical Oxygen Demand

Biochemical oxygen demand (BOD) is the measure of the amount of oxygen required to breakdown organic matter through the action of bacteria. Large amounts of organic matter may consume large amounts of oxygen during this process depriving aquatic organisms and fish of oxygen. Fish kills have resulted from spillage of large quantities of waste manure from confined animal feeding operations into streams. Sources of organic material in streams affecting BOD may include municipal wastewater discharges, runoff from animal feeding operations, storm drain discharge, septic tank leach field systems and agricultural runoff.

SCCD did not sample for BOD during this Project. WDEQ sampled for BOD only in 1998 in conjunction with intensive sampling in the vicinity of the Dayton WWTF. Wyoming and EPA have not established surface water quality standards for BOD. However, required monitoring for

BOD is common for municipal wastewater treatment system discharge to determine effectiveness of the specific treatment system and to evaluate potential impact to receiving water bodies.

6.3.3.3 Benthic Macroinvertebrates

Aquatic macroinvertebrates (bugs) reside in and on bottom substrate of streams. They are small but visible to the naked eye and large enough to be retained in a U.S. Standard No. 30 sieve. Benthic macroinvertebrate populations provide another valuable tool for assessment of water quality. Some may argue that macroinvertebrates provide the most holistic assessment of stream health or aquatic life use attainment because they are year around monitors and incorporate both water quality and habitat quality change. Because macroinvertebrates are relatively immobile and live in the stream for most of their lives, they are exposed to daily and seasonal water quality changes often missed by conventional water quality monitoring. Water chemistry sampling provides information for the quality of water at the time of sample collection. In contrast, macroinvertebrates serve as continuous monitors of stream water quality and are exposed to variable concentrations of pollutants over extended periods of time. This is an important concept because water quality sampling may miss important changes in water quality due to normal seasonal and spatial variability, accidental material spills, or facility wastewater treatment plant malfunction that macroinvertebrates may detect.

Water quality monitoring evaluates a series of individual parameters (i.e. temperature, DO, turbidity) to determine if they are within standards. If they are within standards, then it is assumed that aquatic life use is fully supported. However, this assumption may not be true because this approach fails to account for the usual synergistic interaction between water quality parameters. For example, a stream with higher water temperature and turbidity and lower DO and pH approaching water quality standards, but that are within standards, when combined may produce negative synergistic stress on aquatic biological populations resulting in non-support of aquatic life use.

Wyoming water quality standards established for chemical and physical water quality parameters (*in* WDEQ, 1998, Appendixes B, C, and D, Chapter 1, Wyoming Water Quality Rules and Regulations) are established to protect aquatic life and human health. Instead of using sampling results from individual chemical and physical water quality parameters, evaluation of benthic macroinvertebrate populations may serve as a **direct** measure to determine support for aquatic life use in addition to validating the effectiveness of individual narrative and numeric water quality chemical and physical standards. Benthic macroinvertebrates also serve to integrate water quality and habitat quality interaction, and evaluate potential synergistic effects from multiple chemical and physical water pollutants not measured during routine water quality monitoring.

Wyoming has developed preliminary Biological Criteria for streams statewide (Stribling et al., 2000), but they have not been adopted as numeric, enforceable standards. As such, they may be interpreted as narrative standards to determine beneficial use attainment for protection and propagation of fish and wildlife. WDEQ (2000) proposed narrative Biological Criteria in Chapter 1, Section 32 revised rules and regulations to protect indigenous or intentionally introduced aquatic communities (i.e. brown, brook and rainbow trout species). In addition, Section 4 in the current Wyoming water quality standards relate the presence of food sources (e.g. benthic macroinvertebrates) for game and nongame fish as a criteria for Surface Water Classes and (beneficial) Uses (WDEQ, 1998).

6.3.3.4 Periphyton

Periphyton are microscopic and macroscopic organisms attached to or living in proximity to stream substrates. Periphyton communities are usually dominated by algae, but may include bacteria and microinvertebrates. They are in direct contact with water and are directly affected by water quality. Periphyton are useful for water quality assessments because they have rapid reproduction rates and short life cycles, and thus they respond quickly to anthropogenic (man caused) perturbation.

Wyoming and U.S. EPA have not established biological criteria for periphyton for surface waters. Many of the same advantages offered by the assessment of macroinvertebrates are afforded by the assessment of periphyton communities. They serve to integrate water quality and habitat quality interaction, and evaluate potential synergistic effects from multiple chemical and physical water pollutants not measured during routine water quality monitoring.

SCCD did not sample periphyton during this Project. WDEQ initiated annual periphyton sampling in 1998 at the long term Tongue River Upper reference station and sampled periphyton at the Tongue River Lower station in 1998. Analytical results were not available for this Final Report. USGS sampled algae and periphyton at station 06298000 in 1999, but results were not available for this report.

6.4 Sampling Frequency

SCCD monitoring was based on a random (unbiased) systematic sampling design. Monitoring budget constraints limited the total number of sampling stations, the total number of sampling events and sampling frequency.

With the exception of Five Mile Creek, each tributary to the Tongue River had two sampling stations. One station was sited near the upper boundary and the second station was located near the confluence with the Tongue River. Five Mile Creek had a single lower station established near the confluence with the Tongue River. The Tongue River had three monitoring stations identified as the Upper, Middle and Lower stations. Three monitoring stations allowed SCCD to evaluate changes along the longitudinal gradient and determine potential water quality change from tributary input.

Year around sampling was not conducted due to monitoring budget constraints and historic Tongue River water quality and discharge data indicating that the majority of potential water pollutants were expected to occur between spring runoff (normally starting in April) and the end of the irrigation season (in September).

Tongue River and Lower tributary stations were each sampled two times monthly during April, May and June to coincide with periods of higher stream discharge associated with annual snowmelt runoff. Monthly sampling occurred during the months of July, August and September. Tongue River stations and Lower tributary stations were sampled once in October in association with benthic macroinvertebrate sampling. Upper tributary stations were sampled once monthly due to monitoring budget constraints. SCCD suggests that higher sampling frequency be directed to the Lower tributary stations to better estimate potential pollutants entering the Tongue River. Excluding Fridays, weekends and holidays, sampling dates were chosen randomly with use of the a random number table or computer generated random numbers to prevent “fair day” sampling bias.

Sampling was scheduled to occur at all stations the same day to provide data for upstream - downstream comparisons. However, same day sampling did not regularly occur due to lack of field monitoring personnel and the short holding time afforded by fecal coliform sampling (6 hour holding time). Future sampling should ensure adequate field personnel to complete same day monitoring. Lack of regular same day monitoring did not compromise the integrity of the data set, but rather prevented maximum use of data for upstream - downstream comparisons.

Temperature, pH, conductivity, turbidity and discharge were collected during each sampling event. **Dissolved oxygen** measurements were initiated in 1999 after purchase of an electronic dissolved oxygen meter and measured during each sampling event. **Fecal coliform bacteria** samples were collected monthly at each station. Fecal coliform sampling frequency was increased in 1999 to collection of five (5) samples on separate days during a 30 day period within the recreational season (May 1 through September 30) to better estimate fecal coliform levels and determine attainment of the WDEQ water quality standard for fecal coliform bacteria (See Section 6.3.3.1 and WDEQ, 1998). **Total nitrate** samples were collected monthly at mainstem Tongue River and Lower tributary stations, but not at Upper tributary stations (with the exception of Columbus Creek) due to budget constraints. **Total phosphorus** samples were generally collected twice at each station during the entire Project. WDEQ collected total phosphorus and other water quality parameters annually in September or October at mainstem Tongue River and Lower tributary stations. **Pesticide and herbicide** samples were collected once in 1996 at Tongue River stations, Lower Wolf Creek and Five Mile Creek Lower.

Sampling for **benthic macroinvertebrates** and **habitat assessment** was conducted annually in

September or October at Tongue River and Lower tributary stations. This was the same sampling index period used by WDEQ for benthic macroinvertebrates and habitat assessment. The Tongue River Upper station was sampled by WDEQ because it was a designated long term Reference station monitored annually. No benthic macroinvertebrates or habitat assessments were measured at the Upper tributary stations due to monitoring budget constraints.

6.5 Sampling and Analysis Methods

Field methods followed approved WDEQ sampling protocols (King, 1993). Each sampling location was placed on a riffle marked by permanent fencepost placed above the high water line for easy relocation. Fenceposts served as permanent location markers so that samples would be collected at the same location during the course of the Project thus ensuring sampling consistency. Photopoints were established to provide additional location identification and document general condition of stream habitat.

Riffles were chosen to ensure a well mixed homogenous water mass for representative sample collection (Figure 6-16). Sampling progressed from downstream to upstream locations.

6.5.1 Water Quality

Field water chemistry parameters were measured in-situ, or at the stream, with portable monitoring instruments. Temperature and pH were measured with a Hanna Instruments meter Model No. HI 9025. A two-point calibration using commercially prepared 7 and 10 buffer solutions was performed once prior to sampling or more frequently if the meter appeared to deviate from prior calibration. Calibrations were recorded on field data sheets. Conductivity was measured with a Hanna Instruments conductivity meter Model No. HI 8733. Dissolved oxygen (DO) measurements were made with a YSI 600R multi-probe meter. The meter was calibrated following manufacturers instructions. Other than the DO meter, field meters used by SCCD were the same as those used by WDEQ.

Before sampling, a two gallon plastic bucket was rinsed at least twice with ambient water. Facing upstream, the bucket was filled with stream water and field parameters immediately measured (Figure 6-17). During high water when stream entry was considered hazardous, samples were collected from shore. Buchanan and Somers (1968) and King (1990a) found that a single grab sample adequately represented quality of the water column during high flow and at riffles where water was well mixed. Analytical results were recorded on appropriate field data sheets (Figure 6-18).

Instantaneous grab samples for parameters requiring laboratory analysis were collected directly from the stream in labeled 500 milliliter plastic containers. Fecal coliform bacteria samples were collected in pre-sterilized glass bottles containing sodium thiosulfate to neutralize potential residual chlorine. Pesticide and herbicide samples were each collected in one (1) liter glass containers.

Samples were collected at 0.6 the depth of the water mass when discharge or adequate depth allowed (Ponce, 1980). Care was taken to prevent agitation of stream substrate during low discharge to prevent accidental introduction of sediment into the sample container. With the exception of pesticide and herbicide samples, at least ten percent of samples were collected in duplicate for Quality Assurance and Quality Control (QA/QC) purposes. High analytical cost prevented collection of duplicate pesticide and herbicide samples.

Samples requiring preservation were immediately preserved, placed on ice and hand delivered to the laboratory for analysis (Figure 6-19). Turbidity samples were analyzed at the Ranchester WTP laboratory under supervision of Mr. Harold Herman, Public Works Director. A Hach Turbidimeter Model 2100A was used to analyze samples in accordance with EPA method 180.1 (Figure 6-20). Remaining samples were hand delivered to Intermountain Laboratories, Inc. in Sheridan. Appropriate chain of custody forms and procedures were completed to ensure proper sample tracking, analysis and disposition (EPA, 1988; WDEQ, 1989). Referenced sample analysis methods are listed in Table 6-1.

6.5.2 Discharge

Discharge was measured daily by USGS at Tongue River gage station number 06298000 following normal USGS operational guidelines. Wolf Creek discharge was measured daily by WSBC for USGS from April through September at gage station number 06299500. These data were reported annually in the USGS Water Resources Data Wyoming Water Year publication. Discharge was measured by SCCD at each monitoring station during each sampling event. Staff gages were installed, surveyed and calibrated by SCCD under direction of the NRCS State Hydrologist and assistance from NRCS Sheridan office personnel. Staff gage discharge relationships were developed by the NRCS hydrologist stationed in Casper. The staff gage at Little Tongue River Lower was repositioned during the Project to adequately measure low discharge volume. The staff gage at Five Mile Creek was relocated because it was inundated by a beaver dam.

6.5.3 Precipitation and Air Temperature

Daily precipitation and air temperature were recorded by NRCS at the Burgess Junction Meteorological Station Number WY07E33S. Field data collection and reduction followed established NRCS methods. Daily precipitation and air temperature data were submitted to SCCD electronically from the NRCS Casper, Wyoming office.

6.5.4 Benthic Macroinvertebrates

Benthic macroinvertebrate sample collection and analysis methods were the same as those used by WDEQ described in King (1993). Samples were collected in the late September or October index period. Eight benthic macroinvertebrate samples were collected from a representative maximum 100 foot riffle/run and composited into a single sample. Sampling began at the downstream portion of the riffle and proceeded upstream to prevent substrate disturbance and incidental sampling of drift. A one square foot modified Surber sampler (extended 3 foot net length) fitted with 500 micron (um) netting was used. Computer generated random numbers were used to select individual square foot quadrants. At least ten percent of all locations were sampled in duplicate. Duplicate sampling consisted of two samplers each equipped with a Surber sampler collecting simultaneously next to one other.

The Surber sampler was firmly seated on the stream bottom facing upstream into the stream flow (Figure 6-21). Before disturbing substrate surrounded by the Surber sampler, substrate particle size composition (see Section 6.5.5.1) and embeddedness (see Section 6.5.5.2) measurements were taken. After completion of substrate and embeddedness measurements, larger cobble and gravel within the Surber sampler were scraped by hand and soft brush, visually examined to ensure removal of all organisms, then discarded outside the sampler. Remaining substrate within the sampler was thoroughly agitated to a depth of 2 to 3 inches (5 to 8 centimeters). Net contents were placed in a tub and rinsed into a U.S. Standard No. 35 (500um) sieve. Sieve contents were placed into labeled plastic jars containing an isopropyl alcohol - formalin mixture for preservation (Figure 6-22). A macroinvertebrate sample chain of custody form was completed and placed with samples in a cooler to accompany samples from the field to the laboratory.

Stream current velocity was measured in feet per second (fps) at each Surber sample quadrant after macroinvertebrate collection by placing a portable current meter at 0.6 times the water depth. The meter was placed where the front of the Surber sampler was located. The purpose for velocity measurement was to determine if differences in sediment deposition and embeddedness among stations may be due to differences in current velocity.

Samples were sent to Aquatic Biology Associates (ABA) in Corvallis, OR for processing and analysis. This was the same laboratory used by WDEQ and thus, the same analytical methods were used. Lead taxonomist was Mr. Robert Wisseman, ABA Senior Scientist. Other specialists that may perform specific identifications for rare or unusual specimens included Dr. John Gelhaus of the Philadelphia Academy of Natural Sciences for Tipulidae (crane flies), Dr. Don Klemm of the U.S. EPA, Cincinnati for Hirudinea (leeches), Mr. Douglas Spencer, private consultant, Fowlerville, Michigan and Dr. Thomas L. Boullion of Sierra Consulting Services, Cottonwood, CA for Oligochaeta (worms), Ms. Tracey Anderson, Oregon State University, Corvallis, Dr. Len Ferrington, Jr., University of Kansas, Manhattan and Mr. Gary Lester of Eco-Analysts, Moscow, ID, for Chironomidae (non-biting midges), Dr. Terrence Frest of Deixus

Consulting, Seattle for Gastropoda (snails) and Pelecypoda (clams) and Dr. Cheryl Barr, University of California, Berkeley, for Coleoptera (beetles) and Elmidae (riffle beetles).

In the laboratory, at least 500 organisms (usually 500 to 550) were removed from randomly selected squares in a gridded tray described by Caton (1991). When organism density was high (greater than 300 organisms per square), the next square or subsample was subdivided into quarters by placing an X-shaped frame over the petri dish or sorting container. A random number from 1 to 4 was selected and all organisms were removed from the corresponding quarter. The entire sample was analyzed if less than 500 organisms were present. After subsampling was completed and 500 to 550 organisms removed, the sorter re-distributed the remaining sample within the gridded tray and spent about 5 minutes looking for Large and Rare organisms (Vinson and Hawkins 1996). Organisms removed during the large and rare search were placed in a separate vial and assigned an occurrence of one (1) for the correction factor, density and metric calculations. Organisms were hand picked using illuminated 2X and 3X magnifiers or stereozoom binocular microscope and no flotation methods were employed (Figure 6-23).

The majority of organisms were identified to genus or species with the exception of taxonomically indistinct worms and certain difficult Dipteran taxa. Zooplankton, including Cladocera, Copepoda and Rotifera, terrestrials, fish, amphibians, reptiles, Ostracoda, bryozoans, protozoans and gastrotrichs were noted, but were not included in taxa lists and metric calculations. A consistent Standard Level of Identification was used during the Project to provide comparable data among years (Table 6-4). The same Level of Identification should be used in future benthic macroinvertebrate monitoring for comparability. Density estimates were expressed as number per square meter (No./m^2). Examples of benthic organisms identified were illustrated in Figures 6-24 through 6-26. Figure 6-24 shows an example of a stonefly (*Pteronarcys*), Figure 6-25 shows an example of a snipe fly (*Atherix*) and Figure 6-26 shows an example of a midge fly (*Chironomus*).

Electronic and hard copy analytical results were sent to SCCD from ABA. Included in the data package was a Taxa List and a list of seventy-two (72) macroinvertebrate metrics for each station. See Appendix G for the list of macroinvertebrate metrics.

6.5.4.1 Macroinvertebrate Data Analysis, Determination of Biological Condition and Aquatic Life Use

A series of metrics were calculated for each benthic macroinvertebrate sample. A metric is a descriptor of one facet of the benthic population that responds to water quality and habitat change in a predictable manner (Barbour et al., 1999). Table 6-5 lists select macroinvertebrate metrics and their response to water quality and habitat quality stressors. Appendix Tables G-1 through G-4 lists seventy-four (74) total metrics calculated for each sample.

Benthic macroinvertebrate data were evaluated by using three different methods:

1. Data comparison to biological criteria defined in the Wyoming Biological Condition Index (WBCI) developed by Barbour et al. (1994) for Bighorn Mountain foothill streams less than 6,500 feet elevation in the Middle Rockies Central ecoregion of Wyoming. Tongue River Upper including the USGS sample station 06298000, Little Tongue River Upper (WDEQ station) and Lower, and Columbus Creek Upper (WDEQ station) were sited in the Middle Rockies ecoregion. Barbour et al. (1994) found nine (9) metrics that consistently responded to water quality and habitat quality change (Table 6-6). Scoring criteria were developed to determine if biological condition was Good, Fair or Poor. The metrics and scoring criteria for the WBCI are presented in Table 6-6.

   Metric values were assigned a score of 5, 3, or 1, then summed. The total score was used to determine a biological condition rating of Good, Fair or Poor (Table 6-7). A biological condition rating of Good indicated full support for aquatic life use and fair or poor ratings indicate non-support for aquatic life use. Non-support indicates the aquatic community was stressed and water quality or habitat improvement was required to restore biological condition to full support for aquatic life use.

2. Stribling et al. (2000) expanded on previous work by Barbour et al. (1994) to develop regionally calibrated biological criteria for Wyoming streams statewide. Because Barbour developed biological criteria only for the Middle Rockies ecoregion streams, SCCD stations sited in the Northwestern Great Plains ecoregion (Smith Creek Lower, Columbus Creek Lower, Wolf Creek Lower and Five Mile Creek) could not be assessed using these criteria. Biological communities in the Middle Rockies ecoregion mountain and foothill streams naturally differed from biological communities in the plains streams of the Northwestern Great Plains ecoregion. Because benthic communities naturally differed between ecoregions, expectations for benthic communities required a different set of biological criteria.

   Biological criteria developed by Stribling et al. (2000) updated criteria for the Middle Rockies ecoregion and presented new biological criteria for streams in the Northwestern Great Plains ecoregion of Wyoming. The biological criteria were based on analysis of monitoring data collected by WDEQ from 1993 through 1997 from multiple reference and non-reference quality streams statewide. Stribling used a different approach to develop scoring and assessment criteria than Barbour by using percent comparison of metrics to the reference benthic community. The rationale for selection of metrics and development of scoring criteria is found in Stribling et al. (2000). Interestingly, there was strong agreement in biological condition determination for Middle Rockies streams assessed using both sets of biological criteria (See Section 8.5.19 and Table 8-15). The updated biological criteria for the Wyoming Stream Integrity Index (WSII) are presented in Table 6-8.

Metric values for the monitoring station were compared to metric values from combined reference (least impacted) stations (Table 6-8) and percentages were calculated. Percentages were summed, then divided by the total number of metrics to provide an Average Index Value. The Average Index Value was used to rate the biological community as Very Good, Good, Fair, Poor or Very Poor (Table 6-7). Biological condition ratings of Very Good or Good indicated full support for aquatic life use and ratings of fair, poor, or very poor indicated non-support for aquatic life use. Non-support indicated the aquatic community was stressed and water quality or habitat improvement required to restore the stream to full support for aquatic life use.

3. Benthic macroinvertebrate communities were compared by station among years (temporal comparison) and between stations (spatial or locational comparison; see Table 9-3 and Table 9-5). Biological condition ratings and certain metric values were compared to certain water quality and habitat variables (including discharge) by linear regression to determine significant associations.

6.5.5 Habitat Assessment

Habitat assessments were conducted at the same stream reach where benthic macroinvertebrates were collected after biological sampling was completed. The habitat assessment was conducted following methods found in Platts et al. (1983), Plafkin et al. (1989) and Hayslip (1993) compiled and modified by King (1993) for use in Wyoming.

The habitat assessment included three components:

1. Semiquantitative substrate particle size composition and embeddedness evaluation;

2. Qualitative habitat assessment for the stream reach; and

3. Photopoints

6.5.5.1 Substrate Composition

Evaluation of substrate was required because substrate particle size was an important factor controlling the composition and density of benthic macroinvertebrate populations. Stream reaches dominated by diverse cobble and gravel substrate will have a diverse benthic macroinvertebrate population (in the absence of water pollution). Stream reaches dominated by sand and silt substrate will exhibit different benthic community composition when compared to reaches dominated by cobble and gravel. Population density and diversity is usually reduced because favorable habitat for colonization of organisms is reduced. Water quality monitoring programs must include evaluation of substrate to determine whether observed change in benthic macroinvertebrate population were due to water pollutants or merely to change in stream substrate. Evaluation of differences in substrate particle size among stations may reveal disruptions in the watershed often evidenced by increased sand and sediment deposition

Immediately after the Surber sampler was seated and before substrate was disturbed, , the percent area occupied by cobble, gravel, fine gravel, sand and silt was estimated (DeBrey and Lockwood, 1990; Platts et al., 1983). A piece of plexiglass was used to reduce surface glare to aid in observation of substrate (Figure 6-27). The following particle size classification was based on Plafkin et al. (1989) and Burton (1991). Particle size composition was evaluated for each of the eight Surber sample quadrats.

Stream Substrate Particle Size Classification

Type	**Size**
Boulder	Greater than 10 inches
Cobble	2.5 inches to 10 inches
Coarse Gravel	1 inch to 2.5 inches
Fine Gravel	.3 inch to 1 inch
Silt	.3 inch and below (texture soft, fine)
Sand	.3 inch and below (texture gritty, coarse)
Hard Pack Clay	.3 inch and below (solid, slick)

When silt was greater than approximately 1/4 inch (about 6 millimeters) in depth, it was classified as silt. When silt was less than approximately 1/4 inch, the substrate underneath the silt was classified.

6.5.5.2 Embeddedness (silt cover)

Embeddedness is a measure of the degree to which cobble and gravel were covered or surrounded by fine silt. Silt which settles on, or penetrates into the streambed is detrimental to fish and benthic macroinvertebrate populations compared to silt entrained in the water column (Campbell and Doeg, 1989). Silt deposited on substrate can result in lowered inter-gravel oxygen concentration reducing survival of trout eggs and negatively affect stream productivity and density of aquatic organisms which are the main food source of cold water stream fish (Hynes, 1970; Hawkins et al., 1983; Waters, 1995). Low levels of silt generally reduces the density of organisms while high levels of silt reduces both density and diversity of organisms (Chutter, 1969;

Lenat et al., 1981). Heavy silt deposition combined with nutrient enrichment (from nitrate and phosphorus) may produce drastic effects by reducing diversity through elimination of macroinvertebrate species (Lemly, 1982).

Embeddedness was classified at the same time as substrate particle size classification for each of the 8 Surber sample quadrate.

The following embeddedness rating system used was described by Platts et al. (1983).

Embeddedness Rating Classification

Rating	Description
5	Less than 5 percent of surface covered by silt
4	Between 5 to 25 percent of surface covered by silt
3	Between 25 to 50 percent of surface covered by silt
2	Between 50 to 75 percent of surface covered by silt
1	Greater than 75 percent of surface covered by silt

Embeddedness data from each quadrate were combined into the Weighted Embeddedness Value (WEV) that described the degree that cobble and gravel were covered or surrounded by silt. Because each quadrate was randomly selected, the WEV provided an unbiased estimate of silt coverage at the study riffle/run.

The WEV may range from 20 (complete silt cover) to 100 (no silt cover). Figure 6-28 illustrated stream substrate with a WEV value of 99 and Figure 6-29 shows stream substrate with a WEV value of 20.

6.5.5.3 Qualitative Habitat Assessment

The habitat assessment is a qualitative assessment comprised of thirteen (13) parameters. Because of the subjective nature of the assessment, results must be interpreted with caution. SCCD attempted to reduce uncertainty by estimating precision for assessments through intra-crew assessments at ten percent of total stations assessed. The intra-crew assessment consisted of two or more individuals each performing the assessment independent of one another without communication. Despite uncertainty for accuracy for the subjective assessment, with proper training, general instream and riparian habitat condition may be adequately described to identify significant habitat deficiencies needing improvement.

The majority of habitat assessment parameters were "discharge dependent". This means many habitat parameters rated higher during periods of higher discharge and some rated lower during periods of low discharge. This was an important consideration because discharge at the unregulated Tongue River Upper station may vary 8-fold between spring high flow and the fall and winter low base flow (Figure 8-3). SCCD attempted to conduct habitat assessments within ± two weeks of the preceding annual date of assessment to reduce bias introduced by variable seasonal stream discharge.

The qualitative habitat assessment method used by SCCD was described in King (1993) and was based on compilation of methods presented in Plafkin et al. (1989), EPA (1991) and Hayslip (1993). The length of stream reach assessed was determined by multiplying the bankfull width times 20, or a minimum of 360 feet (Burton, 1991). SCCD determination of stream reach length assessed was the same as that used by WDEQ.

Habitat parameters were weighted according to their influence on aquatic organisms. **Primary parameters** received the greatest weight and described microhabitat characteristics which have a direct influence on macroinvertebrates. **Secondary parameters** described macrohabitat characteristics through stream channel morphology which indirectly influenced macroinvertebrates and fish. **Tertiary parameters** were weighted less than primary and secondary parameters. These parameters described surrounding land use characteristics which affected streambank and riparian zone stability. The higher the individual or cumulative score, the better the habitat. The maximum habitat assessment score was 200 points.

Primary Parameters (each 20-0 points)

1. **Bottom substrate / Percent fines (silt, sand):** estimated the percent of combined sand and silt **only** within the riffle/run sampled. See Section 6.5.5.1 for Substrate Composition methods.

2. **In stream cover (for fish):** estimated the amount of in stream features serving as habitat and cover for fish for the entire reach.

3. **Embeddedness (silt cover):** estimated the degree to which cobble and gravel were covered or surrounded by silt **only** within the riffle/run sampled. See Section 6.5.5.2 for embeddedness evaluation methods.

4. **Velocity / Depth:** estimated the relative contribution for four different velocity and depth regimes within the entire reach.

    a. Fast and deep
    b. Slow and deep
    c. Fast and shallow
    d. Slow and shallow

A stream reach with equal mixtures of each is desirable and would score high. A stream reach dominated by one velocity/depth regime (which may naturally occur in some stream types) would score low.

5. **Channel Flow Status:** estimated how much of the stream channel and in stream structures were covered by water within the entire reach. Complete inundation of the channel and in stream structures would rate highest.

Secondary Parameters (each 15-0 points)

6. **Channel shape (at bankfull stage):** evaluates the approximate shape of the stream channel at the bankfull stage for the entire reach. Four shapes may be selected and a stream channel may normally be comprised of an admixture of two shapes.

   a. Trapezoidal (undercut banks) will rate highest.
   b. Rectangular will rate high.
   c. Triangular will rate lower.
   d. Inverse trapezoidal (obvious deposition and bars in channel) will rate lowest.

7. **Channel alteration (channelization):** the amount of man-caused channelization (straightening) and channel disruption (dredging) was estimated for the entire reach. The length of time in years since channelization was an important element for assessing this parameter.

8. **Pool / Riffle Ratio:** the approximate ratio for the distance between pools and riffles was estimated. A consistent pool and riffle sequence within the entire reach was desired. A variety of pool and riffle habitat would rate high. Lack of a pool and riffle sequence and dominance by all pool or all riffle would rate low.

9. **Width to Depth Ratio:** the approximate average “wetted” channel width divided by average water depth within the entire reach provided an estimate for the amount of channel that may support fish and aquatic life. A low width to depth ratio less than 7 was optimal and a high width to depth ratio greater than 25 would rate low.

Tertiary Parameters (each 10-0 points)

10. **Bank Vegetation Protection:** estimated the amount of stream bank (at the bankfull stage) within the entire reach that was covered by vegetation, large cobble, boulder and larger woody debris serving to provide bank stability. The rating would increase as bank area covered by protective bank features increased.

11. **Bank Stability:** estimated the amount of bank erosion (at the bankfull stage) within the entire reach evidenced by raw, sloughing or unstable banks. A low proportion of unstable bank areas would rate high. A stream reach dominated by unstable banks would rate low.

12. **Disruptive Pressures:** estimated the degree that vegetation was cropped or removed from the streambank immediately adjacent to stream along the entire reach. Presence of all vegetation expected for the ecoregion, stream channel type and seasonal development would rate high. Significant removal of vegetation would rate lower.

13. **Zone of Influence:** estimated the width of the riparian zone within the entire reach. Consideration was given to the degree of human impact within the riparian zone. A wide riparian zone with negligible human impact provides an adequate buffer zone to filter water pollutants and would rate high. A narrow riparian zone impacted by man related activity would rate low.

Stribling et al. (2000) reported that reference (least impaired) streams in the Middle Rockies ecoregion and Northwestern Great Plains ecoregion of Wyoming would have total habitat assessment scores greater than 100.

6.5.5.4 Photopoints

Photopoints were established at the base of the stream reach. Upstream, downstream and panorama photographs were taken of the stream reach to aid in station relocation, provide a visual record and assist in interpretation of habitat assessment data.

TABLE 6-4. Minimum Standard Level of Identification used for Analysis of Benthic Macroinvertebrate Samples Collected by Sheridan County Conservation District and Wyoming Department of Environmental Quality during Tongue River 205j Project, Sheridan County, Wyoming

Ephemeroptera (mayflies)	
Genus for:	Acanthametropodidae, Ameletidae, Ametropodidae, Callibaetis, Heptageniidae, Isonychiidae, Pseudironidae, Polymitarcyidae, Baetiscidae, Caenidae, Tricorythidae, Ephemeridae, Leptophlebiidae, Oligoneuriidae, Siphlonuridae, Metretopodidae, Ephemerellidae (see below for genera *Drunella* **and** *Timpanoga*).
Species for:	Mature nymphs of the Genus *Baetis*; immatures to genus Mature nymphs of the genera *Drunella* and *Timpanoga*; immatures to genus
Plecoptera (stoneflies)	
Genus for:	Perlodidae, Pteronarcyidae, Peltoperlidae, Perlodidae, Nemouridae
Species or Species Groups for:	Perlidae, mature specimens for the genera *Zapada*, *Kathroperla*, *Sweltsa* and *Doddsia*; immatures to genus
Family for:	early instar Capniidae, Leuctridae, Chloroperlidae, Taeniopterygidae
Trichoptera (caddisflies)	
Genus for:	All genera except for genera in the Family Rhyacophilidae
Species or Species Groups for:	Rhyacophilidae
Coleoptera (beetles)	
Genus for:	Elmidae (combine larvae and adults into one taxon)
Genus or Family for:	All other families (combine larvae and adults into one taxon)
Chironomidae (midge flies)	
Genus for:	All genera except certain *Cricotopus*, *Orthocladius*
Species or species groups for:	*Cricotopus nostococladius, C. trifascia, C. bicinctus, C. isocladius, C. festivellus, C. tremulus; Orthocladius* Complex
NOTE!	Combine all pupae into one taxon identified as Chironomidae pupae

TABLE 6-4. Con’t

Assorted Diptera (flies)	
Family for:	Ceratopogonidae, Culicidae, Dolichopodidae, Ephydridae, Scathophagidae, Sciomyzidae, Stratiomyiidae, Tabanidae
NOTE!	Combine all pupae into one family taxon
Oligochaeta (worms)	
Genus or Species for:	Mature specimens
Family for:	Immature specimens; NOTE: immature Tubificidae will be subdivided into two groups: 1. With capilliform setae, and 2. Without capilliform setae
Turbellaria (flatworms or planarians)	
Class for:	Immatures
Genus for:	Matures
Species for:	*Dugesia tigrina*
Hirudinea (leeches)	
Order for:	Immature specimens
Genus or Species for:	Mature specimens such as *Helobdella stagnalis* which may be common and abundant
Mollusca (clams and snails)	
Family for:	Hydrobiidae, Lymnieidae, Physidae, Planorbidae, Ancylidae, Sphaeriidae, Unionidae
Various Orders and Families	
Genus for:	Anostraca, Eubranchiopoda, Lepidoptera, Megaloptera, Mysidacea, Neuroptera, Notostracea, Odonata; **and** for the following Dipteran Families: Anthericidae, Blephariceridae, Chaoboridae, Deuterophlebiidae, Dixidae, Empididae, Pelecorhynchidae, Phoridae, Psychodidae, Ptychopteridae, Simuliidae, Syrphidae, Tanyderidae, Thaumaleidae, Tipulidae
Various Orders	
Phyla or Class for:	Acari, Nematoda, Nemertea, Porifera, Tardigrada, Coelenterata
Order for:	Collembola, Conchostraca, Polychaeta
Genus for:	Isopoda, Amphipoda (*Hyallela azteca* to species)
Family for:	Decapoda, Hemiptera, Nematomorpha, Orthoptera, Hydroida (Coelenterata), Hirudinea

TABLE 6-5. Definition of Select Macroinvertebrate Metrics and Expected Response to Perturbation Including Water Quality and Habitat Change (from King, 1993 and Barbour et al., 1999)

METRIC	DEFINITION	EXPECTED RESPONSE
Total Number Taxa	Measures the overall variety of the macroinvertebrate assemblage	Decrease
Total Number EPT Taxa	Number of taxa in the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies, and Trichoptera (caddisflies)	Decrease
Total Number Ephemeroptera Taxa	Total Number of mayfly taxa	Decrease
% Ephemeroptera	Percent of mayfly nymphs	Decrease
Total Number Plecoptera Taxa	Total Number of stonefly taxa	Decrease
% Plecoptera	Percent of stonefly nymphs	Decrease
Total Number Insect Taxa	Total Number taxa in the Class Insecta	Decrease
Total Number Non - Insect Taxa	Total Number taxa not in the Class Insecta	Increase
% Non - Insects	Percent of Non - Insects	Increase
% Chironomidae	Percent of midge larvae	Increase
% Oligochaeta	Percent of worms	Increase
% 5 Dominant	Total Percent of the 5 most dominant taxa	Increase
% 10 Dominant	Total Percent of the 10 most dominant taxa	Increase
Number Predator Taxa	Number of taxa that feed upon other organisms or themselves in some instances	Variable, but appears to decrease in most regions of Wyoming
Total Number Scraper Taxa	Total Number of taxa that scrape periphyton for food	Decrease
% Scrapers	Percent organisms that scrape periphyton for food	Decrease
% Collector - Filterers	Percent organisms that filter Fine Particulate Organic Material from either the water column or sediment	Increase in most Wyoming ecoregions

TABLE 6-5. Con't

% Collector - Gatherers	Percent organisms that either collect or gather food particles	Increase
Modified HBI	Uses tolerance values to weight abundance in an estimate of overall pollution. Originally designed to evaluate organic pollution.	Increase
BCI CTQa	Tolerance classification based on nonpoint source impact of sedimentation and velocity alteration	Increase
Shannon H (Log base 2)	Incorporates both richness and evenness in a measure of general diversity and composition	Decrease
% Multivoltine	Percent of organisms having short (several per year) life cycle	Increase
% Univoltine	Percent of organisms relatively long-lived (life cycles of 1 or more years)	Decrease

TABLE 6-6. Wyoming Biological Condition Index (WBCI) scoring criteria for Tongue River Watershed 205j Project benthic macroinvertebrate communities developed for streams less than 6,500 feet elevation in the Middle Rockies Central ecoregion of Wyoming (from Barbour et al., 1994)

Macroinvertebrate Metric	**Scoring**		
	5	**3**	**1**
EPT Taxa	>18	18 - 10	<9
% Ephemeroptera	>22	22 - 11	<11
% Plecoptera	>6	6 - 4	<4
% Chironomidae	<12	12 - 39	>39
Predator taxa	>7	7-4	<4
% Scrapers	>8	8 - 5	<5
HBI	<3.7	3.7 - 4.7	>4.7
BCI	>79	79 - 46	<46
% Collector filterers	<2.6	2.6 - 23.2	>23.2

TABLE 6-7. Assessment rating criteria for Tongue River Watershed 205j Project benthic macroinvertebrate communities based on the Wyoming Stream Integrity Index (WSII; from Stribling et al., 2000) and the Wyoming Biological Condition Index (WBCI; from Barbour et al., 1994) for streams less than 6,500 feet elevation in the Middle Rockies Central ecoregion of Wyoming

Rating of Biological Condition (Aquatic Life Use Support)	**WSII (% of Reference)**		**WBCI (Total Score Middle Rockies Streams)**
	Middle Rockies	**Northwestern Great Plains**	
Very Good (Full Support)	>85.1	>78.6	NA
Good (Full Support)	70.2 - 85.1	57.1 - 78.6	≥35
Fair (Non - Support)	46.8 - 70.1	38.1 - 57.0	35 - 23
Poor (Non - Support)	23.4 - 46.7	19.0 - 38.0	21 - 9
Very Poor (Non - Support)	<23.4	<19.0	NA

TABLE 6-8 . Wyoming Stream Integrity Index (WSII) biological condition scoring criteria for Tongue River Watershed 205j Project benthic macroinvertebrate communities developed for Middle Rockies and Northwestern Great Plains ecoregion streams (from Stribling et al., 2000)

Macroinvertebrate Metric	Middle Rockies (5th or 95th %ile)	Northwestern Great Plains (5th or 95th %ile)
Total Taxa	NA[A]	44
Ephemeroptera taxa	12	7
Plecoptera taxa	NA	3
Trichoptera taxa	NA	10
Insect taxa	45	NA
Non-insect taxa	1	NA
% Ephemeroptera	69.8	NA
% Plecoptera	NA	4.0
% non-insects	NA	0.10
% Oligochaeta	0.0	NA
% 5 dominant	49.8	NA
% 10 dominant	NA	74
HBI	1.40	NA
BCI CTQa	NA	73.8
Scraper taxa	NA	7
% scrapers	56.1	NA
% collector-gatherers	NA	13

NA[A] = Metric not applicable to ecoregional scoring criteria.

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Figure 6-29

7 QUALITY ASSURANCE AND QUALITY CONTROL

7.1 FUNCTION OF QUALITY ASSURANCE AND QUALITY CONTROL

Quality Assurance (QA) may be defined as an integrated system of management procedures designed to evaluate the quality of data and to verify that the quality control system is operating within acceptable limits (Friedman and Erdmann, 1982; USEPA, 1995). Quality control (QC) may be defined as the system of technical procedures designed to ensure the integrity of data by adhering to proper field sample collection methods, operation and maintenance of equipment and instruments. Together, QAQC functions to ensure that all data generated is consistent, valid and of known quality (USEPA 1980; 1993). QAQC should not be viewed as an obscure notion to be tolerated by monitoring and assessment personnel, but as a critical, deeply ingrained concept followed through each step of the monitoring process. Data quality must be assured before the results can be accepted with any scientific study.

Project QAQC is described in a document called a Quality Assurance Project Plan (QAPP). A draft QAPP was prepared for the Tongue River 205j watershed Project, but it was not reviewed nor approved by WDEQ or EPA. Major elements of the draft QAPP were embedded throughout this Final Report in Sections 1 through 7 to describe specific QAQC components for this Project. This QAQC guidance provided a framework for groups interested in future Tongue River watershed water quality monitoring or investigators using the Project data base. The following specific QAQC components provide a synopsis of the Tongue River Project QAQC process.

7.2 TRAINING

Personnel involved in collection and analysis of samples should receive adequate training for proper implementation of Project field and laboratory methods. SCCD personnel received training from Mr. Kurt King with the WDEQ Sheridan Field Office. Mr. King was the WDEQ QA Officer, authored WDEQ stream biomonitoring methods (King, 1993), initiated the statewide Reference Stream Project and had over 18 years experience as aquatic biologist and water quality specialist. Personnel received annual refresher training in addition to a water quality monitoring course conducted by the Wyoming Association of Conservation Districts in 1998 and 1999. Mr. King accompanied SCCD field personnel on the majority of macroinvertebrate and habitat assessment sample events. Mr. Harold Herman, Director of RPWD, provided training to SCCD personnel for operation of the Hach 2100A turbidimeter.

7.3 COLLECTION, PRESERVATION, ANALYSIS AND CUSTODY OF SAMPLES FOLLOWING APPROVED METHODS

7.3.1 Collection, Preservation and Analysis

Accepted referenced methods for collection, preservation, and analysis of samples were described in Section 6.0 and listed in Table 6-1 in this Final report.

7.3.2 Sample Custody

Sample custody described the sampling and analysis record starting with sample collection and ending with laboratory analysis and sample disposition. The purpose of sample custody was to ensure that samples were not tampered with by outside entities and the integrity of samples was maintained.

Project field measurements were recorded on field data sheets. Water samples requiring laboratory analysis were immediately placed on ice, preserved (if required) and hand delivered to the analytical laboratory (IML). The IML Chain of Custody (COC) form was prepared and signed by the sampler before samples entered laboratory custody. After samples changed custody, IML internal COC procedures were implemented.

Benthic macroinvertebrate samples were preserved in the field (Section 6.5.4), placed in a cooler and transported to the NRCS/SCCD office in Sheridan. A Project specific macroinvertebrate COC form was completed. After all macroinvertebrate samples were collected, samples and COC forms were sealed inside a cooler and shipped by United Parcel Service to the contract analytical laboratory. The analytical laboratory opened the cooler, performed a visual check for the number and general condition of samples, then signed the COC form. The completed original COC form was returned to SCCD by the analytical laboratory after completion of analyses.

7.4 CALIBRATION AND PROPER OPERATION OF FIELD AND LABORATORY EQUIPMENT ACCORDING TO MANUFACTURER'S INSTRUCTIONS

Frequency and calibration of field equipment were described in Section 6.0. Macroinvertebrate sample collection and habitat assessments required no calibration of equipment. The QA Plan for the contract water quality laboratory (IML) and the contract macroinvertebrate sample analysis laboratory (Aquatic Biology Associates, Inc.) were available upon request.

7.5 COLLECTION OF REPRESENTATIVE SAMPLES

Collection of representative samples was ensured by sampling at well-mixed riffles during random sampling dates. Of concern was the siting of some sampling locations downstream of road crossings due to lack of access and landowner consent. Placement of sampling sites downstream of road crossings normally does not affect collection of representative water quality samples. However, macroinvertebrate populations may be affected by the scouring action often observed downstream of bridges. Habitat assessment may be affected due to channelization often observed downstream of bridges and road crossings.

7.6 DETERMINATION OF DATA QUALITY OBJECTIVES, PRECISION, ACCURACY, COMPLETENESS, AND COMPARABILITY

7.6.1 Data Quality Objectives

Data Quality Objectives (DQO's) are qualitative and quantitative specifications used for water quality monitoring programs. DQO's function to limit data uncertainty to an acceptable level. DQO's were established for each monitoring parameter for precision, accuracy and completeness at levels sufficient to allow SCCD to realize Project goals and objectives. Table 7-1 lists DQO's for this Project.

7.6.2 Precision

Precision was defined as the degree of agreement of a measured value as the result of repeated application under the same condition. Because the determination of precision was affected by changes in relative concentration for certain chemical parameters, the Relative Percent Difference (RPD) statistic was used. RPD is defined as:

$$RPD = [(A - B)/(A + B)] \times 200$$

For example, the field measurement for conductivity Duplicate 1 was 855 umhos/cm and the conductivity Duplicate 2 measurement was 875 umhos/cm. The RPD = [(855 - 875)/(855 + 875)] X 200 = 2.3%. The DQO for precision for conductivity was 10% (Table 7-1) thus, the agreement between duplicate measurements was within the precision DQO established for conductivity.

Precision was determined for chemical, physical (excluding discharge), biological and habitat measurements by conducting duplicate samples at 10 percent of sampling sites. Duplicate intra-crew habitat assessments were conducted by each observer conducting the assessment at the same time as one another without communication.

7.6.3 Accuracy

Accuracy was defined as the degree of agreement of a measured value with the true or actual value. Accuracy for water quality parameters measured in the field was assured by calibration of equipment to known standards. Accuracy for water quality parameters measured by the contract laboratory was determined by % Recovery. Accuracy for water samples requiring laboratory analysis was determined by the contract analytical laboratory (Intermountain Laboratories (IML)). No QA findings were reported by IML concerning accuracy or for other QA/QC components during this Project.

Accuracy for macroinvertebrate sampling and habitat assessment could not be determined since the true or actual value for macroinvertebrate populations or habitat parameters were unknown. In this instance, precision served as the primary QA check for benthic macroinvertebrate sampling and habitat assessment.

7.6.4 Completeness

Completeness refers to the percentage of measurements that are determined to be valid and acceptable compared to the number of samples scheduled for collection. This DQO was achieved by avoiding loss of samples due to accidents, inadequate preservation, holding time exceedences, and proper access to sample sites for collection of samples as scheduled. Completeness was calculated by the following formula:

Completeness = Amount of Valid Data Reported / Amount of Data Expected X 100

For example, 595 valid turbidity measurements were reported during a hypothetical water quality monitoring project out of a total of 605 turbidity samples scheduled for collection. Completeness was determined by the following calculation: 595/605 = .983 X 100 = 98.3%. Because the Project DQO for completeness for turbidity was 95%, the DQO was met for completeness.

7.6.5 Comparability

Comparability refers to the degree that data collected during this Project was comparable to data collected during other past or present studies. This was an important factor because future water quality monitoring will occur in the Tongue River 205j Project area and current Project data must be comparable to future data in order to detect water quality change with confidence. Several steps were taken to assure data comparability including:

- ✓ Collection of samples at the same monitoring stations;
- ✓ Collection of samples during the same time of year;
- ✓ Collection of samples using the same field sampling methods and sampling gear;
- ✓ Analysis of samples using the same laboratory analytical methods and equipment;
- ✓ Use of the same reporting units and significant figures
- ✓ Use of the same data handling and reduction methods (i.e. data rounding and censoring); and
- ✓ Use of similar QAQC processes

Frequent causes for lack of comparability among data sets is due to lack of documentation for historic data sets, change in sensitivity of laboratory analytical equipment and differing monitoring goals and objectives among sampling groups.

Chemical, physical, biological and habitat data collected by SCCD and WDEQ during this Project, with the exception of total phosphorus data, were highly comparable because of close coordination prior to initiation of sampling. Each step identified above was implemented to assure comparability.

Total phosphorus data was not highly comparable because SCCD used an analytical method that was more sensitive (lower Minimum Detection Limit (MDL)) than the analytical method used by WDEQ. This prevented direct comparison of data when phosphorus was present in concentrations between the detection limits provided by each analytical method. However, when this situation occurred, data was compared after "censoring". Censoring is a common statistical treatment employed when numerous data points are reported as less than (<) or greater than (>) the MDL or the maximum detection limit (Gilbert, 1987). Section 7.9.1 described censoring rules employed during this Project.

7.7 DATA VALIDATION

Data generated by SCCD contract laboratories was subject to the internal contract laboratory QAQC process before it was released. Data was assumed valid because the laboratory adhered to it's internal QAQC plan. Field data generated by SCCD was considered valid and usable only after defined QAQC procedure and process were applied, evaluated and determined acceptable. Data determined to be invalid was rejected and not used in preparation of this Final Report. A discussion of the type and quantity of rejected data was presented in Section 8.1.1.

7.8 DOCUMENTATION AND RECORDS

Field data and other information were recorded on separate field data sheets prepared for each monitoring station. Photographs and negatives were placed in station files. Results of water sample results were received hard copy. Macroinvertebrate sample results were received hard copy and electronically. All analytical results were placed in station files.

7.9 DATA BASE AND DATA REDUCTION

7.9.1 Data Base Construction

The Project data base consisted of a series of electronic computer files. Hard copy files were prepared and maintained for each electronic file. Each data base file was constructed with reportable data (accepted after QC checks) by entering into Excel 7.0 spread sheets. Electronic files for water quality, macroinvertebrate, and habitat data were prepared. A second individual checked all computer data entries for mistakes. If a mistake was suspected, the original field or laboratory data sheet was re-examined and data entry corrected. Suspect data not resolved were either not entered into the data base or were deleted from the data base once detected.

Two (2) master data bases were prepared to house all historical and current water quality data:

1. Reportable data (not censored) data base and
2. Censored data base

The **uncensored** data base contained data reported from field measurements and data reported by the analytical laboratory including all values less than MDL's. All data presented in Appendices in this Final Report represent uncensored data.

The **censored** data base contained data that was censored to allow various statistical procedures to be performed. Values for the major sampling parameters (e.g. fecal coliform, total phosphorus, total nitrate) reported as less than the MDL, were "censored to the left" following guidance found in Gilbert (1987).

When a relatively small number of data were censored, the rule was to replace the less than (<) value with a value one half the MDL. For example, the censored value for a fecal coliform reportable value of <20 colonies per 100ml would be 20 divided in half or 10 colonies per 100ml. When more than approximately 20 percent of reportable values for a parameter (such as for total phosphorus and total nitrate samples) were less than (<) values, random numbers generated by computer assisted in the assignment of censored values. For example, 24 total phosphorus values out of a total of 50 reportable values were < the MDL of 0.1 mg/l. A random number ranging from 0.01 mg/l to 0.09 mg/l was selected by computer for each of the 24 total phosphorus samples. The random number value replaced the original reported value in the censored data base.

7.9.2 Data Reduction

After data validation and data base construction, data were imported to a statistics software program, *Statgraphics Plus*®, for statistical analyses. Summary statistics, interpretive statistics and graphs used were documented in the software manufacturer's instruction manual. Statistics calculated included:

- Average
- Geometric mean
- Median
- Maximum

- Minimum
- Range
- Transformation (for non-normal distributions)
- Linear regression
- Multiple regression
- Time series trend analysis

The average and geometric mean were the primary statistics used to determine water quality change between Upper and Lower stations. The use of the annual average or Project average from multiple water quality measurements avoided concerns for potential pseudoreplication should each data point have been treated as an independent observation (Hurlbert, 1994).

Graphics presented in this Final Report were generated in Excel 7.0 using censored data when required.

7.10 DATA REPORTING

Data collected by SCCD were presented in tabular and graphic form in this Final Report. The Final Report will be distributed to WDEQ, EPA and interested parties. Data collected by other monitoring groups concurrent with this Project and historic data accumulated by SCCD have been placed either in the main body of this report or in Appendices. Interested parties may contact SCCD at the address listed on the Title Page of this Final Report to obtain an electronic copy of data at a minimal fee to cover duplication time, compact disc cost and shipping cost. Smaller electronic files may be transferred through Electronic Mail.

7.11 DATA RECONCILIATION

Data collected by SCCD were subjected to two levels of evaluation before accepted and entered into the data base. Obvious outliers were flagged after consideration of "expected" values based on evaluation of historical and current data. Field data sheets were re-checked and if no calibration or field note anomalies or excursions were identified, data was accepted as presented. Otherwise, data were rejected and not included in the data base.

An exception was presented by data collected by WDEQ during 1998 and 1999. This data set had not undergone WDEQ internal QA/QC evaluation and should not be considered as approved. Data was thus presented as **PROVISIONAL**. **Provisional data is subject to change, modification or rejection dependant upon the WDEQ QA/QC evaluation**. The WDEQ 1996 and 1997 data set was previously approved and released to the public.

USGS data presented in this Final Report with the exception of the benthic macroinvertebrate data, had undergone agency QA/QC evaluation and was released for public consumption. **USGS**

benthic macroinvertebrate data was presented as PROVISIONAL and may be subject to change, modification or rejection dependant upon the USGS QA/QC evaluation.   RPWD, WGFD and NRCS data received internal review before release to SCCD.

TABLE 7-1. Data Quality Objectives for Chemical, Physical, Biological and Habitat Sampling Conducted by Sheridan County Conservation District and Wyoming Department of Environmental Quality at Tongue River 205j Project Stations, Sheridan County, Wyoming

Parameter	Precision (%)	Accuracy (%)	Completeness (%)
Temperature	10	10	95
pH	5	5	95
Conductivity	10	10	95
Dissolved Oxygen	20	20	95
Turbidity	10	10	95
T. Suspended Solids	10	10	95
Alkalinity	10	10	95
Total Sulfate	20	20	95
Total Chloride	10	10	95
Total Nitrate	20	20	95
Total Phosphorus	20	20	95
Total Ammonia	20	20	95
Total Hardness	10	10	95
Fecal Coliform	10	10	95
BOD	20	20	95
Macroinvertebrates	NA	NA	95
Total Abundance	50	NA	95
Total Taxa	15	NA	95
Habitat Assessment	NA	NA	95
Intra-Crew	15	NA	10
Periphyton	NA	NA	95
Discharge	NA	NA	95

8 RESULTS AND DISCUSSION

8.1 QUALITY ASSURANCE AND QUALITY CONTROL

The Quality Assurance and Quality Control (QAQC) summary was presented first in the Results and Discussion Section because data must first be accepted as valid and of known quality before it is evaluated and final conclusions and recommendations made.

8.1.1 Summary of QA/QC Evaluation

QA/QC evaluation of data collected during the four year Project indicated adequate data quality was provided to meet Project goals and objectives. Although WDEQ data was **PROVISIONAL** at the time of this report, SCCD conducted a QA/QC evaluation on the data set because both used the same sample collection and analysis methods and implemented similar QA/QC procedures. The following discussion combined SCCD and WDEQ sampling results since data collected by each was included in this Final Report. In addition, the discussion follows the assumption that all WDEQ data determined valid by SCCD QA/QC evaluation will be determined valid by WDEQ. The SCCD QA/QC evaluation of WDEQ data found the data to be complete and approvable. However, the data must be considered **PROVISIONAL** until final approval by WDEQ.

Recommendations were made when QA findings were identified. The recommendations were compiled in Section 10 of this Final Report. Each water quality monitoring project reveals numerous unanswered questions and identifies ways to improve the design and implementation of the sampling program. This Project was no exception. The recommendations found in Section 10 are provided to improve future water quality monitoring and assessment within the Tongue River Project area. Moreover, some recommendations, especially for water temperature and fecal coliform monitoring, have implications to statewide water quality monitoring by Conservation Districts, WDEQ and other groups.

The following is a QA/QC summary for the Tongue River watershed assessment.

1. **Completeness for total number of samples** measured was 101 percent (Appendix Table B-28) which was greater than the DQO of 95 percent. There were a combined total of over 3,200 individual water quality measurements made by SCCD and WDEQ during the Project out of a scheduled 3,170 measurements. Completeness for combined SCCD and WDEQ benthic macroinvertebrate sample collection and habitat assessments was 100 percent which exceeded the DQO of 95 percent.

2. Completeness DQO's for individual water quality parameters was met except for **dissolved oxygen (DO) and pesticide and herbicide sampling**. Only 65 percent of DO sample data were accepted which was below the DQO of 95 percent (Appendix Table B-28). A large number of DO measurements were rejected due to apparent improper calibration of the YSI multi-probe purchased for use in 1999. It should be noted that DO was not a scheduled monitoring parameter until 1999 because SCCD did not have a DO meter prior to that time. Once the DO meter was purchased, DO measurements were integrated into the monitoring program.

Recommendation: All new equipment should be calibrated and maintained according to manufacturer instructions. New equipment should undergo adequate field testing and adequate training by SCCD before use.

The total number of pesticide and herbicide samples were not collected according to schedule because sampling in 1996 included more costly analyses for individual parameters instead of a basic screening to determine presence or absence of parameters. The single sampling event exhausted the entire Project budget for herbicide and pesticide monitoring precluding further sampling. The initial sampling at five stations detected no pesticide and herbicides. This observation, combined with knowledge that USGS NAWQA would conduct herbicide and pesticide sampling in 1998 or 1999 did not jeopardize the overall sampling objective.

Recommendation: The Pre-project planning phase should include better communication with the contract analytical laboratory for specific analytical method used and costs for sample analyses.

3. **Four years of complete data** were not collected as intended. Sampling was scheduled to begin in April 1996, but was not initiated until August 1996. The delay was due to the late purchase of equipment, training delays and other logistical monitoring facets. This resulted in collection of water quality and discharge data during two (2) months instead of six (6) months in 1996 and missing the spring runoff period. This also prevented complete comparison of 1996 data to data collected in 1997, 1998 and 1999.

Recommendation: The Tongue River 205j Project was the first major water quality monitoring effort conducted by SCCD. Project personnel apparently underestimated the amount of time required for planning a project of this scale. Future monitoring efforts by SCCD should allow for adequate time (a minimum of six (6) months) to conduct planning prior to collection of the first sample. This will allow future Projects to begin on schedule.

4. **Same day sampling did not occur** at each sampling station as planned. This did not affect the integrity of data, but prevented complete utilization of the data set to make comparisons between Upper and Lower stations as well as comparisons between the Tongue River stations and tributary stations. Because Upper tributary stations were not sampled at the same frequency as Lower tributary stations, this further added to the reduction in same day comparable data. Failure to collect same day samples appeared to be due primarily to lack of an adequate number of sampling personnel and "runners" needed to deliver fecal coliform samples to the laboratory within the 6 hour holding time. The Project relied heavily on volunteer assistance for sampling and adequate personnel were lacking on several sampling events.

   Recommendations: For future sampling, an adequate number of full-time sampling technicians should be employed and firm commitments from volunteers for monitoring should be secured at least two weeks in advance of scheduled sampling. Field logistics should be improved to account for the short holding time for fecal coliform samples by increasing the number of vehicles for use to deliver samples to the analytical laboratory.

5. **The DQO for total number of duplicate water quality and macroinvertebrate samples was not met.** The total number of duplicate intra-crew habitat assessments (N = 10) representing about twenty-one (21) percent of total assessments was within DQO's (Appendix Table I-6). Of 389 total SCCD water quality sampling events, only six (6) duplicate samples were collected (Appendix Table B-27). This represented only 1.5 percent of total water samples collected in duplicate which was less than the DQO required 10 percent. WDEQ collected duplicate water samples at 6.2 percent of total sites sampled within the Project area. WDEQ Sheridan field office sampling conducted within the Project area was only part of their total water sampling commitment in Northeast Wyoming. During 1996, 1997 and 1998 WDEQ met DQO's for total number and percent of duplicate water sampling, benthic macroinvertebrate sampling and intra-crew habitat assessment. It was unknown whether WDEQ met DQO's for sampling in 1999 because the internal QA/QC evaluation for Northeast District sampling was not available at the time of this Final Report.

   Lack of an adequate number of duplicate water and benthic macroinvertebrate samples placed a degree of uncertainty for sampling precision for certain parameters with normally high variability for precision (i.e. fecal coliform bacteria, turbidity and TSS). Mean Relative Percent Difference (RPD) values (the measure of precision based on comparison of duplicate samples) were within

DQO's for all sampling parameters except fecal coliform and TSS (Appendix Table B-26). The Mean RPD for fecal coliform was 22.3 percent. The higher RPD was due to high variability during 2 of the 6 duplicate sampling events. The high variability occurred when fecal coliform bacteria numbers were highest indicating the need to collect duplicate samples when bacteria numbers were expected to be the highest normally during periods of high turbidity. Increased frequency of duplicate samples would provide a more reliable estimate for fecal coliform levels which was important when concentrations may approach the Wyoming water quality standard for fecal coliform bacteria.

SCCD did not sample TSS during this Project. However, the high mean RPD for TSS was important to note should SCCD sample this parameter during future Tongue River watershed monitoring. An increased number of duplicate samples will provide a better estimate for precision.

The low number of duplicate samples appeared to be due to several factors:

a. Employee turnover during the Project. There were three different Project supervisors during the four year Project due to employee turnover. Employee turnover can lead to QA/QC inconsistency and problems with continuity. Training becomes a critical element because new employees not previously experienced in the Project water quality monitoring program require considerable up front training.

Recommendation: Adequate salaries, benefits, flexibility and support should be provided to personnel involved in monitoring activities to reduce employee turnover and ensure monitoring consistency.

b. **Budget fears.** Personnel may have tried to "pinch pennies" and reduce monitoring and analytical costs by not collecting duplicates at the proper frequency at the expense of QA. The major over run in analytical costs for pesticide and herbicide sampling in 1996 may have been a significant factor adding to cost concerns.

Recommendation: Ensure that duplicate samples are included in budget planning at the start. Provide field samplers with a "tracking sheet" to record the number of duplicate samples required and the total number of duplicate samples collected. Training should stress the importance of duplicate samples in the QA process.

6. **With the exception of dissolved oxygen data** collected in 1999 and lack of

duplicate samples, there were **no problems requiring data reconciliation** for collection, preservation, analysis and custody of samples during this Project.

7. **With the exception of dissolved oxygen data** collected in 1999, there were **no problems noted for calibration and proper operation** of field and laboratory equipment according to manufacturer's instructions. Operation and calibration of field equipment were described in Section 6 of this report. Further, SCCD received no notification of QA problems for calibration and operation of equipment used by contract laboratories for the analysis of water samples and macroinvertebrate samples. It should be noted that benthic macroinvertebrate sample collection and habitat assessments required no calibration of equipment.

8. **Water sampling was determined to be unbiased and representative** because samples were collected at well-mixed riffles during random sampling dates. Concern for placement of some sampling sites downstream of road crossings may have had an unknown effect upon some benthic macroinvertebrate samples as well as habitat assessments.

Recommendation: Establish all monitoring stations upstream of road crossings. Better land owner familiarity and involvement with future monitoring projects may enhance the ability to gain broader access for sampling.

9. Unequal sampling between upstream stations and downstream stations on the same water body was planned due to budget constraints. However, this prevented the maximum amount of information gained from water sampling by reducing comparability of samples between stations as well as reducing the ability to detect change in water quality along the longitudinal gradient of the stream. Unequal sampling among stations was compensated for by using the average annual and average Project values.

Recommendation: Ensure that enough funds are available for identical sampling frequency between all monitoring stations on a water body if required.

10. **With the exception of dissolved oxygen samples** collected in 1999, accuracy for water quality parameters measured in the field was determined to be adequate to meet Project goals and objectives. The contract water quality laboratory reported no problems for internal accuracy checks determined by Percent Recovery. In addition, no QA findings were reported by the contract water quality laboratory concerning accuracy or other QA/QC components during this Project. SCCD was not aware of any written documentation provided by the WDEQ Water Quality Laboratory for accuracy for analyses of WDEQ water samples.

Accuracy for macroinvertebrate sampling or habitat assessment could not be determined since the true or actual value of macroinvertebrate populations and habitat parameters were unknown. In this instance, precision served as the primary DQO to evaluate benthic macroinvertebrate sampling and habitat assessment.

11. **Chemical, physical, biological and habitat data collected by SCCD and WDEQ** during this Project, with the exception of total phosphorus data, **were highly comparable** because of coordination prior to initiation of sampling. Other than for total phosphorus, all water quality, benthic macroinvertebrate and habitat assessment methods were the same between SCCD and WDEQ. Comparability between RPWD, USGS, SCCD and WDEQ water sampling data appeared to be good. Comparability between USGS **PROVISIONAL** benthic macroinvertebrate data collected at the Tongue River 06298000 station and SCCD and WDEQ benthic macroinvertebrate data appeared good (see Section 8.5.19). Biological condition was rated the same by both groups despite the fact that USGS did not sample macroinvertebrates at the same time (about 1 month earlier) nor at the same station (USGS station was about one mile downstream of the SCCD and WDEQ macroinvertebrate station).

    Total phosphorus data was not highly comparable because SCCD used an analytical method that was more sensitive (lower Minimum Detection Limit (MDL)) than the analytical method used by WDEQ. This prevented direct comparison of data when phosphorus was present in concentrations <u>between</u> the MDL's provided by each analytical method. However, when this situation occurred, data was comparable after "censoring" to adjust all values to the same scale. Censoring was a common statistical treatment employed when numerous data points were reported as less than (<) the MDL (Gilbert, 1987).

12. There were no problems encountered for:
    - Data Base Construction
    - Data Reduction
    - Data Reporting

8.2 NRCS Precipitation and Air Temperature at Station WY07E33S

8.2.1 Precipitation

Precipitation was measured daily at the Burgess Junction Meteorological Station Number WY07E33S. The meteorological station was located in the upper Tongue River watershed in the Bighorn National Forest several miles from the Project area. However it provided daily precipitation and temperature data that could be used to evaluate general trends affecting the watershed within the Project area.

Mean monthly cumulative precipitation values compiled since 1982 are presented in Appendix Table J-1. Figure 8-1 illustrates cumulative monthly precipitation during the Project in comparison to the mean annual precipitation from 1982 through 1999.

Precipitation was significantly higher than normal during 1997, near normal during 1999 and below normal during 1996 and 1998. Total precipitation during the Project varied from a high of 29.6 inches in 1997 to a low of 23.6 inches in 1998. Precipitation in 1996 (24.1 total inches) was 4.4 percent lower than the mean annual precipitation from 1982 through 1999 (25.2 inches). Years 1998 and 1999 were 6.3 percent and 4.0 percent lower, respectively while 1997 was 17.5 percent higher than the average annual precipitation recorded since 1982.

Precipitation records during the sampling period (from April through September) showed 1996 was 14.4 percent lower, 1998 was 8.9 percent lower and 1999 was 1.4 percent lower than the average precipitation during this period since 1982. Year 1997 was 20.5 percent higher than the seasonal mean when compared to mean precipitation from April through September.

8.2.2 Air Temperature

Air temperature was measured daily at the Burgess Junction Meteorological Station Number WY07E33S. Mean monthly temperature values compiled since 1990 were presented in Appendix Table J-2. Figure 8-2 illustrates mean monthly air temperature during the Project in comparison to the mean monthly air temperature from 1990 through 1999.

Temperature in 1996 during the Project sampling period (from April through September) was slightly cooler (about 1 degree centigrade (C)) during May and September and slightly warmer (about 1 degree centigrade) from June through August. April, 1996 was equal to the April 10-year average temperature. Air temperature in 1997 during the sampling period, with the exception of April, was near normal. April, 1996 was about 3 degrees C cooler when compared to mean temperatures measured since 1990.

Air temperature in 1998 deviated from the 10-year norm more than the other sampling years. April and June were 1 degree C and 3 degrees C cooler while May and July through September were 1 degree C to 3 degrees C warmer than normal. Air temperature in 1999 was normal except for July and August (2 degrees C warmer) and September (2 degrees C cooler).

8.3 USGS Discharge at Tongue River Station 06298000

Daily discharge was recorded at USGS station No. 06298000. SCCD monitoring station Tongue

River Upper was sited at the USGS station. Mean monthly discharge values compiled since 1982 reported in cubic feet per second (cfs) are presented in Appendix Table K-1. Figure 8-3 illustrates mean monthly discharge during each year of the Project in comparison to the average monthly discharge data from 1982 through 1999.

Mean annual discharge was highest during 1999 (as measured from October, 1998 through September, 1999) followed by 1997, 1996 and 1998. Discharge during the SCCD sampling period (from April through September) was highest during 1997 followed in decreasing order by 1999, 1996 and 1998.

Discharge during the sampling period (April through September) in 1997 was 7.1 percent greater than the average discharge since 1982 during the same sampling period. Year 1999 discharge was 3.4 percent higher than the mean discharge since 1982 while year 1996 and year 1998 discharge were 4.7 percent and 22.5 percent less, respectively.

Discharge increased from April to May followed by peak discharge in June (Figure 8-3). Discharge decreased significantly into July followed by steady decreases in August and September. Lowest base flows generally occurred from December through March. The general seasonal hydrologic pattern for annual discharge exhibited during this Project was similar to the mean seasonal pattern for discharge observed since 1982.

Highest mean monthly discharge for each sampling year occurred in June. Mean June discharge in 1996, 1997, 1998 and 1999 were 759 cfs, 858 cfs, 441 cfs and 775 cfs, respectively. The mean monthly discharge from 1982 through 1999 for June was 621 cfs.

Discharge in the Tongue River was closely associated with total precipitation measured by NRCS at the Burgess Junction meteorological station. Although statistical modeling to further examine the association between discharge and precipitation was beyond the scope of this Project, general relationships between total annual precipitation, precipitation occurring during the Project sampling period (April through September) and discharge could be accurately described. For example, total precipitation and discharge were greatest in 1997. Conversely, total precipitation and discharge were lowest in 1998.

Of all parameters monitored during this Project, discharge in the Tongue River appeared to be the most important factor affecting chemical, physical, biological and habitat components at Tongue River Upper, Middle and Lower stations. Diversion of water from the Tongue River primarily for agricultural use affected stations especially during the warmer summer months of July and August when water demand was greatest. The general and statistical relationships between discharge in the Tongue River and monitoring parameters are discussed later in Section 8 and Section 9.

8.4 USGS Discharge at Wolf Creek Station 06299500

Daily discharge was measured by the Wyoming State Board of Control from April through September at Wolf Creek USGS station 06299500, also known as SCCD monitoring station Wolf Creek Upper. Period of station operation was the same as the SCCD sampling period. Discharge measurements were limited to these months to monitor available water supply for agricultural use.

Mean monthly discharge values reported in cubic feet per second (cfs) compiled since 1982 are presented in Appendix Table K-2. Figure 8-4 illustrates mean monthly discharge during the Project in comparison to the mean monthly discharge from 1982 through 1999.

Seasonal discharge patterns observed at the USGS Wolf Creek station were similar to the seasonal discharge patterns observed at the USGS Tongue River station 06298000. Mean monthly discharge was highest during 1977 (62.2 cfs), followed by 1999 (54.5 cfs), 1996 (50.0 cfs) and 1998 (40.9 cfs). The mean monthly discharge based on values from 1982 through 1999 was 47.1 cfs. Thus, discharge in Wolf Creek was higher than average during each sampling year with the exception of 1998 which was 13.2 percent below normal.

Discharge during each year increased from April to May followed by peak discharge in June (Figure 8-4). Discharge decreased significantly into July followed by steady decreases in August and September. As observed in the Tongue River and suggested at other streams within the Project area, base flows probably occur from December through March. The general pattern in annual discharge exhibited during this Project was similar to the mean annual discharge pattern observed since 1982.

Highest mean monthly discharge for each sampling year occurred in June. Mean June discharge in 1996, 1997, 1998 and 1999 was 139.2 cfs, 171.7 cfs, 84.8 cfs, and 141.0 cfs, respectively. The mean monthly discharge from 1982 through 1999 for June was 121.2 cfs.

8.5. Tongue River Upper, Middle and Lower Stations

8.5.1. Tongue River SCCD and WDEQ Discharge

Instantaneous discharge measurements were recorded by SCCD and WDEQ during sampling at Tongue River Upper, Middle and Lower stations. Summary statistics for discharges are presented in Table 8-1. Discharge measurements during the Project at the Upper station averaged 236 cfs, 421 cfs at the Middle station and 517 cfs at the Lower station (Table 8-1). The average values were difficult to compare among mainstem Tongue River stations due to differing sampling frequency and lack of same day sampling on numerous occasions. Figure 8-5 illustrates discharge measured at each station on the same day. Discharge data not measured at each station on the same day was excluded from Figure 8-5 because discharge may vary daily precluding valid comparison among stations. There were no comparable discharge data collected in 1996 and limited comparable data collected in 1997.

Discharge during the primary low-irrigation months (April, May and September) progressively increased from the Upper station to the Middle Station and from the Middle station to the Lower station. There was a 90 percent increase in discharge from the Upper to Middle stations during this period (Table 8-2). However, this trend was often reversed during the primary irrigation months (June, July and August) when discharge was often reduced from the Tongue River Middle station to the Tongue River Lower station (Figure 8-5). There was a 7 percent reduction in discharge from the Middle station to the Lower station during irrigation season months, but a 31 percent increase between stations during the low-irrigation season months. The effects on chemical, physical, biological and habitat characteristics related to dewatering during the warmer summer months are discussed later in various Sections including Section 8.5.4, Section 8.15.19, Section 8.5.21 and Section 9.1.

8.5.2 WGFD Continuous Tongue River Water Temperature Monitoring in 1988 and 1994

Continuous surface water temperature data was collected by WGFD near the Tongue River Upper station in summer 1988 (Appendix Table E-1) and near the Tongue River Lower station in Ranchester in summer 1994 (Appendix Table E-2). SCCD felt that this data should be presented first since findings affected the discussion of instantaneous water temperature data collected during this Project. The temperature data collected in 1988 near the Tongue River Upper stations were considered "historic" because it was collected five (5) years prior to initiation of this Project. The temperature data collected in 1994 near Tongue River Lower was considered "current" and usable for determination of beneficial use attainment since it was collected within five (5) years of the initiation of this Project in 1996.

Monitoring by WGFD near the Tongue River Upper station indicated water temperatures were well below the upper thermal limit established for Class 2 cold water fisheries (25.6^{o}C). The maximum water temperatures occurred during the last part of July and early August. The maximum water temperature was 18.5^{o}C recorded on July 30, 1988. The majority of maximum daily water temperatures generally ranged from 12^{o}C to 16^{o}C (Figure 8-6). The optimal temperature range for salmonids (including trout) is approximately 12^{o}C to 14^{o}C (MacDonald et al., 1991). Bjornn and Reiser (1991) indicated the optimal upper temperature for most salmonids was 13^{o}C to 16^{o}C. Lethal water temperatures may vary according to the duration that fish are exposed to high temperatures and their acclimation to high temperature, but is generally in the range of 20^{o}C to 25^{o}C. The WGFD water temperature monitoring indicated that water temperature was adequate for trout populations near the Tongue River Upper station.

Water temperatures recorded at the Tongue River Lower station between June 21, 1994 and September 7, 1994 exceeded the Wyoming Water Quality temperature standard for Class 2 waters for cold water fisheries on seventy-two (72) percent of sampling days (Table 8-3). The standard was exceeded on nineteen straight days from July 26, 1994 through August 13, 1994 (Figure 8-6). Maximum daily temperatures were generally recorded between 1700 hours (5:00 pm) and 2000 hours (8:00 pm). The difference between maximum and minimum daily summer water temperatures routinely ranged from 5^oC to 7^oC. This observation was similar to daily stream temperature variability described by MacDonald et al. (1991) where typical maximum daily temperatures occurred in the late afternoon and daily minimum temperatures occurred just before dawn. King (1990a) found considerable fluctuation in daily temperature, pH and dissolved oxygen at Sand Creek, a small spring-fed stream in northeast Wyoming. He found that in order to obtain a sample characteristic of water quality conditions during daylight hours, sampling should be performed in the late afternoon before sunset.

Diurnal (difference between day and night time) temperature ranges of around 6^oC are fairly common in streams during summer (Hynes, 1970) and changes as great as 14^oC have been reported for smaller plains streams (Mackichan, 1967). It is probable that daily temperature ranges exceeded 5^oC to 7^oC at tributaries to the Tongue River Lower since tributaries were smaller in size and contained less discharge. Lower discharge combined with shallow stream depth and reduction in riparian vegetation may increase daily temperature fluctuation.

The time of day that the maximum daily water temperature occurred and the normal range between daily maximum and minimum water temperatures indicated that the SCCD sampling design missed the maximum daily water temperatures needed to evaluate effects on cold water fish species and to determine attainment of the Wyoming water quality standard for water temperature. SCCD sampling generally occurred during the morning through early afternoon when lower water temperatures persist (minimum daily water temperature usually occurs from 8:00 am to 10:00 am; see Appendix Table E-2). This indicated that instantaneous daily water temperature measured by SCCD and WDEQ during this Project usually approximated the lower minimum daily water temperature instead of maximum daily water temperatures needed to determine compliance with the Wyoming temperature standard. This finding suggested that maximum temperatures recorded in the Tongue River and at tributaries during this Project could be conservatively adjusted upward by from 5^oC to 7^oC to provide a better estimate of maximum daily water temperature.

Ambient air temperature recorded at the NRCS Burgess Junction meteorological station and discharge measured at USGS station 06298000 (SCCD Tongue River Upper station) during 1994 were evaluated to examine potential factors related to the high daily summer water temperatures recorded by WGFD. Air temperatures were generally about 1 C cooler than normal indicating that air temperature was not the critical factor. However, discharge measured by USGS near the Tongue River Upper station during this period was considerably lower than mean discharge recorded during the period from 1982 through 1999. June, July, August, and September, 1994 mean monthly discharges were 237 cfs, 115 cfs, 64 cfs and 60 cfs, respectively compared to the June, July, August, and September mean (1982 through 1999) monthly discharges of 621 cfs, 213 cfs, 102 cfs and 80 cfs, respectively. This observation suggested that low discharge in 1994 may have been a significant factor related to the high water temperature and temperature standard exceedence. Ward and Stanford (1979) found that reduced stream flows resulted in more extreme temperature differences. Lower discharge normally results in reduced stream velocity and shallower water depth that may contribute to warmer stream water temperature. Dewatering at the Tongue River Lower station was evident during the July and August months at the height of the summer irrigation period (Figure 8-5) since demand for water was highest during these months. Discharge from tributaries to the Tongue River was also reduced during these months because these water bodies were also subject to dewatering due to irrigation demand.

Even after consideration of water temperature increase due to dewatering, the WGFD water temperature data suggested that the Tongue River in the vicinity of the Lower station may be located near the transition zone between a Class 2 cold water stream and a Class 2 warm water stream. Evaluation of the benthic macroinvertebrate community data (Section 8.5.19) and fish population data (Section 8.5.21 and Appendix Tables C-14 and C-15) suggested that this reach may more closely approximate a Class 2 warm water reach than a Class 2 cold water reach. These observations indicated that reclassification of the Tongue River from a Class 2 cold water stream to a Class 2 warm water stream should be considered. Additional discussion related to re-classification is presented in benthic macroinvertebrate Section 8.5.19 and fisheries Section 8.5.21.

Water temperature in most Wyoming streams will naturally increase during summer months from upstream to downstream along the longitudinal gradient even without effects due to dewatering. However, dewatering at the Tongue River Lower station appeared to accelerate the natural water temperature increase creating unfavorable conditions for game fish populations. Increasing summer flows at Tongue River Lower will subject the stream to fewer adverse temperature changes, decreased water temperature and increase important aquatic habitat needed for fish survival.

It is certain that higher water temperatures occurred than those recorded by SCCD and WDEQ, but were not detected because samples were collected before maximum daily temperature occurred. SCCD did not have adequate funding to purchase continuous water temperature recorders and software for this Project. Additional water temperature monitoring using continuous thermographs is warranted to determine if exceedence of the Wyoming water quality standard for temperature occurs regularly. It is recommended that continuous water temperature recorders be used for future monitoring in the Tongue River Watershed.

8.5.3 RPWD Water Temperature Monitoring at Tongue River Lower Station

RPWD collected instantaneous daily water temperature data at the Tongue River raw water inlet since 1993. Temperature data provided additional insight for observed water temperature exceedences at Tongue River Lower station. Mean monthly, minimum and maximum water temperature values are presented in Appendix Table A-20.

Average monthly, minimum and maximum water temperature values recorded from 1993 through 1999 are illustrated in Figure 8-7. Lowest average monthly water temperature occurred in December and January and highest average monthly water temperature occurred in July and August.

Analysis of the data set (1993 through 1999) revealed one temperature measurement in August, 1994 exceeded the Wyoming water quality standard for water temperature. However, daily temperature readings were measured from 0700 hours to 0900 hours (1999 Personal Communication, Harold Herman, Ranchester Director of Public Works) and did not reflect maximum daily water temperature since maxima generally occurred between 1700 hours and 2000 hours. Conservative maximum daily water temperatures were projected by adding 7^0C to reported water temperature values since the range between daily minimum and maximum water temperature was generally from 5^0C to 7^0C (See Section 8.5.2). Projected maximum daily water temperature revealed numerous exceedences of the water temperature standard each year (Table 8-4). The water quality standard for water temperature was exceeded on 12 days in 1993, 42 days in 1994, 30 days in 1995, 55 days in 1996, 16 days in 1997, 6 days in 1998 and 4 days in 1999. The majority of exceedences occurred during the warmest summer months of July and August when discharge was reduced due to dewatering.

The reliability of the projected maximum daily water temperature was checked by comparison to the WGFD data set collected in 1994. WGFD recorded 57 water temperature standard exceedence days in 1994 and RPWD recorded 42 projected water temperature standard exceedence days in 1994. The projected daily RPWD water temperature exceedences matched the WGFD water temperature exceedence days 74 percent of the time. This indicated that the maximum daily water temperature projected by RPWD was reliable, but generally underestimated the maximum daily water temperature. This indicated that a probable higher number of water temperature standard exceedences occurred from 1993 through 1999 than the number based on projected RPWD data.

Further analysis of the RPWD water temperature data set revealed an interesting trend that required further investigation and evaluation beyond the scope of this Final Report. Average annual water temperature has declined during consecutive years since 1993 (Figure 8-8). A time series regression analysis was conducted on average annual water temperature to determine if the decline in water temperature over time was due to random chance or due to other factors. The regression analysis revealed a correlation coefficient of -0.973422 ($P<0.01$) suggesting that the association between decline in water temperature and year (time) was strong. This indicated that the decline in water temperature was not due to chance, but to other factors. Should the decline in annual water temperature continue to decline or level off, suggested reclassification of this reach of the Tongue River from Class 2 cold water to Class 2 warm water may need to be re-evaluated. Continued monitoring in concert with daily discharge measurement is recommended to further evaluate thermal conditions at the Tongue River Lower station.

8.5.4 SCCD and WDEQ Tongue River Temperature Monitoring

Summary statistics for instantaneous water temperature measurements by SCCD and WDEQ at Tongue River Upper, Middle and Lower stations are presented in Table 8.5. Water quality data for the Upper station is presented in Appendix Tables B-1 and B-2, data for the Middle station in Appendix Tables B-5 and B-6 and data for the Lower station in Appendix Tables B-7 and B-8. Data collected by WDEQ in 1998 at the Tongue River in the vicinity of the Dayton WWTF upstream of the Middle station is presented in Appendix Tables B-3 and B-4.

Average water temperature was lowest at the Upper station (9.6^0C) with a slight increase at the Middle station (9.8^0C) and highest at the Lower station (11.7^0C). Maximum water temperature recorded at the Upper station was 18.0^0C, 21.2^0C at the Middle station and 21.8^0C at the Lower station. Water temperature measurements conducted at each station on the same day indicated a general range of from about 3^0C to 7^0C in temperature between Upper and Lower stations (Figure 8-9). The higher the discharge at Tongue River Upper especially during spring runoff in May and June, the more similar water temperature was among stations indicating increased discharge stabilized water temperature among stations. The greatest temperature differential among stations generally occurred during periods of lower discharge in the summer months of July and August. However, comparison of water temperature measured the same day at Middle and Lower stations during this Project generally showed no large difference in water temperature between stations (Figure 8-10).

There were no exceedences of the Wyoming water quality standard for temperature. However, as indicated in Section 8.5.2, sampling conducted by SCCD and WDEQ did not occur during the time of day to detect maximum daily water temperature. Maximum daily temperature was projected at each station during the months of June, July, August and September as described in Section 8.5.3. Projected maximum daily water temperature indicated no exceedence of Wyoming water quality standard for water temperature at the Upper and Middle stations. Two temperature exceedences occurred at the Lower station. This suggested that the reach of concern for water temperature was downstream of the Middle station in the vicinity of the Lower station and confirmed findings in Sections 8.5.2 and 8.5.3.

8.5.5 SCCD and WDEQ Tongue River pH Monitoring

Summary statistics for instantaneous pH measurements by SCCD and WDEQ at Tongue River Upper, Middle and Lower stations are presented in Table 8.6. The pH varied little among Tongue River Upper, Middle and Lower stations. The average and geometric mean for pH during this Project was 8.2 SU at the Upper station, 8.0 SU at the Middle station and 8.0 SU at the Lower station. The maximum pH recorded at each Tongue River station during the Project was the same (8.6 SU). The minimum pH was 6.9 SU at the Upper and Middle stations and 6.8 SU at the Lower station. All pH measurements were within Wyoming water quality standards (acceptable range from 6.5 SU to 9.0 SU).

Little annual variability in average pH was observed at each station and among sampling stations. The minimum annual pH at Tongue River mainstem stations was 7.9 SU at the Lower station in 1998 and the maximum annual pH was 8.3 SU at the Upper station in 1996.

8.5.6 RPWD pH Monitoring at Tongue River Lower Station

Daily pH measurements recorded by RPWD since 1993 at the Town of Ranchester Water Treatment Plant raw water intake at the Tongue River Lower station provided an excellent long term data set for evaluation of pH dynamics. Mean monthly, minimum and maximum pH values are presented in Appendix Table A-21.

There was little variability for average monthly pH as illustrated in Figure 8-11. The average monthly pH generally varied by less than 0.3 SU. There were exceedences of the upper (9.0 SU) and lower (6.5 SU) limits for the Wyoming water quality standard for pH in 1998 (pH = 9.6 SU in May) and 1999 (pH = 6.3 SU in May and 6.4 SU in June). Although the pH values technically represented a violation of the pH standard, they accounted for less than 0.2 percent of total pH measurements suggesting that pH was suitable for attainment of aquatic life use.

The data set indicated generally lower pH values when compared to pH values measured by SCCD and WDEQ during this Project. The generally lower pH recorded by RPWD appeared to be due to differences in the time that samples were measured. RPWD measured pH around 0800 hours (± one hour) to provide data for daily WTP operations. SCCD and WDEQ sampling occurred later in the day, normally from 0900 hours to 1500 hours. Diurnal variation (variation within a day) for pH is common in streams and is similar in manner to diurnal changes previously described for temperature although the mechanism causing the variability is different. Differences in solar radiation due to sunlight is known to cause differences in pH because instream plant and algal production during daylight hours may reduce the buffering capacity of streams and increase pH. Thus, stream pH may be expected to be lowest in the early morning and highest in the late afternoon, especially on sunny days (Hynes,1970; King, 1990a, King, 1993).

Of significant interest was the gradual decline in pH at the Lower station since 1993 as shown in Figure 8-12. A time series regression analysis was conducted on the average annual pH to determine if the decline in pH over time was due to chance or due to other factors. The regression analysis revealed a correlation coefficient of -0.949931 ($P<0.01$) suggesting that the association between decline in pH and year (time) was strong. This indicated that the decline in pH was not due to chance, but to other factors. The general decrease in pH was interesting because many water bodies in the United States and worldwide have experienced decline in pH due to suspect acid rain precipitation. Research to determine why the pH has declined at Tongue River Lower was beyond the scope of this Project, but should be strongly considered for future monitoring. One area to investigate may be the relationship between a change in water management in Wolf Creek that occurred around 1995 whereby more water may have remained in the water body throughout the year to provide enhanced maintenance of the fishery. Should the decline in pH shown in Figure 8-12 continue in the coming years, implications may be great for the aquatic life, fishery and the ability of the Tongue River to attain the Wyoming water quality standard for pH.

8.5.7 SCCD and WDEQ Tongue River Specific Conductivity Monitoring

Summary statistics for specific conductivity are presented in Table 8-7. Average conductivity during the Project was 209 umhos/cm at the Upper station, 277 umhos/cm at the Middle station and 300 umhos/cm at the Lower station. Conductivity values at the Upper station ranged from a low of 119 umhos/cm to a high of 530 umhos/cm, from a low of 147 umhos/cm to a high of 410 umhos/cm at the Middle Station and from a low of 90 umhos/cm to a high of 495 umhos/cm at the Lower station. The increase in conductivity from the Upper station to the Lower station was normal since conductivity will naturally increase along the longitudinal gradient of most water bodies. Although there was no Wyoming water quality standard for conductivity, values were generally considered low for a water body of this size and drainage area and within the range required for support of aquatic life.

Conductivity values were controlled primarily by stream discharge. The association between conductivity and discharge was strong and inverse such that as discharge increased, conductivity decreased (Figure 8-13). The correlation coefficient at the Upper station was -0.526, -0.736 at the Middle station and -0.709 at the Lower station (Appendix Table L-3). Correlation coefficients were significant ($P<0.01$) at each station indicating there was less than a 1 percent chance that the association was due to random chance alone.

8.5.8 SCCD and WDEQ Tongue River Dissolved Oxygen Monitoring

SCCD initiated monitoring for dissolved oxygen (DO) in 1999. WDEQ conducted monitoring for DO once annually usually in October. Summary statistics for DO are presented in Table 8-8. Average DO was 10.2 mg/l at the Upper station, 11.0 mg/l at the Middle station and 9.9 mg/l at the Lower station. DO values at the Upper station ranged from 8.1 mg/l to 12.0 mg/l, from 8.1 mg/l to 13.6 mg/l at the Middle Station and from 7.9 mg/l to 12.2 mg/l at the Lower station. The general slight decrease in DO from the Upper station to the Lower station was apparently due to the slight decrease in average water temperature from the Upper station to the Lower station. DO will normally decrease as water temperature increases. DO values at each station were generally higher during the spring and fall during periods of cooler water temperature and lower during the summer months when water temperature was higher.

There were no exceedences of the Wyoming water quality standard for DO because no DO values were less than 5 mg/l. The lowest DO value recorded during the Project was 7.9 mg/l measured by SCCD at the Lower station on September 15, 1999. The DO concentration was sufficient to support diverse populations of aquatic organisms and fish indicating full support for aquatic life use for this physical parameter.

8.5.9 SCCD and WDEQ Tongue River Turbidity Monitoring

Summary statistics for turbidity are presented in Table 8-9. Average turbidity during the Project was 7.3 NTU at the Upper station, 9.0 NTU at the Middle station and 13.5 NTU at the Lower station. The geometric mean was 3.6 NTU at the Upper station, 3.7 NTU at the Middle station and 7.1 NTU at the Lower station. The geometric mean is a logarithmic transformation of data and generally provides a more reliable estimate of the mean by smoothing extreme values when variability is high among measurements due to normal seasonal variability. Turbidity values at the Upper station ranged from a low of 0.2 NTU to 26.0 NTU, from 0.4 NTU to 33.0 NTU at the Middle Station and from 1.0 NTU to 61.0 NTU at the Lower station. The increase in turbidity from the Upper station to the Lower station was considered normal since turbidity will naturally increase along the longitudinal gradient of most flowing water bodies.

Turbidity values were closely associated with discharge. There was a relatively strong positive relationship such that turbidity values increased as discharge increased (Figure 8-14). The correlation coefficient between turbidity and discharge at the Upper station was +0.445 ($P<0.01$), +0.595 ($P<0.01$) at the Middle station and +0.582 ($P<0.01$) at the Lower station (Appendix Table L-5). R-squared values for the regression analyses were 19.8 percent at the Upper station, 35.4 percent at the Middle station and 33.9 percent at the Lower station (Appendix Table L-6). The R-squared value is a statistic that shows what percentage of the variability in concentration for a water quality parameter (i.e. turbidity) is explained by another parameter (i.e. discharge). The R-squared value at the Lower station was 33.9 percent indicating that 33.9 percent of the variability in turbidity values during the Project was due to discharge. The correlation coefficients and R-squared values at each station indicated that stream discharge was an important factor controlling turbidity even in the absence of potential anthropogenic (man-caused) effects.

Because of the association between turbidity and discharge, lower turbidity values were recorded during periods of lower discharge (prior to and after spring runoff) in early April, September and October and higher turbidity values were recorded during periods of higher discharge during spring runoff in latter April, May and June. There were no exceedences of the Wyoming water quality standard for turbidity. The average increase in turbidity between the Upper and Middle stations was 1.7 NTU and the average increase in turbidity between the Middle and Lower stations was 4.5 NTU. The average increase in turbidity between the Upper and Lower stations was 6.2 NTU which was well below the increase of 10 NTU allowed by the Wyoming water quality standard for Class 2 cold water, water bodies.

8.5.10 RPWD Turbidity Monitoring at Tongue River Lower Station

Daily turbidity measurements were taken by RPWD since 1983 at the raw water intake to the Ranchester Water Treatment Plant near the Tongue River Lower station. This data set represented the most comprehensive long term water quality record (17 years) evaluated during this Project. It provided valuable information regarding turbidity dynamics and due to the close relationship between turbidity and suspended sediment, may also provide estimates for long term suspended sediment concentration in the Tongue River should the relationship between turbidity and TSS be determined. Mean annual and monthly turbidity values are presented in Appendix Table A-19.

The data set clearly shows the seasonal variability in turbidity values due to the close association with the annual Tongue River discharge regime. Lowest turbidity values occur during the months from October through January when annual base flows are present (Figure 8-15). Turbidity begins to increase in March and April and peaks in May during the period of highest discharge. Values remain relatively high in June and progressively decline into July, August and September in response to the seasonal decline in discharge. The highest average monthly turbidity was 52.6 NTU in May and lowest in October (2.4 NTU) and November (2.3 NTU).

Analysis of the long term record for turbidity revealed that there has been a general, but statistically significant, trend towards reduction in turbidity since 1983 (Figure 8-16). A time series regression analysis was conducted using average annual turbidity to determine if the decline in turbidity was due to chance or due to other factors. The regression analysis revealed a correlation coefficient of -0.5956389 ($P<0.05$) indicating that the association between reduction in turbidity and year (time) was present. This indicated that the decline in turbidity was not due to chance, but to other factors. Further analysis indicated that the apparent decline was primarily related to the large reduction in annual turbidity from 1983 (average = 29.6 NTU) to 1985 (average = 9.2 NTU). Average annual turbidity increased about 5 NTU during 1986 and 1987 and then declined in 1988. Average annual turbidity then fluctuated by less than 3 NTU during the years from 1990 through 1996.

There was no statistically significant relationship ($P>0.05$) between average annual turbidity and average annual discharge measured at USGS station 06298000 from 1983 through 1999. The lack of a relationship between turbidity and discharge was due to the fact that discharge measured at station 06298000 (located at the Tongue River Upper station) did not accurately reflect discharge at the Tongue River Lower station near the RPWD sampling station due to water management that affected discharge between the two stations.

8.5.11 SCCD and WDEQ Tongue River Fecal Coliform Bacteria Monitoring

Summary statistics for fecal coliform bacteria are presented in Table 8-10. The geometric mean for fecal coliform bacteria at the Upper station during the Project was 5 per 100ml, 15 per 100ml at the Middle station and 25 per 100ml at the Lower station. The geometric mean is a logarithmic transformation of data and provided a more reliable estimate of the mean by smoothing extreme values when variability was high among fecal coliform measurements. Fecal coliform concentration at the Upper station ranged from 1 per 100ml to 90 per 100ml, from 1 per 100ml to 200 per 100ml at the Middle Station and from 1 per 100ml to 1060 per 100 ml at the Lower station. The increase in fecal coliform from the Upper station to the Lower station followed the trend exhibited by other water quality parameters in the Tongue River where values increased along the longitudinal gradient.

Direct comparison for fecal coliform bacteria concentration among years could not be made due to differences in sampling frequency between years. SCCD increased the sampling frequency in 1999 from monthly to five (5) samples within a 30 day period during the Recreational Season to provide a better estimate of bacteria contamination and allow direct comparison to the Wyoming water quality standard for fecal coliform bacteria.

The was no exceedence of the Wyoming water quality standard for fecal coliform bacteria at the Upper station. The geometric mean of five (5) samples collected during the Recreational Season in 1999 was 7 per 100ml which was considered low. There was no single sample in excess of 400 per 100ml since the maximum concentration during the Project was 90 per 100ml (collected August 26, 1997).

The was no exceedence of the Wyoming water quality standard for fecal coliform bacteria at the Middle station. The geometric mean of five (5) samples collected during the Recreational Season in 1999 was 90 per 100ml which was considered low. There was no single sample in excess of 400 per 100ml since the maximum concentration during the Project was 200 per 100ml (collected April 21, 1999). Intensive fecal coliform bacteria sampling conducted by WDEQ in fall, 1998 at the Dayton WWTF upstream of the Middle station indicated no significant bacterial contamination was discharged from the treatment plant (Appendix Tables B-3 and B-4). The maximum instantaneous fecal coliform concentration was 24 per 100ml. This indicated the WWTF was performing properly during the sampling period.

There was one exceedence of the Wyoming water quality standard for fecal coliform bacteria at the Lower station. The exceedence was due to a single sample collected April 21, 1999 (prior to the Recreation Season) that had a concentration of 1060 per 100ml. Although the geometric mean of five (5) samples collected during the Recreational Season in 1999 was 63 per 100ml, the standard was exceeded because 10 percent of samples collected in 1999 exceeded 400 ml. However, only 4 percent of total fecal coliform bacteria samples collected during the Project exceeded the standard (1 sample out of 27 total samples) suggesting that significant, but infrequent fecal coliform bacteria contamination may exist. Consistent and significant bacterial contamination probably does not exist, but because there was a technical exceedence of the fecal coliform bacteria standard near the Ranchester Water Treatment Plant intake, remedial action should be taken to ensure that all fecal coliform bacteria samples are less than 400 per 100ml to bring the Lower station into compliance with the Wyoming water quality standard for fecal coliform bacteria.

Results for fecal coliform sampling conducted during this Project were compared to results for historic fecal coliform sampling conducted at comparable Tongue River Upper, Middle and Lower sampling stations. Results of these comparisons are presented in Table 8-11. Historical fecal coliform data collected at the Upper station from 1976 through 1988 were compared to current Project fecal coliform data. There was no large difference in fecal coliform bacteria between periods indicating that the generally low fecal coliform levels have been consistent since 1976 and potential wildlife and recreational sources for fecal coliform bacteria were not contributing significant levels of bacterial contamination. Livestock were not a significant potential source for fecal coliform bacteria because the upstream Tongue River canyon limits access and suitable grazing areas for livestock (see Section 3.1.1).

Historical fecal coliform data collected at the Middle station from 1985 through 1989 were compared to current Project fecal coliform data. Caution was used during this comparison because the number of samples used in the analysis was lower during the historic period (N = 9 samples) than during the current Project (N = 37 samples). Even with this consideration, the data revealed a significant reduction in fecal coliform contamination from 1985 to this Project. All statistical measures including average, median, minimum, maximum and geometric mean fecal coliform levels were reduced from 1985 to this Project. The Wyoming water quality standard for fecal coliform bacteria was exceeded twenty-two percent (22%) of the time during historic sampling, but no exceedence of the Wyoming water quality standard for fecal coliform bacteria occurred during the current Project. The reduction in fecal coliform contamination over time was probably due to the significant upgrade of the Dayton WWTF in the mid-1980's, installation of improved lined, aerated treatment cells, an ultraviolet disinfection system treating effluent before discharge to the Tongue River and adequate operation and maintenance of the facility. Upgrade and maintenance of the WWTF occurred again in 1998 with replacement of the cell liners.

Historic fecal coliform data collected at the Lower station from 1968 through 1990 were compared to current Project fecal coliform data. Caution was used during this comparison because the number of samples used in the analysis was two-fold higher during the historic period (N =57 samples) than during the current Project (N = 27 samples). Despite the unequal sampling between historic and current Project periods, the data suggested that fecal coliform contamination was dropping over time. However, the trend was not as strong than the trend showing reduction in fecal coliform contamination at the Middle station. All statistical measures including average, median, minimum, maximum and geometric mean fecal coliform levels were generally reduced from 1968 to this Project, but the disparity in sampling frequency precluded a firm conclusion that fecal coliform bacteria had been significantly reduced at the Lower station.

8.5.12 SCCD Tongue River Pesticide and Herbicide Monitoring

SCCD conducted pesticide and herbicide sampling at Tongue River Upper, Middle and Lower stations on August 21, 1996. Analytical results are presented in Appendix Table H-1. Sampling occurred once during the Project due to the high cost associated with sample analyses, results from this sampling event and knowledge that USGS NAWQA would conduct more intensive pesticide and herbicide sampling at USGS station 06298000 (the SCCD Tongue River Upper station).

A total of nineteen (19) organochlorine pesticides and ten (10) chlorinated herbicides were sampled. Analytical results found no detectable (less than the minimum detection limit) concentrations for herbicides or pesticides at each station. This observation indicated that no evidence of herbicide and pesticide contamination was present in the Tongue River water column during this sampling event.

8.5.13 USGS NAWQA Organics Monitoring Including Pesticides and Herbicides at Tongue River Upper Station

USGS NAWQA conducted organics sampling for whole body tissue from brown trout and from bed sediment at Tongue River station 06298000 (SCCD Tongue River Upper station) on September 23, 1998. Results for whole body tissue analyses are presented in Appendix Table D-2 and results for bed sediment analyses are presented in Appendix Table D-4. A total of twenty-eight (28) different organic compounds including various pesticides and herbicides were analysed in fish tissue samples. A total of about ninety-five (95) different organic compounds including various pesticides and herbicides were analysed in bed sediment samples.

Analytical results found no detectable organic compounds in brown trout whole body fish tissue samples. This observation indicated that the organic compounds monitored did not exist or persisted in concentrations that were not measurable. There were no exceedences of applicable EPA standards to indicate a fish consumption advisory. Because brown trout are mobile and may migrate several miles during their lives, the results suggested that not only were these organic compounds not detected at the Upper station, but probably were not present in the Tongue River water column for several miles upstream or downstream of the Upper station.

Analysis of bed sediment organics samples detected no organics at the Upper station. Results for eight (8) compounds were not presented in this Final Report because of uncertainty with the analytical results for these compounds presented by USGS. However, the results indicated that a wide array of organic compounds including various pesticides and herbicides were not detected at the Upper station. This observation indicated that potential use of these compounds within the watershed upstream of the Upper station (including the BHNF) has resulted in no detectable levels of these compounds within the bed sediment.

8.5.14 SCCD and WDEQ Tongue River Nitrate Nitrogen Monitoring

Summary statistics for nitrate nitrogen are presented in Table 8-12. Average nitrate nitrogen concentrations were low at each station during the Project. The average nitrate concentration at the Upper station was .028 mg/l, .030 mg/l at the Middle station and .019 mg/l at the Lower station. Nitrate values at the Upper station ranged from .001 mg/1 to .130 mg/l, from .001 mg/l to .100 mg/l at the Middle Station and from .002 mg/l to .120 mg/l at the Lower station.

Average and maximum nitrate values at the Upper, Middle and Lower stations should be considered low. The nitrate concentration was well below the Wyoming water quality standard and drinking water human health standard of 10 mg/l for Class 2 surface waters (WDEQ, 1998). Data for nitrate nitrogen indicated that nitrate concentration in the Tongue River was less than the background concentration of nitrate (about 0.60 mg/L) found in streams in undeveloped areas (i.e. least impacted reference type streams) throughout the United States (USGS, 1999). These observations indicated that nitrate nitrogen was not present in the Tongue River in concentrations that could pose a human health threat or an ancillary threat to aquatic populations by effects caused by eutrophication. Full support for all Wyoming beneficial uses applicable to nitrate was indicated.

8.5.15 SCCD and WDEQ Tongue River Total Phosphorus Monitoring

Summary statistics for total phosphorus are presented in Table 8-13. These statistics were based on “censored” values because the majority of analyses (35 samples out of 36 total samples) were less than the minimum detection limit (minimum detection limit was 0.10 mg/l for WDEQ analytical method; 0.05 mg/l for SCCD analytical method). The minimum detection limit for the WDEQ analytical method did not provide adequate data needed to address the recommended water quality standard for total phosphorus in water bodies draining to a lake or reservoir (0.05 mg/l; EPA, 1977). Data were thus censored to provide an estimate that could be related to the recommended EPA standard of 0.05 mg/l.

Average total phosphorus concentrations were low at each station during the Project. The average total phosphorus concentration at the Upper station was .044 mg/l, .041 mg/l at the Middle station and .028 mg/l at the Lower station. Total phosphorus concentration at the Upper station ranged from .006 mg/1 to .080 mg/l, from .006 mg/l to .090 mg/l at the Middle Station and from

.004 mg/l to .080 mg/l at the Lower station. The geometric mean concentration gradually dropped from the Upper station (.035 mg/l) to the Middle station (.031 mg/l) and to the Lower station (.016 mg/l). The observed reduction in total phosphorus from Upper to Lower stations may be due to the removal of phosphorus by periphyton and submerged rooted aquatic plants since phosphorus is rapidly assimilated by aquatic plants. Macroinvertebrate monitoring and habitat assessment at the Lower station noted increased periphyton at the Lower station when compared to periphyton at the Upper and Middle stations.

Average and maximum total phosphorus values at the Upper, Middle and Lower stations should be considered low. Wyoming has not established surface water quality standards for phosphorus. U.S. EPA (1977) recommended that total phosphorus concentration should not exceed 0.05 mg/l in a stream that enters a lake or reservoir (e.g. Tongue River Reservoir) to prevent development of nuisance algal and plant populations. Mackenthun (1973) suggested a target phosphorus level of less than 0.10 mg/l for streams that did not directly enter lakes or reservoirs. USGS (1999) provided recent information from nationwide NAWQA monitoring and reported national background concentrations for total phosphorus from streams in undeveloped (reference - like) areas was about 0.10 mg/L. This finding suggested that a realistic standard for total phosphorus should be 0.10 mg/l because that value represented a best attainable value for streams in least disturbed watersheds. The USGS report conflicted with the EPA recommended standard because the national background (reference) concentration found by USGS was two-fold greater than the EPA standard. This observation indicated that in order to meet the EPA standard for total phosphorus, a water body would have to reduce its total phosphorus concentration by 50 percent beyond that of natural background. Because this goal was not attainable, SCCD adopted findings by USGS for its interpretation of total phosphorus data collected during this Project.

Using the value of $\leq$0.10 mg/l as a target for total phosphorus concentration, no significant amount of total phosphorus was identified in a single sample collected during this Project. However, sampling frequency was generally low at the Upper and Lower stations (N=10) and at the Middle station (N=16) over a four year period and sampling generally occurred during the fall low base flow period when total phosphorus concentration was normally lower. Additional sampling is required to provide a reliable estimate of total phosphorus concentration in the Tongue River.

8.5.16 WDEQ Tongue River Monitoring for Additional Water Chemistry Parameters

WDEQ collected samples for additional water chemistry parameters during annual monitoring at the Upper station from 1993 through 1999 and at Middle and Lower stations from 1996 through 1999. Summary statistics are presented in Table 8-14. Data for WDEQ intensive monitoring in 1998 at stations upstream and downstream of the Dayton WWTF are presented in Appendix Tables B-3 and B-4.

Alkalinity at the Upper station was generally low ranging from 90 mg/l to 124 mg/l. Average alkalinity was 122 mg/l and the geometric mean was 121 mg/l. Alkalinity increased slightly at the Middle station. Average alkalinity was 145 mg/l and the range was from a low of 120 mg/l to a high of 170 mg/l. Alkalinity continued to increase slightly from the Middle Station to the Lower station. Average alkalinity was 174 mg/l and the range was from a low of 160 mg/l to a high of 180 mg/l. There was no Wyoming water quality or EPA standard to compare alkalinity values to, but data indicated that water was generally productive for aquatic life and was generally capable of withstanding sudden changes in pH due to inputs from point or NPS sources.

Total chloride concentration was low at each station. There were no samples that had total chloride concentrations greater than 5 mg/l. Total chloride values were well within WDEQ and EPA water quality standards indicating full support for Wyoming beneficial uses applicable to chloride.

Total sulfate concentration was low at the Upper station. All samples were <10 mg/l. Average total sulfate concentration increased at the Middle station (23 mg/l) and at the Lower station (33 mg/l). These values may be considered normal because all samples were collected in the fall during lower base flow when ion concentrations were normally highest. The low number of samples collected at the Lower station (N=4) did not provide enough data with which to provide an in depth analysis. Total sulfate sampling is recommended for future monitoring at the Tongue River to determine if the increase in sulfate concentration at the Lower station is a natural occurrence or if the increase is due to potential irrigation return and urban land use influence. Total sulfate values were well within WDEQ standards (for groundwater use) and the EPA secondary drinking water standard (See Table 4-1). This observation indicated full support for Wyoming beneficial uses applicable to sulfate.

Hardness concentration was relatively high at each station and was reflective of the natural limestone geology that predominated much of the upper Tongue River watershed. Average hardness at the Upper station was 209 mg/l, 176 mg/l at the Middle station and 202 mg/l at the Lower station. Water at each station may be termed hard based on the classification found in Table 6-2. There were no Wyoming or EPA water quality standards for hardness, but observed values indicated full support of the Wyoming beneficial use for Industrial use since all values were less than 300 mg/l.

Total Suspended Solids (TSS) concentrations were low at each station. Low values were related to the fact that all samples were collected in the fall during lower base flow when TSS values were normally lowest. Average TSS concentration at the Upper station was 3 mg/l, 2 mg/l at the Middle station and 3 mg/l at the Lower station. Results of limited TSS sampling conducted by WDEQ provided little information for potential sediment problems within the Tongue River watershed. However, further sampling for TSS is not recommended at this time because turbidity sampling did not indicate sediment problems in the Tongue River. Turbidity should continue to be used as a surrogate indicator for TSS unless specific sediment loading questions arise.

Biochemical Oxygen Demand (BOD) sampling was conducted by WDEQ on five (5) days in October and November 1998 at stations upstream and downstream of the Dayton WWTF. All BOD values were low and ranged from <1 mg/l to 2 mg/l. There was no difference in BOD between the upstream and downstream stations indicating that the Dayton WWTF effluent had no effect on BOD values in the Tongue River. Moreover, the low BOD value at the upstream station indicated low ambient BOD concentration at this reach of the Tongue River.

Total Ammonia sampling was conducted by WDEQ on five (5) days in October and November 1998 at stations upstream and downstream of the Dayton WWTF. No ammonia was detected indicating low ambient ammonia concentration at this reach of the Tongue River. Further, this observation indicated effective removal of ammonia in wastewater treated by the Dayton WWTF.

8.5.17 RPWD Alkalinity Monitoring at Tongue River Lower Station

Daily alkalinity measurements have been recorded by RPWD since January 1998 at the Ranchester WTP raw water intake near the Tongue River Lower station. Mean monthly, minimum and maximum alkalinity values are presented in Appendix Table A-22.

Monthly variability for alkalinity was observed (Figure 8-17) and was related to the seasonal discharge regime in the Tongue River. Alkalinity values were highest in the fall and winter months during low discharge and lowest during the spring and early summer months when discharge was highest. The inverse relationship between alkalinity and discharge was normal and may be expected for most Wyoming streams affected by snowmelt runoff that serves to dilute alkalinity during the spring runoff period.

Average monthly alkalinity was lowest in May (80 mg/l) and June (90 mg/l) and highest in December (168 mg/l) and March (172 mg/l). The effect of snowmelt runoff on alkalinity caused an approximate 50 percent reduction in alkalinity between the spring and winter months.

Although the alkalinity data set was relatively small (2 years) compared to the RPWD data set for pH (7 years), the apparent reduction in pH observed by RPWD was reflected in the alkalinity values. There appears to be a general reduction in alkalinity over time which may be an important factor in the reduction observed for pH at the Tongue River Lower station (see Section 8.5.6). Alkalinity serves to buffer the water mass from changes in pH and reduction in alkalinity may result in a reduction in pH. The implications for lower pH include changes in the aquatic community and fisheries and more frequent lower pH readings that may approach the Wyoming water quality standard for pH. As previously indicated, these observations warrant more investigation and in depth analysis to determine causes for the apparent decline in alkalinity and pH.

8.5.18 USGS NAWQA Water Quality, Brown Trout Liver Trace Metals and Bed Sediment Metals Monitoring at Tongue River Station 06298000

USGS NAWQA initiated monthly water quality monitoring at station 06298000 in January 1999. Data collected from January 1999 through August 1999 are presented in Appendix Table B-26. Liver trace metals analysis from brown trout liver samples collected on September 23, 1998 are presented in Appendix Table D-1. Results for trace metals collected from bed sediment are presented in Appendix Table D-3.

Results from water sample analyses confirmed SCCD and WDEQ findings indicating water quality at the Upper station was excellent. Dissolved nutrients (nitrate, nitrite, phosphorus and ammonia) were either not detected or present in low concentration. Water temperature, DO and pH were within Wyoming water quality standards. Dissolved organic carbon and total organic carbon levels were low. Hardness, conductivity, alkalinity, sulfate and chloride concentrations were comparable to those concentrations identified in WDEQ samples. However, USGS chloride and sulfate measurements were reported for dissolved constituents versus total chloride and total sulfate values reported by WDEQ.

Twenty-three dissolved metals were sampled by USGS. Antimony, arsenic, beryllium, cadmium, chromium, cobalt, copper, lead, nickel, selenium, silver, manganese, mercury, molybdenum, uranium and zinc were either not detected or present in low concentration. Dissolved aluminum was present in concentrations up to 8 ug/l and 9 ug/l which was within the WDEQ standard of 750 ug/l for protection of aquatic life use. Mean barium concentration was 24 ug/l which was within the WDEQ standard of 1000 ug/l for protection of human health. Dissolved calcium, magnesium, potassium and sodium were regularly present, but in low concentration and when applicable, were within WDEQ or EPA standards for human health or aquatic life use.

Dissolved iron exceeded the WDEQ water quality standard of 19 ug/l for protection of aquatic life during twenty-seven percent (27%) of sampling events. Dissolved iron was not detected in the water column during sixty-four percent (64%) of sampling events. WDEQ recently proposed a change in the standard for iron to 1000 ug/l for protection of aquatic life use and 300 ug/l for protection of human health, fish and drinking water (WDEQ, 2000). The proposed change has not been formally approved, but the proposal appears appropriate based on dissolved iron values identified at the Lower station which typifies water quality for a minimally disturbed reference quality stream reach. With these considerations, dissolved iron concentrations identified by USGS did not appear to represent a threat to human health, aquatic life or fish populations.

Sodium Absorption Ratio (SAR) values were either 0.0 or 0.1 which were very low. SAR has recently received considerable attention due to development of coal bed methane (CBM) resources in Northeastern Wyoming and the effect that application of CBM water may have on vegetation. The emphasis on this water quality parameter may be misdirected because the SAR of soil receiving CBM water is the most important factor to consider for long term soil fertility for growth and maintenance of vegetation. For example, even though the SAR of water at USGS station 06298000 was very low, it could not be applied to soil with existing high SAR values without developing soil fertility problems developing in the future. However, because of public concern, **generally** and without any previous knowledge of soil SAR values, water with SAR values below 10 are believed to be sufficient for irrigation, and SAR values of 18 or higher are not recommended for irrigation use.

Twenty-two (22) trace metals were analysed by USGS for samples collected from brown trout livers. Fish liver may accumulate metals present in food consumed by trout and provide an estimate for trace metals present in the aquatic and terrestrial environment. Eight (8) out of twenty-two (22) trace metals analysed were not detected. Trace metals detected in order from highest to lowest concentration included iron (450 ug/g), copper (190 ug/g), zinc (99 ug/g), selenium (22 ug/g), manganese (6.5 ug/g), aluminum (3.3 ug/g) and silver (2.3 mg/g). Remaining trace metals detected were present at concentrations less than 1.0 ug/g. Trace metals present in brown trout fish livers were considered low suggesting metal concentration in aquatic and terrestrial Tongue River environs were generally low and posed no significant threat to aquatic resources and human health.

A total of forty-seven (47) trace metals and other parameters were analysed from bed sediment samples. Five (5) of the forty-seven (47) parameters were not detected. Concentrations of those parameters that were detected were generally low and indicated no significant contamination of bed sediment at the Tongue River Upper station.

8.5.19 SCCD, WDEQ and USGS Tongue River Benthic Macroinvertebrate Monitoring

The Tongue River Upper station has been monitored by WDEQ annually since 1993 because it was a long term reference site. USGS sampled benthic macroinvertebrates in August 1999 at station 06298000 located about one mile downstream of the WDEQ station. SCCD and WDEQ sampled benthic invertebrates at Middle and Lower stations annually from 1996 through 1999. WDEQ conducted additional one time benthic macroinvertebrate sampling in 1998 at stations upstream and downstream from the Dayton WWTF discharge outfall.

Metric values for WDEQ samples collected from the Upper station are presented in Appendix Table G-3 under the column heading Tongue R. @ Canyon. Metric values for the USGS sample are presented in Appendix Table G-3 under the column heading Tongue R. @ USGS 06298. Metric values for samples collected at the Middle station and Lower station are presented in Appendix Table G-4. Metric values for samples collected upstream and downstream of the Dayton WWTF are presented in Appendix Table G-3.
Lists of benthic taxa identified, density (number per square meter) of taxa and percent contribution

of each taxon to the total benthic population are presented in Appendix F. WDEQ Upper station taxa lists are presented in Appendix Tables F-28 through F-34, the USGS sample taxa list in Appendix Table F-40, Middle station taxa lists in Appendix Tables F-22 through F-25, stations upstream and downstream of the Dayton WWTF in Appendix Tables F-26 and F-27 and taxa lists for the Lower station in Appendix Tables F-18 through F-21.

Biological condition at the Tongue River Upper station using scoring criteria from both the Wyoming Biological Condition Index (WBCI) from Barbour et al. (1994) and the Wyoming Stream Integrity Index (WSII) from Stribling et al. (2000) was **good** during each year (Table 8-15). This observation indicated full support of aquatic life use. There was little variability among years for WSII scores and WBCI scores. Average WSII scores ranged from 71.5 in 1998 to 78.0 in 1996 and WBCI scores ranged from 39 in 1996 to 43 in 1993, 1994 and 1997.

The benthic community was generally dominated by cool water taxa indicative of good water quality and good habitat. *Baetis tricaudatus* and *Glossosoma* were the two dominant taxa from 1996 through 1999 (Table 8-16). Other dominant taxa in order of decreasing abundance included *Hydropsyche*, *Ephemerella inermis/infrequens* and *Drunella doddsi*. *Hydropsyche* is a common genus of caddisfly in Wyoming and the United States and may be considered a generalist found from high elevation mountain streams to plains streams. *Ephemerella inermis/infrequens* is a mayfly widely distributed throughout western North America and is often present in Wyoming streams with cool, clean water. The nymphs of *E. inermis* and *E. infrequens* are morphologically similar and difficult to separate taxonomically (Walley, 1930; Johnson, 1978). *Drunella doddsi* was reported to inhabit streams from 6,000 feet to 11,000 feet elevation and prefer cold, rapid streams free of silt (Allen and Edmunds, 1962). Worms and other organisms suggesting degraded water quality were collected only in 1993 and 1994 by WDEQ and in 1999 by USGS. Abundance of these organisms was very low. No *Tubifex tubifex* (a worm) were collected indicating a low probability for the occurrence of whirling disease, caused by a destructive parasite that may decimate trout populations. *T. tubifex* is significantly involved in the whirling disease life cycle caused by a parasite (*Myxobolus cerebralis*) that penetrates the head and spinal cartilage of fingerling trout. Whirling disease may eventually cause death in trout.

The total number of EPT taxa was generally consistent among years and ranged from seventeen (17) taxa in 1996 and 1999 to twenty-six (26) taxa in 1994. Percent contribution of scraper taxa was high and ranged from seventeen (17) percent in 1995 to forty-seven (47) percent in 1999. Abundance of scrapers in the benthic population was desirable because their presence indicated low deposition of sediment. The relationship between the percent composition of scrapers in the total benthic population and weighted embeddedness (degree of silt deposited on cobble and gravel substrate) was strong (Figure 8-18). The correlation coefficient was +0.591944; $P<0.05$ for all Tongue River stations indicating that percent scrapers increased as the amount of silt on stream bottom substrate decreased. The percent contribution of collector filterers was generally low and ranged from eight (8) percent in 1995 to fifteen (15) percent of the total benthic population in 1997. Low abundance of collector filterers indicated that fine particulate organic matter originating from sources such as sewage and animal manure was minimal.

There was good agreement between WDEQ and USGS macroinvertebrate sampling in 1999 since each sampling group rated biological condition as **good**. There were differences between numerous metric values and this variability may be due to differences in sample collection methods, sampling location (locations were about one (1) mile apart) and date that samples were collected (WDEQ sampled about 1 ½ months later than USGS).

The benthic macroinvertebrate data collected by WDEQ and USGS indicated that activity occurring upstream in the BHNF had no measurable effect on biological communities at the Upper station. Potential pollutants entering the Tongue River from BHNF were apparently removed by natural stream processes resulting in good year around water quality and healthy biological communities. The good rating for biological condition confirmed the overall good water quality shown through water quality sampling and indicated full support for aquatic life use.

Biological condition at the Tongue River Middle station using scoring criteria from the WSII was **very good** during each year (Table 8-15). The WBCI was not applicable to this station because the Middle station was located in the Northwestern Great Plains ecoregion and the WBCI was developed for Middle Rockies ecoregion mountain and foothill streams. The rating of very good indicated full support of aquatic life use. There was more variability among years for WSII scores at the Middle station when compared to variability among years for WSII scores at the Upper station. Average WSII scores ranged from 79.7 in 1998 to 97.9 in 1999.

The benthic community at the Middle station was generally dominated by cooler water taxa indicative of good water quality and good habitat. Dominant taxa in order of decreasing abundance included *Hydropsyche*, *Lepidostoma*, *Brachycentrus occidentalis*, *Drunella grandis/spinifera* and the riffle beetle, *Optioservus* (Table 8-16). *Hydropsyche* was also abundant at the Upper station. *Lepidostoma* is a caddisfly most often found in cool streams and is widespread throughout the United States, but is most common in the western United States (Wiggins, 1996). The pollution tolerance value (TV) for this genus was 1 indicating that this group was intolerant of pollution. *Brachycentrus occidentalis* is a common caddisfly in Wyoming and throughout the western United States. It is found in clear cold waters throughout the state (Ruiter and Lavigne, 1985) and has a TV value of 1 indicating this species was intolerant of pollution. *Drunella grandis/spinifera* is a pollution intolerant group of mayfly that is widely distributed throughout the western United States. *Optioservus* is a common riffle beetle genus that often replaces the riffle beetle genus *Heterlimnius* (common in Wyoming mountain streams) in lower elevation streams. *Optioservus* was a scraper and has a TV of 4 indicating that it was mildly tolerant of pollution. Worms, including *Pristina jenkinae* and *Nais variabilis*, were collected in 1996 and 1998. No worms were collected in 1997 and 1999. Worms comprised 6.5 percent of the benthic community in 1996 and 0.2 percent of the community in 1998. No *Tubifex tubifex* were collected indicating a low probability for the occurrence of whirling disease.

The total number of EPT taxa was generally consistent among years and ranged from sixteen (16) taxa in 1996 and 1999 to twenty-four (24) taxa in 1999. Percent contribution of scraper abundance was generally lower than at the Upper station and ranged from eight (8) percent in 1999 to twenty-five percent in (25) percent in 1997. Lower percent composition of scrapers at the Middle station indicated increased silt deposition when compared to the Upper station. Embeddedness was relatively low at the Middle Station, but higher than embeddedness at the Upper station. The percent contribution of collector filterers increased at the Middle station when compared to the Upper station. Collector filterers comprised seven (7) percent of the population in 1996, but percentage contribution increased in 1997 to 17 percent and to 40 percent in 1998 and 1999. The increase in collector filterers indicated an increase in fine particulate organic matter that may originate from sources such as sewage and animal manure.

The benthic macroinvertebrate data collected in 1998 at Tongue River stations upstream and downstream of the Dayton WWTF using scoring criteria from the WSII was **very good** (Table 8-15). The average WSII score was 86.7 at the upstream station and 84.2 at the downstream station. The slight reduction in WSII score from the upstream station to the station downstream of the WWTF indicated that effluent discharged from the WWTF had little measurable effect on the biological community.

The benthic macroinvertebrate data at the Middle station found biological condition was very good indicating healthy biological communities. The very good rating for biological condition confirmed the overall good water quality shown through water quality sampling and indicated full support for aquatic life use. Changes in the benthic macroinvertebrate population from the Upper to Middle stations appeared to reflect slightly higher water temperature, increased input of fine particulate organic material, and increased (but relatively low) amounts of sediment.

The biological condition of the benthic macroinvertebrate community at the Tongue River Lower station rated **very good** each year (Table 8-15). Average WSII values ranged from 80.4 in 1999 to 85.2 in 1998. Average index values were slightly lower when compared to average index values at the Middle station indicating a slight reduction in biological condition at the Lower station. However, the WSII values indicated water quality and habitat quality was among the highest when compared to water quality and habitat quality at other Wyoming plains streams located in the Northwestern Great Plains (including streams in the counties of Sheridan, Johnson, Natrona, Converse, Crook and Niobrara). These observations indicated full support for aquatic life use at the Lower station.

Average total macroinvertebrate population density each year, although often highly variable in freshwater benthic communities, was over three-fold higher at the Lower station (average density = 24, 968 m^2) when compared to the Middle station (average density = 7,154 m^2). Higher density at the Lower station indicated higher production due to change in water quality and warmer water temperature. Warmer water temperature appeared to be important because there was a shift from primarily cool water taxa at the Middle station to more warm water taxa characteristic of warmer water plains streams. The mayfly, *Tricorythodes minutus* and the riffle beetle, *Microcylloepus* were two of the five most dominant macroinvertebrate taxa at the Lower station (Table 8-16). Both taxa are common in warmer water Wyoming plains streams affected by increased siltation. The presence of *T. Minutus* in streams in the western United States has been associated with increased sediment deposition (Winget and Mangum, 1991). *Microcylloepus* appears to favor Wyoming streams with higher sediment deposition when compared to the riffle beetle taxon *Heterlimnius*, found in mountain and foothill streams and *Optioservus*, found in intermediate elevation and lowland Wyoming streams. *Optioservus* was a dominant taxon at the Tongue River Middle station. The regular occurrence of the caddisflies, *Helicopsyche borealis* and *Cheumatopsyche* at the Lower station during each year indicated warmer water temperature and increased sand and silt deposition.

The total number of taxa at the Lower station was relatively consistent among years ranging from 36 taxa in 1998 to 40 taxa in 1999. The number of EPT taxa was likewise consistent ranging from 19 taxa in 1996 to 21 taxa in 1999. Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), or the EPT taxa, are probably the most intolerant macroinvertebrate groups to agricultural runoff (McCafferty, 1978; Lenat, 1984). The total number of taxa and EPT taxa ranked high when compared to other plains streams in the Northwestern Great Plains ecoregion.

Percent scrapers decreased from the Middle station (average = 14.3 percent) to the Lower station (average = 8.3 percent) indicating increased sediment deposition at the Lower station. Embeddedness (silt deposition) increased from the Middle station (average weighted embeddedness = 76.9) to the Lower station (average weighted embeddedness =32.0) (Table 8-20). Weighted embeddedness values decrease with increased sediment deposition. The percent contribution of collector gatherers increased at the Lower station (average = 38.3 percent) when compared to the Middle station (average = 25.5 percent) indicating the presence of increased coarse particulate organic matter (i.e. leaves, algae, vegetation) due to apparent increased production at this reach.

The number of worm taxa and percent contribution of worms to the total benthic population increased slightly from the Middle station to the Lower station. The number of worm taxa and percent contribution (in parenthesis) at the Lower station in 1996 was 3 (3.6 percent), 4 (1.4 percent) in 1997 and 0 (0.0 percent) in 1998 and 1999. The number and percent of worms were considered quite low for Wyoming plains streams. No *Tubifex tubifex* worms were identified from samples *T. tubifex* is significantly involved in the whirling disease life cycle caused by a parasite (*Myxobolus cerebralis*) that penetrates the head and spinal cartilage of fingerling trout. Whirling disease may eventually cause death in trout and the absence of this worm indicated low probability for the occurrence of whirling disease.

The shift from a benthic community comprised primarily by cool water taxa at the Middle station to a community comprised of more warm water and generalist taxa at the Lower station indicated fundamental change in the thermal regime and slightly higher sediment deposition at the Lower station. There were no large differences for stream substrate particle size between stations to account for the shift in composition of taxa (Table 8-20). Evaluation of the benthic macroinvertebrate data, water quality data, temperature data and fishery data (see Section 8.5.21) indicated that the Tongue River Lower station was sited near the transition zone from a cold water environment (WDEQ Class 2 cold water body) to a warm water environment (WDEQ Class 2 warm water body). Dewatering during the critical warmer summer months (June, July and August) appeared to increase average and daily maximum water temperature. The thermal effects at the Lower station were further compounded by the fact that each tributary within the Project area (with the exception of Five Mile Creek and Smith Creek) were dewatered during the summer irrigation period thus reducing discharge to the Tongue River. Water temperature will naturally increase during summer months, but dewatering appeared to accelerate the increase in water temperature. Other than for these critical summer months, thermal conditions appeared suitable for maintenance of cold water aquatic populations including trout. Dewatering induced water temperature increase provided more favorable conditions for inhabitation by warm water benthic macroinvertebrate and fish species than to cold water macroinvertebrate and trout species. Coldwater benthic and fish species may be present and survive in this transition zone, but warm water benthic and fish species will increase in dominance within the transition zone.

The apparent effect of seasonal dewatering and increased water temperature was to allow warm water species to expand their range further upstream in the Tongue River than normal; the range for coldwater species was thus reduced to reaches further upstream where favorable year around water temperature persisted. The reduction in habitat for cold water species represented a loss of habitat for trout. The loss of trout habitat due to summer dewatering is a complex issue in Wyoming due to competing interests for water resources. The issue becomes more complex because the political climate has avoided linking Wyoming water quality standards to water quantity that is under jurisdiction of the Wyoming State Engineer. However, the link between water quality and water quantity becomes clear when dewatering contributes to exceedence of the Wyoming water quality standard for temperature. The balance between water use for irrigation and survival of the agricultural community and water use to maintain trout habitat and recreation has, historically for years, proven to be a difficult issue to resolve.

Dewatering and water temperature increase at the Lower station may be successfully addressed only at the watershed scale because water quantity reduction and water temperature increase observed at tributaries to the Tongue River affect mainstem Tongue River water resources. Riparian vegetation management should be further evaluated since shading affects water temperature. The Tongue River Watershed Plan prepared by SCCD, the Tongue River

Watershed Steering Committee and Tongue River watershed landowners addresses the need for better water management within the Project area (SCCD, 2000). Implementation of water management change may succeed only with full cooperation of all water users, suitable financial incentives and a dedication to improve year around water resources in the Tongue River and tributaries. This may prove a difficult task since future development within the Tongue River Project area will require increased use of water. The landowners must take the lead in concert with SCCD and the Tongue River Watershed Steering committee since the majority of water is used to sustain the agricultural economy. Measures that may be implemented to conserve water resources include upgrade of irrigation water transmission systems (i.e. piping versus unlined ditches), use of managed sprinkler systems instead of flood irrigation and better monitoring of soil moisture in fields and pastures.

However, regardless of the effect on water temperature caused by seasonal dewatering, natural changes in water quality and water temperature indicated that the entire Tongue River in Wyoming was not a Class 2 cold water, water body as currently classified by WDEQ (1998). Chemical, physical and biological data collected during this Project in accordance with the intent of the Wyoming Credible Data statute, provided suitable credible data to propose a change in stream classification from Class 2 cold water to Class 2 warm water. Despite scientific data collection, defining the division point between Class 2 cold water and Class 2 warm water segments remains an arbitrary exercise because there is no sharp distinction within the transition zone. Water temperature appeared to be the single most reliable indicator to determine the division point between cold water and warm water classifications.

Other than for anthropogenic affects related to dewatering and water temperature increase observed during the summer period from June through August, it appeared that natural favorable conditions exist for cold water species downstream from the Lower station approximately 8 to 9 stream miles to the Interstate 90 bridge crossing. Communication with WGFD indicated that this location may be the logical point to reclassify the Tongue River to reflect the natural change in water temperature. SCCD may consider submittal of a formal petition to WDEQ to initiate the reclassification process at a later date. Data and findings contained in this Final Report should provide adequate justification for initiation of the proposed reclassification. The proposed reclassification will not change the current status for placement of the Tongue River Lower segment on the Wyoming 303d list, but will provide more appropriate water quality goals for the downstream segments.

8.5.20 SCCD and WDEQ Tongue River Habitat Assessment

Qualitative habitat assessments were conducted annually at each Tongue River station. WDEQ conducted annual habitat assessments in 1998 at a station upstream of the Dayton WWTF and a station downstream of the Dayton WWTF. Because habitat assessments were subjective, SCCD used caution by providing a conservative interpretation of data.

The average habitat score at the Upper station was 174 (Table 8-17), 140 at the Middle station and 134 at the Lower station (Table 8-18). The habitat assessment score was 152 at the station above Dayton WWTF and 144 at the station below Dayton WWTF, The range in annual habitat scores at the Upper station from 1993 through 1999 was from 165 in 1993 to 181 in 1996. Scores at the Middle station ranged from 116 in 1999 to 158 in 1997. Scores at the Lower station ranged from 127 in 1996 to 137 in 1997. Variation in habitat scores between years appeared to be related to difference in annual stream discharge. Although assessments were generally conducted on sampling dates within ± two (2) weeks of one another each year, differences in annual discharge affected scoring for some habitat parameters because they were flow dependent. Scores for instream cover, velocity / depth, channel flow status and width depth ratio will normally score higher when discharge is increased, but will score lower when discharge is decreased.

The reduction in habitat score from the Upper station to downstream stations was due to lower scores for embeddedness, channel flow status, channel shape, channelization, width depth ratio and bank stability. Reduced scores for some of these parameters were related not only to current land use practices, but to lingering effects from the period of extensive channelization that apparently occurred in the late 1950's to early 1960's. Effects of channelization from that period continue to affect the Tongue River stream channel to this day requiring patch work repair and bank stabilization projects. Despite the lower habitat scores at the Middle and Lower stations, these stations ranked high when compared to habitat scores at other Wyoming plains streams. This observation indicated that although Tongue River in-stream and riparian habitat have been altered due to channelization, habitat was still in better condition when compared to most Wyoming plains streams in the Northwestern Great Plains ecoregion.

The semi-quantitative stream substrate particle size distribution varied little between the Upper, Middle and Lower stations including the stations located upstream and downstream of the Dayton WWTF monitored by WDEQ in 1998. Average percent cobble was 73 percent at the Upper station, 85 percent at the station above Dayton WWTF, 76 percent at the station below Dayton WWTF, 67 percent at the Middle station and 62 percent at the Lower station (Tables 8-19 and 8-20). Average percent coarse gravel ranged from 12 percent at the Upper station and the station upstream of the Dayton WWTF, to 28 percent at the Lower station. Silt deposition was minimal. Only the Upper and Lower stations had detectable silt deposition and silt comprised about 1 percent of total substrate at each station. Sand comprised 5 percent, 3 percent, 1 percent, 2 percent and 1 percent of the average total substrate at the Upper station, stations above and below Dayton WWTF, Middle and Lower stations, respectively. Silt and sand are detrimental to trout egg survival and maintenance of healthy benthic macroinvertebrate populations that provide food for trout. The dominance of cobble and gravel at each station allowed reliable comparison of macroinvertebrate communities between stations because potential variability caused by difference in substrate was minimal.

Embeddedness (silt covering cobble and gravel) was low at the Upper station and stations upstream and downstream of the Dayton WWTF. Average weighted embeddedness at the Upper station from 1993 through 1999 was 95.9. Average weighted embeddedness at stations upstream and downstream of the Dayton WWTF were 100 and 99, respectively (Table 8-19). The higher the weighted embeddedness value, the lower the embeddedness or amount of silt deposited on cobble and gravel. Average weighted embeddedness at the Middle station was 76.8, and 32.0 at the Lower station. The decrease in weighted embeddedness at the Middle and Lower stations indicated increased deposition of silt when compared to the Upper station. Deposition of silt is controlled by the amount of silt contained in the water column and by the current velocity. Silt deposition will normally increase as current velocity decreases.

Average current velocity measured at the Upper station was 2.1 feet per second (fps), 2.5 fps at the stations upstream and downstream of the Dayton WWTF, 2.3 fps at the Middle station and 2.6 fps at the Lower station. Because average water current velocity was slightly higher at Middle and Lower stations when compared to the Upper station and stations near the Dayton WWTF, increased silt deposition was not related to difference in current velocity among stations, but was due to increased amount of silt contained in the water column. This observation was confirmed by turbidity sampling conducted at Upper, Middle and Lower stations.

The general decrease in substrate particle size from the Upper station to the Lower station was normal because particle size generally decreases as stream size and stream order increase (Rosgen, 1996). Observed increase in embeddedness (silt deposition) from the Upstream station to the Lower station was likewise considered normal for stream size and stream order. Embeddedness at the Lower station was low when compared to weighted embeddedness values at other plains streams in the Northwestern Great Plains ecoregion. Low levels of sediment tends to decrease organism density while producing only slight effects on species diversity (Lenat et al., 1979; Lenat et al., 1981). Heavy levels of sedimentation will usually result in decreases in both density and diversity of organisms (Lenat, et al., 1981; Lemly, 1982; Olive et al., 1988). The benthic macroinvertebrate population density was highest at the Lower station when compared to organism densities at Upper and Middle stations. Fine sediment which settles on, or penetrates into, the streambed is more detrimental to fish and macroinvertebrate populations than is suspended sediment entrained in flowing water (Campbell and Doeg, 1989). Deposited sediment can result in lowered inter-gravel oxygen concentrations reducing survival of trout eggs and negatively affect stream productivity and density of aquatic organisms which are the main food source of cold water stream fish (Hynes, 1970; Hawkins et al., 1983; Waters, 1995). Embeddedness at the Lower station had no apparent detrimental effect on the benthic macroinvertebrate population because biological condition was rated very good and full support of aquatic life use was indicated.

8.5.21 WGFD Tongue River Fish Population Monitoring

WGFD conducted historic and current monitoring of fish populations at various Tongue River locations within the Project area over the period from 1959 through 1994. Approximate location of sampling stations are illustrated in Figure 5-1 and Figure 5-2. Results from fifteen (15) sampling events are presented in Appendix Tables C-1 through C-15.

Sampling at stations located near the mouth of the Tongue River canyon (near SCCD station Tongue River Upper) has occurred since 1959. Game fish populations were dominated by brown trout, mountain whitefish and rainbow trout. No Yellowstone cutthroat trout or other cutthroat trout sub-species have been collected in the Tongue River within the Project area. The Yellowstone cutthroat trout is the only native trout species known to have inhabited the Tongue River watershed. Non-game species were dominated by longnose dace. Longnose sucker and mountain sucker were collected less frequently. Absolute presence/absence data and relative contribution of non-game species presented in sampling results contained an unknown degree of bias because many historic fish surveys concentrated on capture of game (trout) species. Further, the small size and often high density of longnose dace prevented high capture efficiency for this species. Although presence/absence data for game fish species appeared reliable, changes in trout abundance that may have occurred through the years could not be made due to differing sampling effort and variable capture efficiencies.

Fish populations changed dramatically as the Tongue River exited the canyon and flowed toward the Town of Dayton. Mountain whitefish became the dominant game species, followed in order of general abundance by brown trout and rainbow trout. Non-game species increased significantly. Longnose dace was probably the primary non-game species, but reliable estimates for abundance could not be made due to unknown capture efficiency. Non-game species identified in this reach, but which were absent from the Canyon reach, included white sucker, longnose sucker and mountain sucker. The change in fish population from one dominated by trout species in the canyon to one dominated by whitefish appeared to be related not to water quality change, but to extensive channelization, which had widened the stream and reduced habitat required for trout to thrive (Mueller, 1966). Channelization effects reduced the diversity in stream habitat by creating more riffle and run habitat favorable for whitefish, but reducing the number of pools preferred by trout.

Mueller (1966) conducted an investigation of the Tongue River in the vicinity of Dayton at the request of then Mayor, Mr. Herman Northrup, to determine if pollution from septic tanks and houses with no septic tanks were seeping into the Tongue River. The Town of Dayton had submitted an application for federal aid to construct a new sewage disposal plant. The pollution investigation found no correlation between fish populations and domestic pollution (if any) from the Town of Dayton. Mueller indicated that channel clearing and the resulting deterioration of trout habitat had a greater effect on the trout population than potential effects due to pollution (no pollution was identified).

Following a landowner complaint regarding an increase in non-game fish, WGFD conducted a study in 1969 of fish populations in the Tongue River within the approximate current Project area from the canyon mouth downstream to the Town of Ranchester (Mueller et al., 1970). The report found extensive channelization of the Tongue River consisting of channel clearing, reshaping of the banks and changing the channel. The purpose of the channelization was to allow more rapid passage of flood water and prevent erosion and flooding of adjacent crop or pasture land. The United States Department of Agriculture Soil Conservation Service provided technical assistance and landowners received cost share from the Agriculture Stabilization and Conservation Committee. Prior to issuance of this report, a memorandum dated November 17, 1967 from John Mueller to Mr. Fred Eiserman and Mr. Don Dexter indicated that dewatering and water temperature were additional problems to be dealt with for establishing a good fishery in the Tongue River. Mueller et al. (1970) found that the end result of channelization was the elimination of fish habitat for game fish. The loss of essential habitat substantially reduced both game and non-game fish. Flood conditions in 1967 and 1968 were believed to have affected fish populations sampled in 1969. Prior to channelization, it was reported that reasonably good habitat and fish populations existed in the Tongue River and natural reproduction provided a fishery without supplemental stocking.

A subsequent investigation was conducted by Mueller (1979) in response to a complaint from a Wyoming state senator regarding whitefish abundance on the IXL ranch upstream of Dayton. The report stated that the Tongue River had been channelized to protect land adjacent to the river from flood damage. Channelization occurred essentially from Ranchester upstream to the state-owned public fishing area (Tongue River canyon area), an area which was once considered excellent trout water. Most of the good trout habitat was destroyed by channelization leaving long stretches of riffle area. The riffle areas were more conducive to maintenance of whitefish populations. Whitefish populations had increased while trout populations declined due to lack of cover and resting areas.

Subsequent sampling by WGFD at the IXL Ranch in 1991 found whitefish were still relatively abundant, but brown trout was the most abundant game species (Appendix Table C-11).

A survey of the Tongue River from about five (5) miles above Dayton to the Wyoming state line was reported by Bjorn (1938). He reported that the Tongue River canyon water was very suitable for trout. Brown and rainbow trout were taken from the canyon reach in great numbers in the spring of the year. No game fish were taken from the middle (downstream of Ranchester?) or lower (near the state line) stations. Flathead chub, longnose dace, common white sucker, chub minnow and mountain suckers were found either at the middle or lower stations. The report indicated no game fish were taken below the Middle station which was believed to be located downstream of Ranchester. Bjorn did not mention extensive stream channelization in the survey. This historic record adds additional information to suggest that the proposed division between Class 2 cold water and Class 2 warm water in the vicinity of the I-90 bridge was reasonable.

Sampling in 1962 above the halfway bridge (near the current SCCD Tongue River Middle station) found mountain whitefish and brown trout in similar number followed by rainbow trout and stonecat, a game species. Only one (1) rainbow trout and stonecat were collected (Appendix Table C-13).

Fish populations were monitored by WGFD near the SCCD Tongue River Lower station in 1993 and 1994. Twelve (12) fish species were captured in 1993 and sixteen fish species were captured in 1994. Sampling indicated a diverse fishery comprised of both cold water species and warm water fish species. High species diversity is often encountered in larger rivers where there is an admixture of cold water and warm water fish species due to the transition from a cold water system to a warm water system (Funk, 1970). This observation further indicated that the Tongue River Lower station was sited near the transition zone between cold water and warm water reaches.

The apparent decline in the fishery from the Tongue River canyon downstream to the Town of Ranchester was an important concern for this Project. Evaluation of the water quality, macroinvertebrate, fishery and habitat data indicated that the decline in the Tongue River fishery was primarily due to historic large scale channelization causing destruction of in stream fishery habitat. Dewatering and water temperature increase due to irrigation demand in the critical warmer summer months from June through August compound the lack of physical habitat by stressing cold water fish species present in the limited habitat. Limited channelization still occurs within the Project area and bank stabilization efforts continue. Water quality (other than high summer water temperature) does not appear to produce deleterious effects on the fishery. Aquatic life use was fully supported at Tongue River Upper, Middle and Lower stations. However, habitat loss has apparently reduced the number of game fish and increased the number of non-game fish.

8.6 Little Tongue River Stations

8.6.1 Little Tongue River Discharge

Instantaneous discharge measurements were recorded by SCCD and WDEQ during sampling at Little Tongue River Upper and Lower stations. Summary statistics for discharges are presented in Table 8-21. Discharge measurements during the Project at the Upper station averaged 11.7 cfs, and 15.3 cfs at the Lower station. The geometric mean at the Upper station was 7.1 cfs, and 3.7 cfs at the Lower station. The average values were difficult to compare among Upper and Lower stations due to differing sampling frequency and lack of same day sampling on numerous occasions. Figure 8-19 illustrates discharge measured at each station on the same day. Discharge data not measured at each station on the same day was excluded from Figure 8-19 because discharge may vary daily precluding valid comparison among stations.

Discharge during the primary low-irrigation months (April, May and September) often increased from the Upper station downstream to the Lower station. However, overall discharge measured on all comparable days was reduced by about six (6) percent (Table 8-2). Discharge was often reduced from the Upper station to the Lower station during the primary irrigation months (June, July and August) (Figure 8-19) although there was no overall difference in average discharge between the Upper and Lower stations during this period.

The Little Tongue Lower station had a discharge less than 1 cfs on 42 percent of the irrigation season days. The lowest discharge measurement at the Little Tongue River Upper station during irrigation season days was 4.51 cfs on August 10, 1999. The reduction in discharge from the Upper station to the Lower station was due to dewatering. Dewatering at the Lower station was especially evident in 1999 when discharge was less than 1 cfs on sampling days from July 21, 1999 to September 15, 1999. The generally low discharge at the Lower station appeared to be a primary factor responsible for impairment of biological condition during each year of the Project (see Section 8.6.11).

The contribution of discharge from the Little Tongue River to the Tongue River was estimated by comparing discharge at the Little Tongue River Lower station to discharge measured at the Tongue River Upper station on the same day. This comparison revealed the Little Tongue River contributed an estimated 6.2 percent of the Tongue River discharge (Appendix Table M-2). This suggested that potential pollutants entering the Tongue River from the Little Tongue River would be significantly diluted.

8.6.2 SCCD and WDEQ Little Tongue River Temperature Monitoring

Summary statistics for instantaneous water temperature measurements by SCCD and WDEQ at Little Tongue River Upper and Lower stations are presented in Table 8.22. Water quality data for the Upper station is presented in Appendix Tables B-9 and B-11 and data for the Lower station in Appendix Tables B-10 and B-12.

Average water temperature was lowest at the Upper station (10.7^{0}C) and slightly higher at the Lower station (11.7^{0}C). Maximum water temperature recorded at the Upper station was 15.9^{0}C, and 20.8^{0}C at the Lower station. Based on instantaneous measurements there were no exceedences of the Wyoming water quality standard for water temperature. However, as indicated in Section 8.5.2, sampling conducted by SCCD and WDEQ did not occur during the time of day required to detect maximum daily water temperature. Maximum daily temperature was projected at each station during the months of June, July, August and September as described in Section 8.5.3. Projected maximum daily water temperature indicated no exceedence of Wyoming water quality standard for temperature at the Upper station. One temperature exceedence probably occurred at the Lower station on August 3, 1999 and possibly a second exceedence on July 21, 1999. This observation indicated the need for future continuous water temperature monitoring during warmer summer month at the Lower station to determine frequency of occurrence for exceedence of the water temperature standard.

8.6.3 SCCD and WDEQ Little Tongue River pH Monitoring

Summary statistics for instantaneous pH measurements by SCCD and WDEQ at Little Tongue River Upper and Lower stations are presented in Table 8.23. The pH varied little among the Upper and Lower stations. The average and geometric mean for pH during this Project was 8.0 SU at the Upper station and 8.1 SU at the Lower station. The maximum pH recorded at the Upper station during the Project was 8.6 SU, and 8.5 SU at the Lower station. The minimum pH was 7.1 SU at the Upper station and 7.4 SU at the Lower station. The generally high pH at both stations reflected the predominant limestone geology in the Little Tongue River watershed. All pH measurements were within Wyoming water quality standards.

8.6.4 SCCD and WDEQ Little Tongue River Specific Conductivity Monitoring

Summary statistics for specific conductivity are presented in Table 8-24. Average conductivity during the Project was 234 umhos/cm at the Upper station and 436 umhos/cm at the Lower station. The geometric mean was 212 umhos/cm at the Upper station and 395 umhos/cm at the Lower station. Conductivity values at the Upper station ranged from a low of 124 umhos/cm to a high of 580 umhos/cm and from a low of 197 umhos/cm to a high of 829 umhos/cm at the Lower station. The average increase in conductivity from the Upper station to the Lower station was 86 percent. The increase in conductivity between stations using the geometric mean was also 86 percent. The increase in conductivity was higher than expected and suggested that irrigation return or urban storm water effluent may be affecting conductivity at the Lower station especially during periods of low discharge. Although there was no Wyoming water quality standard for conductivity, values were generally considered low and within the range required for support of aquatic life.

Conductivity values were controlled primarily by stream discharge. The association between conductivity and discharge was strong and inverse such that as discharge increased, conductivity decreased. The correlation coefficient between conductivity and discharge at the Upper station was -0.742, and -0.652 at the Lower station (Appendix Table L-3). Correlation coefficients were significant ($P<0.01$) at each station indicating there was less than a 1 percent chance that the association was due to random chance alone. This observation indicated that conductivity at the Lower station could be reduced by increasing discharge.

8.6.5 SCCD and WDEQ Little Tongue River Dissolved Oxygen Monitoring

SCCD initiated monitoring for dissolved oxygen (DO) in 1999. WDEQ conducted monitoring for DO once annually usually in October. Summary statistics for DO are presented in Table 8-25. DO was similar at each station. Average DO during the Project was 9.6 mg/l at the Upper station and 9.9 mg/l at the Lower station. DO values ranged from 7.8 mg/l to 10.7 mg/l at the Upper station and from 7.2 mg/l to 10.4 mg/l at the Lower station.

There were no exceedences of the Wyoming water quality standard for DO because no DO values were less than 5 mg/l. The lowest DO value recorded during the Project was 7.2 mg/l measured by SCCD at the Lower station on September 15, 1999. The DO concentrations were sufficient to support diverse aquatic populations and fish indicating full support for aquatic life use for this physical parameter.

8.6.6 SCCD and WDEQ Little Tongue River Turbidity Monitoring

Summary statistics for turbidity are presented in Table 8-26. Average turbidity measurements during the Project were similar between stations considering variability normally present in turbidity sampling. Average turbidity was 5.8 NTU at the Upper station and 8.5 NTU at the Lower station. The geometric mean was 3.2 NTU at the Upper station and 3.5 NTU at the Lower station. Turbidity values at the Upper station ranged from a low of 0.1 NTU to 20.0 NTU and from 0.3 NTU to 36.0 NTU at the Lower station. The increase in turbidity from the Upper station to the Lower station was low even considering that turbidity naturally increases along the longitudinal gradient of most flowing water bodies.

Turbidity values were strongly associated with discharge. There was a significant positive relationship such that turbidity values increased as discharge increased. The correlation coefficient between turbidity and discharge at the Upper station was +0.673 ($P<0.01$), and +0.716 ($P<0.01$) at the Lower station. R-squared values for the regression analyses were 41.0 percent at the Upper station and 51.3 percent at the Lower station (Appendix Tables L-5 and L-6). Because of the association between turbidity and discharge, lower turbidity values were recorded during periods of lower discharge (prior to and after spring runoff) in early April, September and October and higher turbidity values were generally recorded during periods of higher discharge during spring runoff in latter April, May and June. There was no exceedence of the Wyoming water quality standard for turbidity. The average increase in turbidity between the Upper and Lower stations was 2.7 NTU which was well below the increase of 10 NTU allowed by the Wyoming water quality standard for Class 2 water bodies.

8.6.7 SCCD and WDEQ Little Tongue River Fecal Coliform Bacteria Monitoring

Summary statistics for fecal coliform bacteria are presented in Table 8-27. The geometric mean for fecal coliform bacteria at the Upper station during the Project was 4 per 100ml, and 32 per 100ml at the Lower station. The geometric mean is a logarithmic transformation of data and provided a more reliable estimate of the mean by smoothing extreme values when variability was high among fecal coliform measurements characteristic in fecal coliform sampling. Fecal coliform bacteria concentration at the Upper station ranged from 1 per 100ml to 98 per 100ml.

The number of bacteria was quite low indicating that the primary land uses (wildlife, recreation and limited seasonal livestock grazing) in the vicinity of the Upper station were not significant sources of fecal coliform bacteria. Fecal coliform bacteria concentration at the Lower station ranged from 1 per 100ml to 770 per 100ml.

The was no exceedence of the Wyoming water quality standard for fecal coliform bacteria at the Upper station. The geometric mean of five (5) samples collected during the Recreational Season in 1999 at the Upper station was 11per 100ml which was considered low. There was no single sample in excess of 400 per 100ml since the maximum level during the Project was 98 per 100ml (collected August 3, 1999).

Fecal coliform bacteria levels at the Lower station exceeded the Wyoming water quality standard for fecal coliform bacteria. The geometric mean of five (5) samples collected during the Recreation Season in 1999 was 290 per 100ml which exceeded the standard of 200 per 100ml. Two samples had fecal coliform levels in excess of 400 ml. A sample collected on July 21, 1999 contained 770 per 100ml and sampling on July 28, 1999 found 570 per 100 ml. The exceedence of the standard indicated remedial measures were required to lower fecal coliform levels to bring the Lower station into compliance with the Wyoming water quality standard for fecal coliform bacteria.

There were no exceedences of the fecal coliform standard in 1996, 1997 and 1998. SCCD increased the sampling frequency in 1999 from monthly to five (5) samples within a 30 day period during the Recreation Season to provide a better estimate of bacteria contamination and allow direct comparison to the Wyoming water quality standard for fecal coliform bacteria. Other sampling sites within the Project area exceeded the Wyoming fecal coliform standard only in 1999. It appeared the increased sampling frequency in 1999 compared to previous years increased the probability for detection of fecal coliform levels in excess of the Wyoming fecal coliform standard. Extensive discussion related to the effects of sampling frequency for reliable estimates of fecal coliform bacteria is presented in Section 8.11.1.

The increase in fecal coliform bacteria from Upper to Lower stations may be related to sources from different land uses. Because the Lower station was sited in the Town of Dayton, urban land use may contribute bacteria in addition to wildlife, domestic animals and agricultural influences upstream. A sampling station upstream of the Town of Dayton is required to separate potential effects from urban land use from the effects of other land uses. The relationship between fecal coliform bacteria level and land use within the Project area is discussed in Section 8.11.4.

8.6.8 SCCD and WDEQ Little Tongue River Nitrate Nitrogen Monitoring

Total nitrate samples were collected infrequently (N = 3 total samples) at the Little Tongue River Upper station due to Project monitoring budget constraints. Sampling for nitrate nitrogen was concentrated at the Lower station because potential nutrients entering the Tongue River could be best estimated at this station. Summary statistics for nitrate nitrogen are presented in Table 8-28. Average nitrate nitrogen concentrations was low at each station during the Project. The average nitrate concentration at the Upper station was .001 mg/l, and .022 mg/l at the Lower station. Nitrate values at the Upper station based on four (4) samples (including one sample collected by WDEQ in 1993) ranged from .010 mg/1 to .170 mg/l, and from .001 mg/l to .130 mg/l at the Lower station.

Average and maximum nitrate values at the Upper and Lower stations were considered low. Nitrate concentration was well below the Wyoming water quality standard and drinking water human health standard of 10 mg/l for Class 2 surface waters (WDEQ, 1998). Data for nitrate nitrogen indicated that nitrate concentration in the Little Tongue River was less than the background concentration of nitrate (about 0.60 mg/L) found in streams in undeveloped areas throughout the United States (USGS, 1999). These observations indicated that nitrate nitrogen was not present in the Little Tongue River in concentrations that could pose a human health threat or an ancillary threat to aquatic life use manifest by effects due to eutrophication. Full support for all Wyoming beneficial uses that may be affected by nitrate nitrogen was indicated.

8.6.9 SCCD and WDEQ Little Tongue River Total Phosphorus Monitoring

Total phosphorus samples were collected infrequently by SCCD (N = 2 total samples) at the Little Tongue River Upper and Lower stations due to Project monitoring budget constraints. The majority of total phosphorus data was provided by WDEQ sampling during annual bioassessments. Summary statistics for total phosphorus are presented in Table 8-29. These statistics were based on "censored" values because the majority of analyses (8 samples out of 9 total samples) were less than the minimum detection limit (minimum detection limit was 0.10 mg/l for WDEQ analytical method; 0.05 mg/l for SCCD analytical method). The minimum detection limit for the WDEQ analytical method did not provide adequate data needed to address the recommended water quality standard for total phosphorus in water bodies draining to a lake or reservoir (0.05 mg/l; EPA, 1977). Data were thus censored to provide an estimate that could be compared to the recommended EPA standard of 0.05 mg/l.

Average total phosphorus concentrations were low at each station during the Project. The average total phosphorus concentration at the Upper station based on three (3) total samples was .037 mg/l, and .042 mg/l at the Lower station. Total phosphorus concentrations at the Upper station ranged from .020 mg/1 to .050 mg/l, and from .020 mg/l to .090 mg/l at the Lower station.

Average and maximum total phosphorus values at the Upper and Lower stations were based on a low total number of samples. However, total phosphorus values should be considered low. Wyoming has not established surface water quality standards for phosphorus. U.S. EPA (1977) recommended that total phosphorus concentration should not exceed 0.05 mg/l in a stream that enters a lake or reservoir (e.g. Tongue River Reservoir) and Mackenthun (1973) suggested a target phosphorus level of less than 0.10 mg/l for streams that did not directly enter lakes or reservoirs. USGS (1999) provided recent information from nationwide NAWQA monitoring and reported that national background concentrations for total phosphorus from streams in undeveloped (reference - like) areas was about 0.10 mg/L. SCCD adopted findings by USGS for its interpretation of total phosphorus data collected during this Project.

Using the value of $\leq$0.10 mg/l as a target for total phosphorus concentration, no significant amount of total phosphorus was identified in a single sample collected at Little Tongue River stations during this Project. However, sampling frequency was generally low at the Upper (N = 4 samples) and Lower station (N = 6 samples) over a four year period and sampling generally occurred during the fall low base flow period when total phosphorus concentration is normally lower. Additional sampling is required to provide a reliable estimate of total phosphorus concentration in the Little Tongue River.

8.6.10 WDEQ Little Tongue River Monitoring for Additional Water Chemistry Parameters

WDEQ collected samples for additional water chemistry parameters during annual monitoring at the Little Tongue River Upper station in 1993 and the Little Tongue River Lower station from 1996 through 1999. Summary statistics are presented in Table 8-30.

Alkalinity at the Upper station based on a single sample was 180 mg/l. Average alkalinity at the Lower station based on four (4) samples was 210 mg/l. The geometric mean was 198 mg/l. The range was from 153mg/l to 238 mg/l. There was no Wyoming water quality or EPA standard to compare alkalinity values to, but data indicated that water was generally productive for aquatic life and was generally capable of withstanding sudden changes in pH due to inputs from point and NPS sources.

Total chloride concentration was low at each station during the limited sampling. There were no samples collected at either Upper or Lower stations that had total chloride concentrations greater than 5 mg/l. Total chloride values were well within WDEQ and EPA water quality standards indicating full support for Wyoming beneficial uses for chloride.

Total sulfate concentration was low at the Upper station. No sulfate was detected in the single sample collected in 1993. Average total sulfate concentration based on four (4) total samples at the Lower station was 210 mg/l. The range in total sulfate was from 153 mg/l to 238 mg/l. These values were higher than expected even considering samples were collected in the fall during lower base flow when ion concentrations were normally highest. Possible sources for the higher total sulfate concentrations may include irrigation return and urban land use (i.e. storm water drain discharge). Conductivity, of which total sulfate is a component, was higher than expected at the Lower station and increased from Upper to Lower stations. Toal sulfate sampling is recommended for future monitoring at the Little Tongue River to determine if the increase in sulfate concentration at the Lower station was a natural occurrence or if the increase was due to potential irrigation return and urban land use influence. Total sulfate values were within WDEQ standards (for groundwater use), but approached the EPA secondary drinking water standard of 250 mg/l. This observation indicated full support for Wyoming beneficial uses for sulfate at this time.

Hardness concentration was relatively high at each station and may be due to the natural limestone geology that predominated much of the upstream Little Tongue River watershed. Hardness at the Upper station based on a single sample was 205 mg/l. Average hardness at the Lower station was 380 mg/l. The range in hardness at the Lower station was from 346 mg/l to 392 mg/l. Water at each station may be termed very hard based on the classification found in Table 6-2. There were no Wyoming or EPA water quality standards for hardness, but observed values indicated partial support of the Wyoming beneficial use for Industrial use since all values were greater than 300 mg/l and treatment may be required before industrial use. More year around sampling was required to determine if the relatively high hardness values were due to seasonal sampling artifact during low flow periods, to natural limestone geology in the watershed, irrigation return or to potential urban land use influence.

Total Suspended Solids (TSS) concentrations were low at each station. Low values appeared to be related to the fact that all samples were collected in the fall during lower flow when TSS values were normally lowest. The TSS concentration at the Upper station based on a single sample was <2 mg/l. Average TSS at the Lower station was 2 mg/l with a range from 1 mg/l to 3 mg/l. Results of limited TSS sampling conducted by WDEQ provided little information for potential sediment problems within the Little Tongue River watershed. However, results of turbidity sampling (Section 8.6.6) indicated no large amount of sediment was entering the Little Tongue River between Upper and Lower stations. Further sampling for TSS is not recommended at this time because turbidity sampling did not indicate sediment problems within the Little Tongue River watershed. Turbidity should continue to be used as a surrogate indicator for TSS unless specific sediment loading questions arise.

8.6.11 SCCD and WDEQ Little Tongue River Benthic Macroinvertebrate Monitoring

The Little Tongue River - Upper station (upstream of the SCCD Little Tongue River Upper station) was monitored by WDEQ once in 1993. SCCD and WDEQ sampled benthic macroinvertebrates at the Lower station annually from 1996 through 1999.

Metric values for the single WDEQ sample collected from the Upper station is presented in Appendix Table G-1. Metric values for samples collected at the Lower station are presented in Appendix Table G-1.

Lists of benthic taxa identified, density (number per square meter) of taxa and percent contribution of each taxon to the total benthic population are presented for each station in Appendix F. The WDEQ Upper station taxa list is presented in Appendix Table F-9. Taxa lists for the Lower station are presented in Appendix Tables F-10 through F-13.

Biological condition at the Little Tongue River Upper station using scoring criteria from both the Wyoming Biological Condition Index (WBCI) from Barbour et al. (1994) and the Wyoming Stream Integrity Index (WSII) from Stribling et al. (2000) was **fair** (Table 8-15). This observation indicated partial support for aquatic life use indicating that this station needed improvement to attain full support for aquatic life use.

The fair biological condition rating was primarily due to the relatively low number of Ephemeroptera (mayfly) taxa (N = 7), low percent contribution of Ephemeroptera (5 percent), low percent contribution of scrapers (7 percent) and higher percentage of the 5 most dominant taxa (82 percent).

Although biological condition was rated fair, at least one additional year of sampling for benthic macroinvertebrates is recommended because only one sample was taken. Should additional sampling indicate impairment of the biological community and confirm biological impairment, remedial measures should be considered. The WDEQ sample station was located upstream of the SCCD water sampling station. The WDEQ benthic macroinvertebrate sampling station should be relocated to the SCCD water quality sampling station to allow better comparison of the macroinvertebrate community with water quality data and USGS gage station Number 06298500.

Biological condition at the Little Tongue River Lower station using scoring criteria from both the Wyoming Biological Condition Index (WBCI) from Barbour et al. (1994) and the Wyoming Stream Integrity Index (WSII) from Stribling et al. (2000) was **fair** (Table 8-15). This observation indicated partial support of aquatic life use indicating impairment of the biological community and the need for improvement to attain full support for aquatic life use.

The benthic community was dominated by a mixture of cool and warm water taxa indicative of fair water quality and fair habitat quality. Three (3) genera of riffle beetles were among the five most dominant taxa including *Cleptelmis*, *Optioservus* and *Zaitzevia* (Table 8-16). *Paraleptophlebia*, a mayfly genus and *Hydropsyche*, a genus of caddisfly were the other dominant benthic macroinvertebrate taxa. Worms were present at the Lower station each year ranging in percent contribution from two (2) percent in 1999 to six (6) percent in 1998. There were two (2) worm taxa in 1996 and 1997, eight (8) worm taxa in 1998 and three (3) worm taxa in 1999. Increased density of worms (Oligochaeta) may be associated organic pollution (Klemm, 1985), pollution from feedlots (Prophet and Edwards, 1973), and pollutants contained in urban storm water runoff (Lenat et al., 1979; Lenat and Eagleson, 1981). The number of worm taxa and percent contribution did not indicate a severe pollution problem, but rather a moderate amount of pollution indicative of animal waste from agricultural, wildlife or urban sources. This observation was supported by the violation of the Wyoming water quality standard for fecal coliform bacteria.

The total number of EPT taxa was generally low each year and ranged from twelve (12) and thirteen (13) taxa in 1999 and 1998, respectively, to twenty-three (23) taxa in 1997. Percent contribution of scraper taxa was relatively low and ranged from twelve (12) percent in 1999 to twenty (20) percent in 1997. The lower abundance of scrapers in the benthic population suggested moderate deposition of sediment. This observation was confirmed by the average weighted embeddedness value of 62.9 at the Lower station (Table 8-32).

The apparent effect of seasonal dewatering and increased water temperature was to allow warm water species to colonize this expected cool water environment. Channelization and widening the stream channel (see Section 8.6.12) probably assisted in increasing water temperature. The higher water temperature combined with fecal coliform contamination and probable organic pollution from animal or human origin resulted in a fair biological condition rating and partial attainment for aquatic life use. Dewatering may be addressed through water management practices. The apparent input of animal and human waste from potential agricultural, wildlife and urban land use requires resolution to bring the stream into compliance with Wyoming water quality standards and to fully support aquatic life use.

8.6.12 SCCD and WDEQ Little Tongue River Habitat Assessment

Qualitative habitat assessments were conducted once by WDEQ in 1993 at the Upper station and annually by SCCD and WDEQ from 1996 through 1999 at the Lower station. Because habitat assessments were subjective, SCCD used caution by providing a conservative interpretation of data.

The total habitat score based on the single 1993 assessment at the Upper station was 147 (Table 8-31). The score indicated moderate to high habitat quality. Percent fines (silt and sand) comprising the stream substrate was low (sand = 0 percent, silt = 0 percent) (Table 8-32). Riparian condition indicator parameters including bank vegetation stability, bank stability, disruptive pressures and riparian zone width scored high.

Habitat assessment scores were lower at the Little Tongue River Lower station when compared to the Upper station. Total habitat scores varied little during the Project ranging from 103 in 1999 to 117 in 1996 (Table 8-31). The reduction in habitat score from the Upper station to the Lower station was due to lower scores for instream cover, velocity / depth, pool riffle ratio and width depth ratio. The lower scores for these parameters was related to extensive habitat alteration by channelization that occurred years ago in the Town of Dayton. Channelization has straightened and widened the stream channel reducing instream habitat for aquatic organisms and fish. The reduction in habitat coupled with low discharge due to dewatering and probable higher water temperature appeared to place stress on aquatic communities to result in non-support for aquatic life use. The low width depth ratio coupled with low discharge appeared to be a critical element because there was not enough water to adequately fill the stream channel.

The semi-quantitative stream substrate particle size distribution differed between the Upper and Lower stations. Average percent cobble was 95 percent at the Upper station, and 60 percent at the Lower station. Average percent coarse gravel ranged from 4 percent at the Upper station to 21 percent at the Lower station. Silt deposition was not detected at either station. Sand deposition was not detected at the Upper station and was minimal at the Lower station. Only the Lower station had detectable sand deposition and it comprised about 3 percent of total substrate. The low degree of silt and sand deposition at each station indicated no large scale disruption within the watershed that could contribute sand and silt to the stream channel.

Embeddedness (silt covering cobble and gravel) was high the Upper station and moderately high at the Lower station. The weighted embeddedness value at the Upper station was 27. This low value indicated that although there were no deposits of sediment in the channel, the majority of cobble and gravel substrate was covered or surrounded by fine silt. The average weighted embeddedness value at the Lower station for the period from 1996 through 1999 was 62.9. This value indicated a moderate amount of silt was covering and surrounding cobble and gravel substrate. Silt deposition is controlled by the amount of silt contained in the water mass and by the current velocity. Silt deposition will normally increase as current velocity is decreased.

The current velocity measured at the Upper station was 0.8 feet per second (fps) and 1.0 fps at the Lower station (Table 8-32). The lower current velocity and apparent lack of flushing flows at each station may have been factors related to the higher embeddedness values because low current velocity will allow entrained sediment to settle out of the water column.

The general decrease in substrate particle size from the Upper station to the Lower station was normal because particle size generally decreases as stream size and stream order increase (Rosgen, 1996). High embeddedness at the Upper station may have affected the benthic macroinvertebrate community by reducing the mayfly population and other benthic groups sensitive to sediment. Biological condition at the Upper station was Fair indicating partial support for aquatic life use. Moderate embeddedness at the Lower station apparently had some effect on the benthic macroinvertebrate community. Effects due to channelization, low discharge and probable higher water temperature were the apparent determinants that led to moderate impairment of the benthic aquatic population and partial support for aquatic life use. Because sediment does not appear to be a problem in the watershed, full support of aquatic life use could probably be attained by increasing the amount of water in the stream channel, especially during the summer. Increased stream discharge would correspondingly lower the water temperature during the critical warmer summer months and aid in transport of sediment through the system.

8.6.13 WGFD Little Tongue River Fish Population Monitoring

WGFD conducted historic and current monitoring of fish populations at various locations within the Little Tongue River Project area over the period from 1972 through 1997. Approximate location of sampling stations are illustrated in Figure 5-1 and Figure 5-2. Results from six (6) sampling events are presented in Appendix Tables C-16 through C-21.

Most historic fish sampling occurred at three (3) different stations identified by WGFD as Leonard Grahams property. Game species collected included brown trout, rainbow trout and brook trout. No whitefish were collected. No non-game species were collected, but it was unknown whether non-game species were absent or if they were present, but not netted during sampling. Brown trout were generally most abundant, followed by rainbow trout and brook trout. Brook trout were most abundant during sampling in 1981 and 1984.

Sampling conducted at the Little Tongue River Ranch in 1997 found brown trout most abundant and identification of a single Snake River cutthroat trout. Longnose dace, apparently the most abundant non-game species in the Tongue River, were collected. No rainbow trout or brook trout were collected. The apparent change in fish populations from the historic record to the current 1997 sampling event appeared to be related to change in fish stocking practice implemented by WGFD in the 1990's. The occurrence of the Snake River cutthroat trout in 1997 was perplexing because its origin could not be identified. WGFD no longer routinely stocks trout species in the watershed except for specific case by case requests where public fishing opportunity may exist.

The chemical, physical and biological data combined with fish population data indicated water quality and habitat were sufficient to fully support a fishery from the near the Upper station to at least as far downstream as the Little Tongue River Ranch. Habitat alteration and dewatering have probably occurred within that stream segment, but have apparently not prevented trout from maintaining themselves. No fish sampling was conducted downstream at the Little Tongue River Lower station to determine how low discharge, apparent warmer water temperature and altered habitat caused by channelization have affected the trout fishery.

8.7 Smith Creek Stations

8.7.1 Smith Creek Discharge

Instantaneous discharge measurements were recorded by SCCD and WDEQ during sampling at Smith Creek Upper and Lower stations. Summary statistics for discharges are presented in Table 8-21. Average discharge during the Project at the Upper station averaged 2.1 cfs, and 3.9 cfs at the Lower station. The geometric mean at the Upper station was 1.6 cfs and 3.1 cfs at the Lower station. The average values were difficult to compare among Upper and Lower stations due to differing sampling frequency and lack of same day sampling on numerous occasions. Figure

8-20 illustrates discharge measured at each station on the same day. Discharge data not measured at each station on the same day was excluded from Figure 8-20 because discharge may vary daily precluding valid comparison among stations.

Discharge during the primary low-irrigation months (April, May and September) usually increased from the Upper station downstream to the Lower station. Overall discharge measured on all comparable days increased by about fifty-six (56) percent from the Upper to the Lower station (Table 8-2). Discharge was seldom reduced from the Upper station to the Lower station during the primary irrigation months (June, July and August) (Figure 8-20) and there was an overall fifty-three percent (53) increase in discharge between the Upper and Lower stations during that period.

Smith Creek, with the exception of Five Mile Creek that was dominated by irrigation source water, was unique among primary tributaries to the Tongue River in that there was an increase in discharge from Upper to Lower stations. The other primary tributaries exhibited a decrease in discharge from Upper to Lower stations. The decrease in discharge at the other tributaries was usually most pronounced during the irrigation season. The difference in discharge between Smith Creek and the other tributaries was probably related to water management practices and probable trans-watershed diversion of water into Smith Creek from other sources.

Discharge at the Upper station ranged from 0.3 cfs to 6.3 cfs and the range at the Lower station was from 0.3 cfs to 11.0 cfs. The relatively low discharge at Smith Creek stations when compared to other tributary stations was related to the smaller watershed drainage area (Upper station = 3.7 square miles and Lower station = 11.7 square miles). Discharge at the Lower station was less than 2.5 cfs on only 6 of 38 days sampled (16 percent of total days). The generally high and consistent discharge appeared to be a primary factor for observed good biological condition and full support for aquatic life use described in Section 8.7.11.

The contribution of discharge to the Tongue River from Smith Creek was estimated by comparing discharge at the Smith Creek Lower station to discharge measured at the Tongue River Upper station on the same day. This comparison revealed that Smith Creek contributed an estimated 1.3 percent of the Tongue River discharge (Appendix Table M-2). This suggested that potential pollutants entering the Tongue River from Smith Creek would be highly diluted and have no significant effect on Tongue River water quality.

8.7.2 SCCD and WDEQ Smith Creek Temperature Monitoring

Summary statistics for instantaneous water temperature measurements by SCCD and WDEQ at the Smith Creek Upper and Lower stations is presented in Table 8.22. Water quality data collected by SCCD at the Upper station is listed in Appendix Table B-13. Water quality data collected by SCCD and WDEQ at the Lower station is presented in Appendix Tables B-14 and B-15, respectively.

Average water temperature during the Project was lowest at the Upper station (10.2^0C) and slightly higher at the Lower station (12.6^0C). Maximum water temperature recorded at the Upper station was 14.5^0C, and 21.1^0C at the Lower station. Based on instantaneous measurements there were no exceedences of the Wyoming water quality standard for temperature. However, as indicated in Section 8.5.2, sampling conducted by SCCD and WDEQ did not occur during the time of day required to detect maximum daily water temperature. Maximum daily water temperature was projected at each station during the months of June, July, August and September as described in Section 8.5.3. Projected maximum daily water temperature indicated no exceedence of Wyoming water quality standard for water temperature at the Upper station. One temperature exceedence probably occurred at the Lower station on July 29, 1999 representing about three (3) percent of total instantaneous temperature measurements. This observation indicated the need for future continuous water temperature monitoring during warmer summer months at the Lower station to determine frequency of occurrence for exceedence of the water temperature standard.

8.7.3 SCCD and WDEQ Smith Creek pH Monitoring

Summary statistics for instantaneous pH measurements by SCCD and WDEQ at Little Tongue River Upper and Lower stations are presented in Table 8.23. The pH varied little among the Upper and Lower stations. The average and geometric mean for pH during this Project was 8.1 SU at the Upper station and 8.2 SU at the Lower station. The maximum pH recorded at the Upper station during the Project was 8.8 SU, and 8.7 SU at the Lower station. The minimum pH was 7.1 SU at the Upper station and 7.8 SU at the Lower station. The generally high pH at both stations reflected the predominant limestone geology in the Smith Creek watershed. All pH measurements were within Wyoming water quality standards.

8.7.4 SCCD and WDEQ Smith Creek Specific Conductivity Monitoring

Summary statistics for specific conductivity are presented in Table 8-24. Average conductivity during the Project was 371 umhos/cm at the Upper station and 574 umhos/cm at the Lower station. The geometric mean was 366 umhos/cm at the Upper station and 557 umhos/cm at the Lower station. Conductivity values at the Upper station ranged from a low of 295 umhos/cm to a high of 690 umhos/cm, and from a low of 375 umhos/cm to a high of 943 umhos/cm at the Lower station. The average increase in conductivity from the Upper station to the Lower station was 55 percent. The increase in conductivity between stations using the geometric mean was 52 percent. The increase in conductivity was higher than expected and suggested that irrigation return or urban storm water effluent may be affecting conductivity at the Lower station especially during periods of lower discharge. Although there was no Wyoming water quality standard for conductivity, values were generally considered low and within the range required for support of aquatic life.

The relationship between conductivity and discharge noted at Little Tongue River and Tongue River stations was not as apparent at Smith Creek stations. The association between conductivity and discharge at Smith Creek Upper was weak and inverse such that as discharge increased, conductivity decreased slightly. The correlation coefficient between conductivity and discharge at the Upper station was -0.274 ($P>0.05$). The correlation coefficient between conductivity and discharge at Smith Creek Lower was +0.339 ($P<0.05$) indicating that as discharge increased, conductivity increased. The only other station where this positive relationship was observed was at Wolf Creek Lower. This observation suggested that Smith Creek Lower and Wolf Creek Lower discharge during the irrigation season was comprised primarily by irrigation return water higher in conductivity and thus, dissolved solids. This observation provided another indication that more constant and sustained discharge at Smith Creek Lower than at other Lower tributary stations was due to irrigation return (see Section 8.7.1).

8.7.5 SCCD and WDEQ Smith Creek Dissolved Oxygen Monitoring

SCCD initiated monitoring for dissolved oxygen (DO) in 1999. WDEQ conducted monitoring for DO once annually usually in October at Smith Creek Lower. Summary statistics for DO are presented in Table 8-25. DO was similar at each station. Average DO during the Project was 9.3 mg/l at the Upper station, and 9.2 mg/l at the Lower station. DO values ranged from 7.9 mg/l to 10.4 mg/l at the Upper station and from 7.9 mg/l to 10.1 mg/l at the Lower station.

There were no exceedences of the Wyoming water quality standard for DO because no DO values were less than 5 mg/l. The lowest DO value recorded during the Project was 7.9 mg/l measured by SCCD at both the Upper and Lower stations on September 16, 1999. The DO concentrations were sufficient to support a diverse population of aquatic organisms and fish indicating full support for aquatic life use for this physical parameter.

8.7.6 SCCD and WDEQ Smith Creek Turbidity Monitoring

Summary statistics for turbidity are presented in Table 8-26. Average turbidity measurements during the Project were higher at the Lower station when compared to turbidity at the Upper station. Average turbidity was 4.2 NTU at the Upper station and 19.0 NTU at the Lower station which represented an average increase of 14.8 NTU. The geometric mean was 2.4 NTU at the Upper station and 12.8 NTU at the Lower station which represented an average increase of 10.4 NTU. Turbidity values at the Upper station ranged from a low of 0.3 NTU to 14.0 NTU and from 1.8 NTU to 79 NTU at the Lower station.

The increase in turbidity from the Upper station to the Lower station was high even considering the expected natural increase in turbidity along the longitudinal gradient of most flowing water bodies. The average and geometric mean increase in turbidity between stations represented an exceedence of the Wyoming water quality standard for turbidity at the Lower station. The average increase of 14.8 NTU and geometric mean increase of 10.4 NTU was greater than the increase of 10 NTU allowed by the Wyoming water quality standard for Class 2 water bodies.

The normal association between discharge and turbidity observed at Tongue River stations and Little Tongue stations was absent at the Smith Creek Lower station. Turbidity was associated with discharge at the Upper station, but not at the Lower station. The correlation coefficient between turbidity and discharge at the Upper station was +0.413 ($P<0.05$), and +0.196 ($P>0.05$) at the Lower station. R-squared values for the regression analyses were 17.1 percent at the Upper station and 3.8 percent at the Lower station (Appendix Tables L-5 and L-6). This indicated that higher turbidity was more likely to occur during lower periods of discharge which strongly suggested negative influence of irrigation return water on turbidity levels. Because irrigation return water appeared to comprise a majority of discharge at the Lower station, the increase in turbidity may be related to higher turbidity contained in returns entering Smith Creek. The effect that irrigation return may have on turbidity levels in Smith Creek should receive further investigation by establishing additional sampling sites on the Creek and at identified irrigation returns entering the Creek. Land use activity connected to turbidity increase should be identified and corrective action implemented.

8.7.7 SCCD and WDEQ Smith Creek Fecal Coliform Bacteria Monitoring

Summary statistics for fecal coliform bacteria are presented in Table 8-33. The geometric mean for fecal coliform bacteria at the Upper station during the Project was 12 per 100ml, and 176 per 100ml at the Lower station. The geometric mean is a logarithmic transformation of data and provided a more reliable estimate of the mean by smoothing extreme values when variability was high among fecal coliform measurements. Fecal coliform bacteria concentration at the Upper station ranged from 1 per 100ml to 180 per 100ml. The number of bacteria was relatively low indicating that the primary land uses (wildlife, recreation and seasonal livestock grazing) in the vicinity of the Upper station were not significant sources of fecal coliform bacteria. Fecal coliform bacteria concentration at the Lower station ranged from 8 per 100ml to 2790 per 100ml. The highest fecal coliform level occurred on August 26, 1997 and a level of 2150 per 100ml was detected on July 29, 1999.

The was no exceedence of the Wyoming water quality standard for fecal coliform bacteria at the Upper station. The geometric mean of five (5) samples collected during the Recreation Season in 1999 at the Upper station was 57 per 100ml which was considered relatively low. There was no single sample in excess of 400 per 100ml since the maximum level during the Project was 180 per 100ml (collected August 26, 1997).

Fecal coliform bacteria levels at the Lower station exceeded the Wyoming water quality standard for fecal coliform bacteria. The geometric mean of five (5) samples collected during the Recreation Season in 1999 was 534 per 100ml which exceeded the standard of 200 per 100ml. Six samples had fecal coliform levels in excess of 400 ml. The exceedence of the standard indicated remedial measures were required to lower fecal coliform levels to bring the Lower station into compliance with the Wyoming water quality standard.

There were no exceedences of the fecal coliform standard at the Lower station in 1996 and 1998. SCCD increased the sampling frequency in 1999 from monthly to five (5) samples within a 30 day period during the Recreational Season to provide a better estimate of bacteria contamination and allow direct comparison to the Wyoming water quality standard for fecal coliform bacteria. Other sampling sites within the Project area exceeded Wyoming fecal coliform standards only in 1999. The increased sampling frequency in 1999 provided a better estimate of fecal coliform bacteria contamination and increased the probability for detection of fecal coliform levels that may pose a risk to public health and safety. Extensive discussion related to this finding is presented in Section 8.11.1.

The sources of fecal coliform at the Lower station may be difficult to define due to multiple land uses affecting this station, apparent significant irrigation return and trans-watershed water diversion. Urban land use may be considered the predominant land use since this station was located within the Town of Dayton. Rural subdivision development, irrigated hayland, livestock grazing and dryland pasture land use are present upstream. The role that irrigation return may have on fecal coliform levels should be closely evaluated since this water body appears to receive return water high in proportion to total discharge.

8.7.8 SCCD and WDEQ Smith Creek Nitrate Nitrogen Monitoring

Total nitrate samples were collected infrequently (N = 2 total samples) at the Smith Creek Upper station due to Project monitoring budget constraints. Sampling for nitrate nitrogen was concentrated at the Lower station because potential nutrients entering the Tongue River could be best estimated at this station. Summary statistics for nitrate nitrogen are presented in Table 8-28. Average nitrate nitrogen concentrations were low at each station during the Project. The average nitrate concentration at the Upper station was .155 mg/l, and .036 mg/l at the Lower station. Nitrate values at the Upper station based on two (2) samples ranged from .140 mg/1 to .170 mg/l, and from .001 mg/l to .190 mg/l at the Lower station.

Average and maximum nitrate values at the Upper and Lower stations were considered low. Nitrate concentration was well below the Wyoming water quality standard and drinking water human health standard of 10 mg/l for Class 2 surface waters (WDEQ, 1998). Data for nitrate nitrogen indicated that nitrate concentration in Smith Creek was less than the background concentration of nitrate (about 0.60 mg/L) found in streams in undeveloped areas throughout the United States (USGS, 1999). These observations indicated that nitrate nitrogen was not present in Smith Creek in concentrations that could pose a human health threat or an ancillary threat to aquatic life use that could be caused by indirect effects due to eutrophication. Full support for all Wyoming beneficial uses applicable to nitrate was indicated.

8.7.9 SCCD and WDEQ Smith Creek Total Phosphorus Monitoring

Total phosphorus samples were collected infrequently by SCCD (N = 2 total samples) at both the Upper and Lower stations due to Project monitoring budget constraints. The majority of total phosphorus data was provided by WDEQ during annual bioassessment sampling. Summary statistics for total phosphorus are presented in Table 8-29. These statistics were based on "censored" values because the majority of analyses (6 samples out of 8 total samples) were less than the minimum detection limit (minimum detection limit was 0.10 mg/l for WDEQ analytical method; 0.05 mg/l for SCCD analytical method). The minimum detection limit for the WDEQ analytical method did not provide adequate data needed to address the recommended water quality standard for total phosphorus in water bodies draining to a lake or reservoir (0.05 mg/l; EPA, 1977). Data were thus censored to provide an estimate that could be compared to the recommended EPA standard of 0.05 mg/l.

Average total phosphorus concentrations were low at each station during the Project. The average total phosphorus concentration based on two (2) total samples at the Upper station was .013 mg/l, and .067 mg/l at the Lower station. Total phosphorus concentrations at the Upper station ranged from .006 mg/1 to .020 mg/l, and from .050 mg/l to .080 mg/l at the Lower station.

Average and maximum total phosphorus values at the Upper and Lower stations were based on a low total number of samples. However, total phosphorus values should be considered low. Wyoming has not established surface water quality standards for phosphorus. U.S. EPA (1977) recommended that total phosphorus concentration should not exceed 0.05 mg/l in a stream that enters a lake or reservoir (e.g. Tongue River Reservoir) to prevent development of nuisance algal and plant populations. Mackenthun (1973) suggested a target phosphorus level of less than 0.10 mg/l for streams that did not directly enter lakes or reservoirs. USGS (1999) provided recent information from nationwide NAWQA monitoring and assessment and reported that national background concentrations for total phosphorus from streams in undeveloped (reference - like) areas was about 0.10 mg/L. Because the EPA goal was not attainable, SCCD adopted the finding by USGS for its interpretation of total phosphorus data collected during this Project.

Using the value of ≤0.10 mg/l as a target for total phosphorus concentration, no significant amount of total phosphorus was identified in a single sample collected at Smith Creek stations during this Project. However, sampling frequency was generally low at the Upper (N = 2 samples) and Lower station (N = 6 samples) over a four year period and sampling generally occurred during the fall low flow period when total phosphorus concentration was normally lower. Additional sampling was necessary to provide a reliable estimate of total phosphorus concentration in Smith Creek.

8.7.10 WDEQ Smith Creek Monitoring for Additional Water Chemistry Parameters

WDEQ collected samples for additional monitoring parameters during annual monitoring at the

Smith Creek Lower station from 1996 through 1999. WDEQ conducted no sampling at the Smith Creek Upper station. Summary statistics are presented in Table 8-30.

Alkalinity averaged 271 mg/l at the Lower station based on four (4) samples. The geometric mean was 269 mg/l. The range was from 235 mg/l to 320 mg/l. There was no Wyoming water quality or EPA standard to compare alkalinity values to, but data indicated that water was generally productive for aquatic life and was generally capable of withstanding sudden changes in pH due to inputs from point and NPS pollutants.

Total chloride concentration was low at the Lower station. There were no samples collected that had total chloride concentrations greater than 5 mg/l. Total chloride values were well within WDEQ and EPA water quality standards indicating full support for Wyoming beneficial uses that may be affected by chloride.

Total sulfate concentration at the Lower station was considered moderately high. Average total sulfate concentration based on four (4) total samples at the Lower station was 151 mg/l. The range in total sulfate was from 113 mg/l to 216 mg/l. These values were higher than expected even considering samples were collected in the fall during lower flow when ion concentrations were normally highest. Possible sources for the higher total sulfate concentrations may include irrigation return and urban land use (i.e. storm water drain discharge). Conductivity, of which total sulfate is a component, was higher than expected at the Lower station and was observed to increase from Upper to Lower stations. Total sulfate sampling is recommended for future monitoring at Smith Creek to determine if the increase in sulfate concentration at the Lower station was a natural occurrence or if the increase was due to potential irrigation return or urban land use influence. Total sulfate values were within WDEQ standards (for groundwater use), but approached the EPA secondary drinking water standard of 250 mg/l. This observation indicated full support for Wyoming beneficial uses that may be affected by sulfate.

Hardness concentration was relatively high at the Lower station and may be due to the natural limestone geology that predominated much of the upstream Smith Creek watershed. Average hardness at the Lower station was 361 mg/l. The range in hardness at the Lower station was from 281 mg/l to 456 mg/l. Water at the Lower station may be termed very hard based on the classification found in Table 6-2. There were no Wyoming or EPA water quality standards for hardness, but observed values indicated partial support of the Wyoming beneficial use for Industrial use since the majority of values were greater than 300 mg/l and treatment may be required before industrial use. More year around sampling at upstream and downstream stations was required to determine if the relatively high hardness values were due to seasonal sampling artifact during low flow, natural limestone geology in the watershed, irrigation return, or to potential urban land use influence.

Total Suspended Solids (TSS) concentrations were moderately high at the Lower station despite the fact that all samples were collected in the fall during lower flow when TSS values should normally be lowest. Average TSS concentration at the Lower station was 10 mg/l with a range from 1 mg/l to 20 mg/l. Results of limited TSS sampling conducted by WDEQ provided little information for potential sediment problems within the Tongue River watershed. However, results of turbidity sampling (Section 8.7.6) found an exceedence of the Wyoming water quality standard for turbidity. This observation suggested that a significant amount of sediment was entering Smith Creek between the Upper and Lower stations. Further sampling for TSS may be considered because turbidity sampling indicated potential sediment problems within the Smith Creek watershed. However, turbidity monitoring should continue to be used as the primary surrogate indicator for TSS unless specific sediment loading questions arise.

8.7.11 SCCD and WDEQ Smith Creek Benthic Macroinvertebrate Monitoring

SCCD and WDEQ sampled benthic macroinvertebrates at the Lower station annually from 1996 through 1999. No benthic macroinvertebrate sampling occurred at the Upper station due to monitoring budget constraints.

Metric values for samples collected at the Lower station are presented in Appendix Table G-2. Lists of benthic taxa identified, density (number per square meter) of taxa and percent contribution of each taxon to the total benthic population are presented in Appendix Tables F-14 through F-17.

Biological condition at the Smith Creek Lower station using scoring criteria from the Wyoming Stream Integrity Index (WSII) from Stribling et al. (2000) was **good** during each year (Table 8-15). The WBCI (Barbour et al., 1994) was not applicable to this station because the Lower station was located in the Northwestern Great Plains ecoregion and the WBCI was developed for Middle Rockies ecoregion mountain and foothill streams. The range in average WSII scores was from 57.1 in 1996 to 74.0 in 1997. The range in scores was greater than the range observed at most other tributary stations. This observation indicated full support for aquatic life use.

The benthic community at the Smith Creek Lower station was dominated by a mixture of warm and cool water taxa indicative of moderate water quality and habitat. Dominant taxa in order of decreasing abundance included the caddisflies, *Hydropsyche, Helicopsyche borealis*, the riffle beetle, *Optioservus*, the mayfly, *Paraleptophlebia* and the mayfly, *Baetis tricaudatus* (Table 8-16). Worms were present at the Lower station each year and ranged in percent contribution from one (1) percent in 1996 and 1998 to two (2) percent in 1997 and 1999. There was one (1) worm taxa in 1996, four (4) taxa in 1997 and 1999 and two (2) worm taxa in 1998. The worms *Ophidonais serpentina* and *Eiseniella tetraedra* occurred most frequently. The number of worm taxa and percent contribution did not indicate a severe pollution problem, but rather a moderate amount of pollution indicative of animal waste from agricultural, wildlife or urban sources. This observation was supported by the violation of the Wyoming water quality standard for fecal coliform bacteria. No *Tubifex tubifex* were collected indicating a low probability for the occurrence of whirling disease.

The total number of EPT taxa was generally consistent among years and ranged from seven (7) taxa in 1996 to twelve (12) taxa in 1997 and 1999. Percent contribution of scraper abundance was variable, but was generally good ranging from nine (9) percent in 1996 to forty-three (43) percent in 1998. Collector filterers comprised seventy-three (73) percent of the population in 1996 and sixty-one (61) percent of the population in 1999. The high percentage of collector filterers indicated the significant presence of fine particulate organic matter originating from potential sources as sewage and animal waste. This observation combined with the exceedence of the Wyoming water quality standard for fecal coliform suggested sources for human sewage, animal waste, or both were impacting the Smith Creek Lower station.

The good rating for biological condition indicated that with the exception of turbidity and fecal coliform bacteria contamination, water quality and habitat were sufficient to provide for a healthy benthic community when compared to other streams in the Northwestern Great Plains of Wyoming. Full support for aquatic life use was indicated, but continued benthic macroinvertebrate monitoring is recommended to track water quality change.

8.7.12 SCCD and WDEQ Smith Creek Habitat Assessment

Qualitative habitat assessments were conducted by SCCD and WDEQ annually from 1996 through 1999 at the Lower station. No benthic macroinvertebrate sampling or habitat assessments were conducted at the Smith Creek Upper station. Because habitat assessments were subjective and based on best professional judgement, SCCD used caution by providing a conservative interpretation of data.

The average total habitat assessment score at the Lower station was 128 (Table 8-53). Total scores varied 117 in 1997 to 136 in 1998. Scores were high for substrate / percent fines (indicating little sediment deposition), channel flow status (due to consistent discharge that sufficiently covered the stream channel), and riparian condition parameters, with the exception of riparian zone width. The riparian zone was narrow due to historic channelization and down cutting of the stream channel which elevated the riparian zone above surface and groundwater influence. Habitat parameter scores were relatively low for instream cover (historic channelization had altered fish habitat and cover), embeddedness (silt cover apparently related to increased turbidity and silt; see Section 8.7.6) and pool riffle ratio (channelization had reduced the number of pools compared the length of riffles).

The semi-quantitative stream substrate particle size distribution indicated that the Lower station was dominated by cobble (average = 64%), coarse gravel (average = 16%) and fine gravel (average = 14%). Deposition of sand varied little among years and ranged from three (3) percent in 1998 and 1999 to four (4) percent in 1996 and 1997. Deposition of silt was not observed in

1996, 1998 and 1999, but comprised seven (7) percent of total substrate in 1997. The low degree of silt and sand deposition at each station indicated no large scale disruption within the watershed upstream that may contribute sand and silt to the stream channel. The diversity in stream substrate particle size afforded a variety of niches for colonization and maintenance by benthic microinvertebrates.

Embeddedness (silt covering cobble and gravel) was moderately high at the Lower station. The weighted embeddedness at the Lower station was 48.1 (Table 8-54). Annual weighted embeddedness values ranged from 33.2 (high amount of silt deposition) to 64.0 (moderate amount of silt deposition). These values indicated that although there were no deposits of sediment in the channel, the majority of cobble and gravel substrate was partially covered or surrounded by fine silt. Silt deposition is controlled by the amount of silt contained in the water mass and by the current velocity. Silt deposition will normally increase as current velocity is decreased provided adequate silt is contained in the water column.

The average current velocity measured at the Lower station was 1.5 feet per second (fps). The current velocity at the Lower station combined with higher turbidity may have been a factor related to the higher embeddedness values because lower current velocity apparently allowed entrained sediment to settle out of the water. However, silt deposition was apparently not high enough to significantly affect benthic macroinvertebrate populations because biological condition was rated good.

8.7.13 WGFD Smith Creek Fish Population Monitoring

WGFD conducted fish sampling in 1959 at a single location at the old Glen Mock Ranch in the upper Smith Creek watershed. Approximate location of the sampling station is illustrated in Figure 5-1. Results from the single sampling event are presented in Appendix Table C-22.

Brook trout dominated the fish community followed by collection of only two (2) brown trout. No other game and non-game fish species were collected. It was unknown whether non-game species were present because fish surveys conducted during that period appeared to concentrate on collection of game species. Lack of other historic or current fish data prevented further evaluation for current water quality or habitat conditions. However, the historic data indicated that sufficient water quality and habitat were present to support cold water fish species in 1959.

8.8 Columbus Creek Stations

8.8.1 Columbus Creek Discharge

Instantaneous discharge measurements were recorded by SCCD and WDEQ during sampling at Columbus Creek Upper and Lower stations. Summary statistics for discharges are presented in

Table 8-34. Discharge measurements during the Project at the Upper station averaged 7.6 cfs, and 7.2 cfs at the Lower station. The geometric mean at the Upper station was 5.7 cfs, and 4.6 cfs at the Lower station. Discharge at the Upper station during the Project ranged from 1.8 cfs to 26.8 cfs and from 0.0 cfs to 33.6 cfs at the Lower station. The average values were difficult to compare among Upper and Lower stations due to differing sampling frequency and lack of same day sampling on numerous occasions. Figure 8-21 illustrates discharge measured at each station on the same day. Discharge data not measured at each station on the same day was excluded from Figure 8-21 because discharge may vary daily precluding valid comparison among stations.

Discharge during the primary low-irrigation months (April, May and September) often increased from the Upper station downstream to the Lower station. However, overall discharge measured on all comparable days was reduced by about thirty-two (32) percent from the Upper station to the Lower station (Table 8-2). Discharge was reduced by twenty-nine (29) percent from the Upper station to the Lower station during the primary irrigation months (June, July and August) (Figure 8-19).

The Columbus Creek Lower station had a discharge less than 4 cfs during thirty-four (34) percent of all sampling days. The reduction in discharge from the Upper station to the Lower station during the Project was due to diversion of water into the Five Mile Ditch serving the Five Mile Creek drainage. Dewatering at the Lower station was especially evident in October of each year when discharge was less than 1.5 cfs (Appendix Table B-19). The generally lower discharge at the Lower station appeared to be a primary factor responsible for impairment of biological condition during each year of the Project (see Section 8.8.11).

The contribution of discharge to the Tongue River from Columbus Creek was estimated by comparing discharge at the Columbus Creek Lower station to discharge measured at the Tongue River Middle station on the same day. This comparison revealed that Columbus Creek contributed an estimated 1.3 percent of the Tongue River discharge (Appendix Table M-2). This observation indicated that potential pollutants entering the Tongue River from Columbus Creek would be significantly diluted and have no significant effect on Tongue River water quality.

8.8.2 SCCD and WDEQ Columbus Creek Temperature Monitoring

Summary statistics for instantaneous water temperature measurements by SCCD and WDEQ at Columbus Creek Upper and Lower stations are presented in Table 8-35. Water quality data for the Upper station is presented in Appendix Tables B-16 and B-18 and data for the Lower station in Appendix Tables B-17 and B-19.

Water temperature varied among Columbus Creek Upper and Lower stations. Average water temperature during the Project was lowest at the Upper station (9.6^{0}C) and higher at the Lower station (13.5^{0}C). Maximum water temperature recorded at the Upper station was 14.1^{0}C, and

25.1^{0}C at the Lower station. The average increase in water temperature between Upper and Lower stations was not specific because of the difference in sampling frequency and lack of same day sampling. However, the data indicated a consistent increase in water temperature between Upper and Lower stations on comparable sampling days. Maximum water temperature at each station occurred during the summer months of July and August when ambient air temperature was highest. Lowest water temperature generally occurred during April, May or October when discharge was dominated by snowmelt runoff or cooler seasonal ambient air temperature persisted.

Based on instantaneous measurements there were no exceedences of the Wyoming water quality standard for water temperature at the Upper and Lower stations. However, as indicated in Section 8.5.2, sampling conducted by SCCD and WDEQ did not occur during the time of day required to detect maximum daily water temperature. Maximum daily temperature was projected at each station during the months of June, July, August and September as described in Section 8.5.3. Projected maximum daily water temperature indicated no exceedence of Wyoming water quality standard at the Upper station. Six water temperature exceedences probably occurred at the Lower station during the summer. In addition, water temperature appeared to approach the temperature standard (was within 1.0^{0}C) on six (6) other sampling days. This observation indicated the need for future continuous water temperature monitoring during warmer summer months at the Lower station to determine frequency of occurrence for exceedence of the Wyoming water quality standard for water temperature.

8.8.3 SCCD and WDEQ Columbus Creek pH Monitoring

Summary statistics for instantaneous pH measurements by SCCD and WDEQ at Columbus Creek Upper and Lower stations are presented in Table 8-36. The pH varied little among the Upper and Lower stations. The average and geometric mean for pH during this Project was 8.2 SU at the Upper station and 7.9 SU at the Lower station. As indicated in previous sections, direct comparisons between Upper and Lower stations could not be made due to different sampling frequency among stations and lack of same day sampling. The maximum pH recorded at the Upper station during the Project was 8.6 SU, and 8.5 SU at the Lower station. The minimum pH was 7.1 SU at the Upper station and 6.8 SU at the Lower station. The pH at both stations generally decreased in response to higher discharge and increased during periods of lower discharge. The generally high pH at both stations reflected the predominant limestone geology in the Columbus Creek watershed. There were no samples <6.5 SU or > 9.0 SU indicating pH was within the Wyoming water quality standard for pH.

8.8.4 SCCD and WDEQ Columbus Creek Specific Conductivity Monitoring

Summary statistics for specific conductivity are presented in Table 8-37. Average conductivity during the Project was 404 umhos/cm at the Upper station and 525 umhos/cm at the Lower station. The geometric mean was 401 umhos/cm at the Upper station and 479 umhos/cm at the Lower station. Conductivity values at the Upper station ranged from a low of 319 umhos/cm to a high of 496 umhos/cm, and from a low of 260 umhos/cm to a high of 977 umhos/cm at the Lower station. The average increase in conductivity from the Upper station to the Lower station was 30 percent. The increase in conductivity between stations using the geometric mean was 19 percent. The increase in conductivity was slightly higher than expected and suggested that irrigation return higher in conductivity may be affecting conductivity at the Lower station especially during periods of low discharge. Although there was no Wyoming water quality standard for conductivity, values were generally considered moderate and within the range required to support aquatic life.

Conductivity values were controlled primarily by stream discharge at the Upper station. The association between conductivity and discharge was relatively strong and inverse such that as discharge increased, conductivity decreased. The correlation coefficient between conductivity and discharge at the Upper station was -0.439 (Appendix Table L-3). The correlation coefficient was significant ($P<0.05$) indicating there was less than a 5 percent chance that the association was due to random chance alone. The association between conductivity and discharge was not as apparent at the Lower station. The correlation coefficient was -0.132 ($P>0.05$) which indicated a weak and insignificant inverse association. The lack of a strong relationship between conductivity and discharge was also observed at Smith Creek Lower where discharge appeared to be comprised primarily by irrigation return. This observation indicated that discharge at Columbus Creek Lower was also comprised primarily by irrigation return.

8.8.5 SCCD and WDEQ Columbus Creek Dissolved Oxygen Monitoring

SCCD initiated monitoring for dissolved oxygen (DO) in 1999. WDEQ conducted monitoring once in 1993 at the Upper station, then once annually usually in October at the Lower station. Summary statistics for DO are presented in Table 8-38. DO was similar at each station. Average DO during the Project was 10.1 mg/l at the Upper station and 9.0 mg/l at the Lower station. DO values ranged from 8.1 mg/l to 11.0 mg/l at the Upper station and from 7.9 mg/l to 11.2 mg/l at the Lower station.

There were no exceedences of the Wyoming water quality standard for DO because no DO values were less than 5 mg/l. The lowest DO value recorded during the Project was 7.9 mg/l on July 21, 1999 at the Lower station. The DO concentrations were sufficient to support diverse populations of aquatic organisms and fish indicating full support of aquatic life use for this physical parameter.

8.8.6 SCCD and WDEQ Columbus Creek Turbidity Monitoring

Summary statistics for turbidity are presented in Table 8-39. Average turbidity measurements during the Project were much higher at the Lower station than at the Upper station. Average turbidity was 4.8 NTU at the Upper station and 51.7 NTU at the Lower station. The geometric mean was 2.3 NTU at the Upper station and 36.2 NTU at the Lower station. Turbidity values at the Upper station ranged from a low of 0.5 NTU to 15.0 NTU and from 3.4 NTU to 185 NTU at the Lower station. Turbidity values greater than or equal to 15 NTU were recorded at the Lower station on thirty-one (31) different sampling dates representing 84 percent of total sampling events.

Turbidity values were strongly associated with discharge. There was a significant positive relationship such that turbidity values increased as discharge increased. The correlation coefficient between turbidity and discharge at the Upper station was +0.502 ($P<0.01$), and +0.721 ($P<0.01$) at the Lower station. R-squared values for the regression analyses were 25.2 percent at the Upper station and 52.0 percent at the Lower station (Appendix Tables L-5 and L-6). Because of the association between turbidity and discharge, lower turbidity values were generally recorded during periods of lower discharge (prior to and after spring runoff) in early April, September and October and higher turbidity values were generally recorded during periods of higher discharge during spring runoff in latter April, May and June. However, turbidity values greater than 30 NTU were sometimes measured at the Lower station when discharge was relatively low during the summer. A portion of the higher turbidity may be related to the natural geology and soil type upstream of this station, but frequent high turbidity strongly suggested sediment input from unknown upstream sources. This scenario suggested influence from irrigation return water, other land uses that may affect stream bank stability, or water management practices that may produce an irregular discharge pattern. The average increase in turbidity between the Upper and Lower stations was 46.9 NTU. The increase in turbidity represented an exceedence of the Wyoming water quality standard because an increase up to 10 NTU is allowed for Class 2 cold water, water bodies. Additional sampling stations are required upstream from the Lower station for future turbidity sampling to identify the source(s) for turbidity affecting the Lower station.

8.8.7 SCCD and WDEQ Columbus Creek Fecal Coliform Bacteria Monitoring

Summary statistics for fecal coliform bacteria are presented in Table 8-40. The geometric mean for fecal coliform bacteria at the Upper station during the Project was 12 per 100ml, and 107 per 100ml at the Lower station. The geometric mean is a logarithmic transformation of data and provided a more reliable estimate of the mean by smoothing extreme values when variability was high among measurements.

Fecal coliform bacteria concentration at the Upper station ranged from 1 per 100ml to 3300 per 100ml. With the exception of the single high sample collected on May 4, 1998, the number of bacteria was generally quite low indicating that the primary land uses (wildlife, recreation and limited seasonal livestock grazing) in the vicinity of the Upper station were not significant sources of fecal coliform bacteria. The median fecal coliform bacteria concentration was 19 per 100 ml. The median statistic is the number at which 50 percent of the observed values are above and 50 percent of the observed values are below.

Fecal coliform bacteria concentration increased significantly at the Lower station and ranged from

1 per 100ml to 1800 per 100ml. The median value during the Project was 190 per 100 ml and the median during 1999 was 480 per 100 ml.

The was a technical exceedence of the Wyoming water quality standard for fecal coliform bacteria at the Upper station because a single sample collected in 1998 exceeded the standard of 400 per 100 ml. However, only four (4) percent of fecal coliform samples collected during the Project exceeded the standard of 400 per 100 ml. The geometric mean of five (5) samples collected during the Recreational Season in 1999 at the Upper station was 49 per 100ml which was considered low. The single high sample represented an exceedence of the standard, but this observation should be tempered by the fact that only four (4) percent of total samples exceeded the standard. SCCD proposes that the reach upstream of Columbus Creek Upper not be placed on the WDEQ (303d) list for water quality limited segments based on the single high sample. Rather, SCCD proposes that sampling for fecal coliform continue to determine if frequent, significant bacteria levels are present to ensure that public health and safety are protected.

Fecal coliform bacteria levels at the Lower station exceeded the Wyoming water quality standard for fecal coliform bacteria. The geometric mean of five (5) samples collected during the Recreational Season in 1999 was 405 per 100ml which exceeded the standard of 200 per 100ml. During the Project seven (7) samples had fecal coliform levels in excess of 400 ml representing twenty-six (26) percent of total samples. The exceedence of the standard indicated remedial measures were required to lower fecal coliform levels to bring the Lower station into compliance with Wyoming water quality standards.

There were no exceedences of the fecal coliform standard in 1996 and 1998. SCCD increased the sampling frequency in 1999 from monthly to five (5) samples within a 30 day period during the Recreation Season to provide a better estimate of bacteria contamination and allow direct comparison to the Wyoming water quality standard for fecal coliform bacteria. Other sampling sites within the Project area exceeded Wyoming fecal coliform standards only in 1999. It appeared that the increased sampling frequency in 1999 compared to previous years increased the probability for detection of fecal coliform levels in excess of the Wyoming fecal coliform standard. Extensive discussion related to the effects of sampling frequency for reliable estimates of fecal coliform bacteria is presented in Section 8.11.1.

8.8.8 SCCD and WDEQ Columbus Creek Nitrate Nitrogen Monitoring

Summary statistics for nitrate nitrogen are presented in Table 8-41. The nitrate data was more comparable between the Upper and Lower stations than for most other tributaries because sampling frequency was similar at both stations. Twenty-five (25) samples were collected at the Upper station and twenty-seven (27) samples were collected at the Lower station. However, same day sampling did not occur on all sampling dates.

Average nitrate nitrogen concentrations were relatively low at each station during the Project. The average nitrate concentration at the Upper station was .161 mg/l, and .057 mg/l at the Lower station. Nitrate values at the Upper station ranged from .004 mg/1 to .720 mg/l, and from .001 mg/l to .800 mg/l at the Lower station. The average nitrate values at each station were higher than the average nitrate values at mainstem Tongue River stations, Little Tongue River and Smith Creek.

Average and maximum nitrate values at the Upper and Lower stations were considered low to moderate. Nitrate concentration was well below the Wyoming water quality standard and drinking water human health standard of 10 mg/l for Class 2 surface waters (WDEQ, 1998). Data for nitrate nitrogen indicated that nitrate concentration in Columbus Creek was generally less than the background concentration of nitrate (about 0.60 mg/L) found in streams in undeveloped areas throughout the United States (USGS, 1999). These observations indicated that average nitrate nitrogen levels in Columbus Creek were lower than natural background levels found throughout the United States, but an occasional value slightly higher than background was detected. This suggested occasional influence by anthropogenic (man-caused) influence. However, nitrate was not present in Columbus Creek in concentrations that could pose a human health threat or an ancillary threat to aquatic life use by indirect effects caused by eutrophication. Full support for all Wyoming beneficial uses applicable to nitrate was indicated.

8.8.9 SCCD and WDEQ Columbus Creek Total Phosphorus Monitoring

Total phosphorus samples were collected infrequently by SCCD (N = 2 total samples) at the Columbus Creek Upper and Lower stations due to Project monitoring budget constraints. The majority of total phosphorus data was provided by WDEQ during annual bioassessments usually in October. Summary statistics for total phosphorus are presented in Table 8-42. These statistics were based on "censored" values because the majority of analyses (6 samples out of 9 total samples) were less than the minimum detection limit (minimum detection limit was 0.10 mg/l for WDEQ analytical method; 0.05 mg/l for SCCD analytical method). The minimum detection limit for the WDEQ analytical method did not provide adequate data needed to address the recommended water quality standard for total phosphorus in water bodies draining to a lake or reservoir (0.05 mg/l; EPA, 1977). Data were thus censored to provide an estimate that could be related to the recommended EPA standard of 0.05 mg/l.

Average total phosphorus concentrations were low at each station during the Project. The average total phosphorus concentration at the Upper station based on three (3) total samples was .039 mg/l, and .065 mg/l at the Lower station. Total phosphorus concentrations at the Upper station ranged from .006 mg/1 to .070 mg/l, and from .008 mg/l to .180 mg/l at the Lower station.

Average and maximum total phosphorus values at the Upper and Lower stations were based on a low total number of samples. However, total phosphorus values should be considered low.

Wyoming has not established surface water quality standards for phosphorus. U.S. EPA (1977) recommended that total phosphorus concentration should not exceed 0.05 mg/l in a stream that enters a lake or reservoir (e.g. Tongue River Reservoir) to prevent development of nuisance algal and plant populations. Mackenthun (1973) suggested a target phosphorus level of less than 0.10 mg/l for streams that did not directly enter lakes or reservoirs. USGS (1999) provided recent information from nationwide NAWQA monitoring and assessment and reported that national background concentrations for total phosphorus from streams in undeveloped (reference - like) areas was about 0.10 mg/L. Because the EPA goal of 0.05 mg/l was not attainable, SCCD adopted findings by USGS for its interpretation of total phosphorus data collected during this Project.

Using the value of $\leq$0.10 mg/l as a target for total phosphorus concentration, one sample exceeded the target value (August 17, 1999 at the Lower station collected by SCCD). Because one (1) out of nine (9) total samples (11 % of total samples) exceeded the target value, sampling frequency was generally low at the Upper (N = 3 samples) and Lower station (N = 6 samples) over a four year period and sampling generally occurred during the fall low flow period when total phosphorus concentration is normally lower, additional sampling was necessary to provide a reliable estimate of total phosphorus concentration in Columbus Creek.

8.8.10 WDEQ Columbus Creek Monitoring for Additional Water Chemistry Parameters

WDEQ collected samples for additional monitoring parameters during annual monitoring at the Columbus Creek Upper station in 1993 and the Columbus Creek Lower station from 1996 through 1999. Summary statistics are presented in Table 8-43.

Alkalinity at the Upper station based on a single sample was 170 mg/l. Average alkalinity at the Lower station based on four (4) samples was 326 mg/l. The geometric mean was 317 mg/l. The range was from 210 mg/l to 390 mg/l. There was no Wyoming water quality or EPA standard to compare alkalinity values to, but data indicated that water was moderate to highly alkaline, highly productive for aquatic life and was generally capable of withstanding sudden changes in pH due to inputs from point and NPS sources.

Total chloride concentration was low at each station during the limited sampling. Chloride was not detected in the single sample collected at the Upper station. Chloride was detected during each sampling event at the Lower station, although at low concentration. Average chloride based on four (4) samples was 10 mg/l with a range from 2.5 mg/l (censored value) to 17.3 mg/l. Total chloride values were well within WDEQ and EPA water quality standards indicating full support for Wyoming beneficial uses that may be applicable to total chloride. However, presence of chloride, although at low levels suggested that irrigation return may have some effect on the Lower station.

Total sulfate concentration based on a single sample at the Upper station was relatively high (68 mg/l) when compared to the Upper Tongue River station and Upper tributary stations. The average total sulfate concentration based on four (4) total samples at the Lower station was 162 mg/l. The range in total sulfate was from 65 mg/l to 223 mg/l. These values were higher than expected even considering samples were collected in the fall during lower flow when ion concentrations were normally highest. The primary source for the higher total sulfate concentration at the Lower station appeared to be natural sources (based on the Upper station concentration) and a secondary source was probably related to irrigation return.

Total sulfate values for both stations were within WDEQ standards (for groundwater use), but the Lower station approached the EPA secondary drinking water standard of 250 mg/l. This observation indicated full support for Wyoming beneficial uses for sulfate. Total sulfate sampling is recommended for future monitoring at Columbus Creek due to its approach to the EPA secondary drinking water standard and to determine if the increase in sulfate concentration at the Lower station was a natural occurrence or if the increase was related to irrigation return.

Hardness concentration was high at each station and may be due to the natural limestone geology that predominated much of the upstream Columbus Creek watershed. Hardness at the Upper station based on a single sample was 320 mg/l. Average hardness at the Lower station was 392 mg/l. The range in hardness at the Lower station was from 239 mg/l to 510 mg/l. Water at each station may be termed very hard based on the classification found in Table 6-2. There were no Wyoming or EPA water quality standards for hardness, but observed values indicated partial support of the Wyoming beneficial use for Industrial use since all values were greater than 300 mg/l and treatment may be required before industrial use. More year around sampling was required to determine if the high hardness values were due to seasonal sampling artifact during low flow periods or to natural limestone geology in the watershed.

Total Suspended Solids (TSS) concentration was low at the Upper station. The single TSS sample was <2 mg/l. The low value appeared to be related to the fact that the sample was collected in the fall during lower flow when TSS values were normally lowest. However, average TSS at the Lower station was 18 mg/l with a range from 6 mg/l to 23 mg/l. These values were considered seasonally high because most stations in the Project area displayed TSS values near or slightly above minimum detection limits during the low flow season. Results of turbidity sampling (Section 8.8.6) showed high turbidity levels in excess of the Wyoming water quality standard. This suggested that significant amounts of sediment were entering Columbus Creek between Upper and Lower stations. Further sampling for TSS is not recommended at this time unless specific sediment loading questions arise. Turbidity should continue to be used as a surrogate indicator for TSS. As recommended in Section 8.8.6, further turbidity sampling is required at Columbus Creek.

8.8.11 SCCD and WDEQ Columbus Creek Benthic Macroinvertebrate Monitoring

The Columbus Creek Upper station was monitored by WDEQ once in 1993. SCCD and WDEQ sampled benthic macroinvertebrates at the Lower station annually from 1996 through 1999.

Metric values for the single WDEQ sample collected from the Upper station is presented in Appendix Table G-1. Metric values for samples collected at the Lower station are presented in Appendix Table G-1.

Lists of benthic taxa identified, density (number per square meter) of taxa and percent contribution of each taxon to the total benthic population at each station are presented in Appendix F. The WDEQ Upper station taxa list is presented in Appendix Table F-1. Taxa lists for the Lower station are presented in Appendix Tables F-2 through F-5.

Biological condition at the Columbus Creek Upper station using scoring criteria from the Wyoming Biological Condition Index (WBCI) from Barbour et al. (1994) was **good**. Biological condition using scoring criteria from the Wyoming Stream Integrity Index (WSII) from Stribling et al. (2000) was **fair** (Table 8-15). The good biological condition rating indicated full support of aquatic life use whereas the fair biological condition rating indicated partial support of aquatic life use. Partial support of aquatic life use requires improvement in the aquatic resource to restore biological condition to full support for aquatic life use. Contradictory or “gray area” determination of biological condition may be expected to occur in as much as fifteen (15) to twenty (20) percent of bioassessments (1998 Personal Communication, Kurt King, WDEQ). SCCD used the WBCI from Barbour et al. (1994) as the primary indicator of biological condition because the WBCI was developed specifically for streams in the mountains and foothills of the Big Horn Mountains in the Middle Rockies Ecoregion and appeared to provide the most reliable assessment. In contrast, the WSII was developed for all mountain streams statewide and may, perhaps be less sensitive than the WBCI for assessment of biological condition in the Big Horn Mountain foothill streams.

Although biological condition was rated good using the WBCI, at least one additional year of sampling for benthic macroinvertebrates is recommended because only one sample was taken and confirmation was required. Biological condition ratings that border between two ratings (i.e. fair and good) should always be re-sampled the next year to confirm findings from the previous year especially when the determination may result in listing the stream segment for non-support for aquatic life use. Should additional sampling indicate impairment of the biological community, another sample should be collected and if impairment is reconfirmed, remedial measures should be considered.

Biological condition at the Columbus Creek Lower station using scoring criteria from the Wyoming Stream Integrity Index (WSII) from Stribling et al. (2000) was **fair** in 1996 and 1998 and **good** in 1997 and 1999 (Table 8-15). The Wyoming Biological Condition Index (WBCI) from Barbour et al. (1994) could not be used at this station since it was developed for mountain and foothill streams and not for plains stream sites such as the Columbus Creek Lower station. The ratings in 1997 and 1999 indicated full support for aquatic life use whereas the ratings in 1996 and 1998 indicated partial support for aquatic life use. The contradictory ratings may be clarified by concurrent evaluation of water quality and habitat quality data. The Lower station was water quality limited due to projected high water temperature and it exceeded the Wyoming water quality standard for turbidity and fecal coliform bacteria. Habitat quality ranked second to last among all tributary streams assessed (Table 9-4). Evaluation of specific metrics for the benthic macroinvertebrate community indicated that the Lower station was being negatively impacted by warmer water temperature, sediment and possible organic enrichment from animal waste. Based on these factors, SCCD took the conservative approach to declare the Lower station as partially supporting aquatic life use. This observation will require remedial measures to restore biological condition. It is likely that reduction in turbidity and sediment deposition, reduction in water temperature and improvement in summer discharge will result in restoration of biological condition at the Lower station.

The benthic community was dominated by primarily warmer water taxa indicative of fair water quality and fair habitat quality. Of note was the importance of worms in the benthic community. Increased density of worms (Oligochaeta) may be associated organic pollution (Klemm, 1985), pollution from feedlots (Prophet and Edwards, 1973), and pollutants contained in urban storm water runoff (Lenat et al., 1979; Lenat and Eagleson, 1981). *Ophidonais serpentina* and *Uncinais uncinata* were worm taxa that were among the five most dominant taxa in the benthic population (Table 8-16). *O. serpentina* and *U. uncinata* are widespread throughout the United States (Hiltunen and Klemm, 1980; Brinkhurst, 1986) and are often associated with sediment and organic deposits (e.g. animal waste). Both have pollution tolerance values of 8 (Table 8-16) indicating they are highly tolerant of pollution. The average number of Oligochaete (worm) taxa during the Project was five (5) which was the highest average number of worm taxa among tributary stations. Percent contribution of worms to the total benthic community was nineteen (19) percent in 1996, eight (8) percent in 1997, four (4) percent in 1998 and twenty-six (26) percent in 1999 (Appendix Table G-1). *Cheumatopsyche*, a pollution tolerant caddisfly, was one of the five most dominant taxa. This caddisfly genera is widespread and often becomes more abundant as water quality deteriorates.

The total number of EPT taxa was generally low each year and ranged from eight (8) taxa in 1996 to thirteen (13) taxa in 1999. Percent contribution of scraper taxa was low and ranged from one (1) percent in 1997 to four (4) percent in 1999. The lower percentage of scrapers in the benthic population suggested high deposition of sediment. This observation was confirmed by the average weighted embeddedness value of 21.8 at the Lower station (Table 8-32). The low percentage of shredders in the benthic population suggested riparian disturbance and vegetation removal. Shredders feed on coarse particulate organic material such as leaves and vegetation that enter smaller stream systems usually from the riparian zone. Shredders comprised 0.2 percent, 0.0 percent, 0.3 percent and 0.3 percent of the total benthic community during 1996, 1997, 1998 and 1999, respectively. The high percentage of collector filterers in the benthic population further indicated degraded water quality at the Lower station because this macroinvertebrate functional feeding group consumes fine particulate organic material suspended in the water column originating from sources contributing organic material such as animal waste. Collector filterers comprised 15 percent, 47 percent, 53 percent and 21 percent of the total benthic community during 1996, 1997, 1998 and 1999, respectively.

The apparent effect of seasonal dewatering and projected higher water temperature in excess of the Wyoming water quality standard was to allow warm water species to colonize and dominate this expected cool water environment. The higher water temperature, high turbidity and sediment deposition, combined with fecal coliform contamination and probable organic pollution from animal origin result in a fair biological condition rating and partial attainment aquatic life use. Dewatering may be addressed through water conservation practice. The apparent input of animal waste and sediment from suspect wildlife or agricultural land use requires resolution to bring the stream into compliance with Wyoming water quality standards and to fully support aquatic life use.

8.8.12 SCCD and WDEQ Columbus Creek Habitat Assessment

Qualitative habitat assessments were conducted once by WDEQ in 1993 at the Upper station and annually by SCCD and WDEQ from 1996 through 1999 at the Lower station. Because habitat assessments were subjective, SCCD used caution by providing a conservative interpretation of data.

The total habitat score based on the single 1993 assessment at the Upper station was 147 (Table 8-31). The score indicated good habitat quality. Percent fines (silt and sand) comprising the stream substrate was relatively high (sand = 16 percent, silt = 3 percent) (Table 8-32). Riparian condition indicator parameters including bank vegetation stability and riparian zone width scored high. However, bank stability and riparian disruptive pressures scored lower because unstable banks were common and vegetation was cropped by animals.

Habitat assessment scores were lower at the Columbus Creek Lower station when compared to the Upper station. Total habitat scores varied during the Project and ranged from 66 in 1996 and 1999 to 97 in 1998 (Table 8-31). The lower scores indicated moderate to poor habitat. The reduction in habitat score from the Upper station to the Lower station was due to lower scores for all habitat parameters with the exception of disruptive pressures. The lower scores may be partially due to the location of the station downstream of the Highway 14 crossing. Channelization effects commonly occur downstream of bridges in the form of scouring. However, percent fines (sand and silt) comprising the stream bed substrate was relatively high and embeddedness (silt covering or surrounding cobble and gravel) were high resulting in lower habitat scores for these parameters. Instream cover was low due to low discharge and channelization effects. Banks were unstable and eroding and the riparian zone width was low because the stream channel had down cut leaving the riparian zone without access to stream water or ground water.

The reduction in habitat coupled with low discharge due to dewatering and probable higher water temperature appeared to place stress on aquatic communities to result in non-support for aquatic life use.

The semi-quantitative stream substrate particle size distribution differed between the Upper and Lower stations. Average percent cobble was 64 percent at the Upper station and 36 percent at the Lower station. Average percent coarse gravel at the Upper station was 10 percent, and 15 percent at the Lower station. The largest change between Upper and Lower stations was in silt deposition and related high embeddedness. Silt comprised 3 percent of the Upper station and 29 percent at the Lower station. Embeddedness was generally low at the Upper station (weighted embeddedness value = 81) and high at the Lower station (weighted embeddedness value = 22). The higher the Weighted Embeddedness value, the lower the amount of silt covering cobble and gravel substrate. Silt deposition was affected by the apparent amount of silt entrained in the water column (i.e. turbidity exceedence of the water quality standard), low discharge due to dewatering and low current velocity. Silt deposition will normally increase as current velocity is decreased provided the water column contains significant fine sediment.

The current velocity measured at the Upper station was 2.6 feet per second (fps) and average current velocity at the Lower station was 0.5 fps (Table 8-32). Current velocity in 1999 was 0.05 fps. The low average current velocity appeared to be related to low discharge during sampling.

The general decrease in substrate particle size from the Upper station to the Lower station was expected, but the amount of silt deposition was greater than anticipated. High embeddedness at the Lower station, combined with low discharge, warmer water temperature and higher turbidity appeared to negatively affect the benthic macroinvertebrate community by reducing the cool water and pollution intolerant organisms with more warmer water taxa and pollution tolerant organisms. Increased stream discharge and reduced turbidity would benefit aquatic organisms and improve biological condition.

8.8.13 WGFD Columbus Creek Fish Population Monitoring

SCCD located no historic fish sampling data in the Columbus Creek watershed. However, SCCD was later notified by WGFD that one fish sampling event occurred in 1959 at a station near the SCCD Columbus Creek Upper station. The data could not be incorporated into this Final Report due to time constraints; however, the data has been received and will be retained in the Project file.

8.9 Wolf Creek Stations

8.9.1 Wolf Creek Discharge

Instantaneous discharge measurements were recorded by SCCD and WDEQ during sampling at Wolf Creek Upper and Lower stations. Summary statistics for discharges are presented in Table 8-1. Discharge measurements during the Project at the Upper station averaged 33.5 cfs, and 39.2 cfs at the Lower station. The geometric mean at the Upper station was 19.0 cfs, and 8.7 cfs at the Lower station. The average values were difficult to compare among Upper and Lower stations due to differing sampling frequency and lack of same day sampling on numerous occasions.

Daily discharge was also measured by WSBC from April through September at Wolf Creek USGS station 06299500 also known as SCCD monitoring station Wolf Creek Upper. Figure 8-4 illustrated the mean monthly discharge during the Project in comparison to the mean monthly discharge from 1982 through 1999. Discharge measurements were limited to these months to monitor available water supply for agricultural use.

Figure 8-22 illustrates discharge measured by SCCD and WDEQ at each station on the same day. Discharge data not measured at each station on the same day was excluded from Figure 8-22 because discharge may vary daily precluding valid comparison among stations.

Discharge during the primary low-irrigation months (April, May and September) seldom increased from the Upper station to the Lower station. Increase in discharge from upstream to downstream is normal in unregulated stream systems due to increased drainage area. Overall discharge measured on all comparable days was reduced by about fifty (50) percent (Table 8-2). Discharge was normally reduced from the Upper station to the Lower station during the primary irrigation months (June, July and August) (Figure 8-22). Discharge was reduced by about sixty-eight (68) percent during the irrigation season.

Wolf Creek Lower had a discharge less than 4 cfs on 24 percent of the sampling days, the majority occurring during the irrigation season. The lowest discharge measurement at the Lower station was less than 1 cfs on consecutive sampling days from July 20, 1999 to August 18, 1999.

The contribution of discharge from Wolf Creek to the Tongue River was estimated by comparing discharge at the Wolf Creek Lower station to discharge measured at the Tongue River Lower station on the same day. This comparison revealed that Wolf Creek contributed an estimated 8.9 percent of the Tongue River Lower discharge (Appendix Table M-2). This suggested that potential pollutants entering the Tongue River from Wolf Creek may have little effect on the Tongue River due to dilution effects. The percent contribution of discharge to the Tongue River was higher for Wolf Creek than for any other tributary within the Project area.

8.9.2 SCCD and WDEQ Wolf Creek Temperature Monitoring

Summary statistics for instantaneous water temperature measurements by SCCD and WDEQ at Wolf Creek Upper and Lower stations are presented in Table 8-44. Water quality data for the Upper station is presented in Appendix Table B-20 and data for the Lower station in Appendix Tables B-21 and B-23. Water quality data collected by WDEQ in 1995 for a single sample event at a station identified as Wolf Creek - Upper (Berry's) is presented in Appendix Table B-22.

Average water temperature during the Project was lowest at the Upper station (10.3^0C) and slightly higher at the Lower station (13.4^0C). Maximum water temperature recorded at the Upper station was 16.3^0C and the maximum water temperature recorded at the Lower station was 22.0^0C. Based on instantaneous measurements there were no exceedences of the Wyoming water quality standard for temperature. However, as indicated in Section 8.5.2, sampling conducted by SCCD and WDEQ did not occur during the time of day required to detect maximum daily water temperature. Maximum daily temperature was projected at each station during the months of June, July, August and September as described in Section 8.5.3. Projected maximum daily water temperature indicated no exceedence of the Wyoming water quality standard for water temperature at the Upper station. However, the standard for water temperature was probably exceeded on nine (9) different days at the Lower station. This represented water temperature exceedences on about twenty-four (24) percent of total sampling days. All projected water temperature exceedences occurred during the months of July and August usually when stream discharge was relatively low. This observation indicated the need for future continuous water temperature monitoring during warmer summer month at the Lower station to determine frequency of occurrence for exceedence of the water temperature standard.

8.9.3 SCCD and WDEQ Wolf Creek pH Monitoring

Summary statistics for instantaneous pH measurements by SCCD and WDEQ at Wolf Creek Upper and Lower stations are presented in Table 8.45. The pH varied little among the Upper and Lower stations. The average and geometric mean for pH during this Project was 7.8 SU at the Upper station and 8.0 SU at the Lower station. The maximum pH recorded at the Upper station during the Project was 8.4 SU, and 8.5 SU at the Lower station. The minimum pH was 6.9 SU at the Upper station, and 7.3 SU at the Lower station. All pH measurements were within Wyoming water quality standards because measurements were within the range from 6.5 SU to 9.0 SU.

8.9.4 SCCD and WDEQ Wolf Creek Specific Conductivity Monitoring

Summary statistics for specific conductivity are presented in Table 8-46. Average conductivity during the Project was 198 umhos/cm at the Upper station, and 429 umhos/cm at the Lower station. The geometric mean was 179 umhos/cm at the Upper station, and 388 umhos/cm at the Lower station. Conductivity values at the Upper station ranged from a low of 78 umhos/cm to a high of 635 umhos/cm, and from a low of 144 umhos/cm to a high of 964 umhos/cm at the Lower station. The average increase in conductivity from the Upper station to the Lower station was 117 percent. The increase in conductivity between stations using the geometric mean was 101 percent. The increase in conductivity was higher than expected and suggested that irrigation return may be affecting conductivity at the Lower station especially during periods of low discharge. Although there was no Wyoming water quality standard for conductivity, values were generally considered low to moderate and within the range required for support of aquatic life.

The strong association between conductivity and stream discharge observed at other sampling stations in the Project area was not present at either Wolf Creek station. The correlation coefficient between conductivity and discharge at the Upper station was -0.190, and +0.054 at the Lower station (Appendix Table L-3). Neither correlation coefficient was statistically significant (P>0.05).

8.9.5 SCCD and WDEQ Wolf Creek Dissolved Oxygen Monitoring

SCCD initiated monitoring for dissolved oxygen (DO) in 1999. WDEQ conducted monitoring for DO once annually usually in October. Summary statistics for DO are presented in Table 8-47. DO was slightly lower at the Lower station when compared to DO at the Upper station. Average DO during the Project was 10.0 mg/l at the Upper station and 9.5 mg/l at the Lower station. DO values ranged from 8.4 mg/l to 11.6 mg/l at the Upper station, and from 8.1 mg/l to 11.3 mg/l at the Lower station.

There were no exceedences of the Wyoming water quality standard for DO because no DO values were less than 5 mg/l. The lowest DO value recorded during the Project was 8.1 mg/l measured by SCCD at the Lower station on September 15, 1999. The DO concentrations were sufficient to support diverse populations of aquatic organisms and fish indicating full support for aquatic life use for this physical parameter.

8.9.6 SCCD and WDEQ Wolf Creek Turbidity Monitoring

Summary statistics for turbidity are presented in Table 8-48. The average difference in turbidity between Upper and Lower stations during the Project was higher than expected even when considering natural increases in turbidity normally observed along the longitudinal gradient in streams. Average turbidity was 4.7 NTU at the Upper station and 21.0 NTU at the Lower station. The geometric mean was 2.4 NTU at the Upper station and 13.2 NTU at the Lower station. Turbidity values at the Upper station ranged from 0.5 NTU to 20.0 NTU, and from 1.9 NTU to 125 NTU at the Lower station. The increase in turbidity from the Upper station to the Lower station was considered relatively high and in excess of the Wyoming water quality standard.

Turbidity values were positively associated with discharge at the Upper station and at the Lower station. There was a significant positive relationship such that turbidity values increased as discharge increased. The correlation coefficient between turbidity and discharge at the Upper station was +0.582 ($P<0.01$), and +0.454 ($P<0.01$) at the Lower station. R-squared values for the regression analyses were 34.5 percent at the Upper station and 51.8 percent at the Lower station (Appendix Tables L-5 and L-6). Because of the association between turbidity and discharge, lower turbidity values were normally recorded during periods of lower discharge (prior to and after spring runoff) in early April, September and October and higher turbidity values were generally recorded during periods of higher discharge and spring runoff in latter April, May and early June.

The average and geometric mean increase in turbidity between Upper and Lower stations was 16.3 NTU and 10.8 NTU, respectively. This represented an exceedence of the Wyoming water quality standard for turbidity because increase in turbidity was greater than 10 NTU allowed for Class 2 cold water, water bodies. Additional sampling stations are required for future turbidity sampling to identify the source(s) for turbidity affecting the Lower station.

8.9.7 SCCD and WDEQ Wolf Creek Fecal Coliform Bacteria Monitoring

Summary statistics for fecal coliform bacteria are presented in Table 8-49. The average for fecal coliform bacteria at the Upper station was 11 per 100ml, and 148 per 100ml at the Lower station. The geometric mean for fecal coliform bacteria at the Upper station during the Project was 5 per 100ml, and 57 per 100ml at the Lower station. The geometric mean is a logarithmic transformation of data and provided a more reliable estimate of the mean by smoothing extreme values due to high variability among fecal coliform measurements. Fecal coliform bacteria concentration at the Upper station ranged from 1 per 100ml to 41 per 100ml. The number of fecal coliform bacteria was quite low indicating that the primary land uses (wildlife, recreation and limited seasonal livestock grazing) in the vicinity of the Upper station were not significant sources of fecal coliform bacteria. Fecal coliform bacteria concentration at the Lower station ranged from 1 per 100ml to 700 per 100ml.

The was no exceedence of the Wyoming water quality standard for fecal coliform bacteria at the Upper station. The geometric mean of five (5) samples collected during the Recreation Season in 1999 at the Upper station was 17 per 100ml which was low. There was no single sample collected in excess of 400 per 100ml since the maximum level recorded during the Project was 41 per 100ml (collected July 28, 1999).

Fecal coliform bacteria levels at the Lower station exceeded the Wyoming water quality standard for fecal coliform bacteria. The geometric mean of five (5) samples collected during the Recreation Season in 1999 was 147 per 100ml which did not exceed the standard of 200 per 100ml. However, samples collected on June 16, 1997, June 19, 1998 and April 21, 1999 had fecal coliform levels in excess of 400 per 100ml that exceeded the Wyoming water quality standard for fecal coliform bacteria. The exceedence of the standard indicated remedial measures were required to lower fecal coliform levels to bring the Lower station into compliance with the Wyoming water quality standard.

There was no exceedence of the fecal coliform standard in 1996 because of apparent low sampling frequency (N = 3 total samples). Exceedences in 1997, 1998 and 1999 were due to single samples that exceeded the standard of 400 per 100 ml. Fourteen percent of samples exceeded the standard during combined sampling in 1997, 1998 and 1999. SCCD increased the sampling frequency in 1999 from monthly to five (5) samples within a 30 day period during the Recreation Season to provide a better estimate of bacteria contamination and allow direct comparison to the Wyoming water quality standard for fecal coliform bacteria. Some sampling sites within the Project area exceeded Wyoming fecal coliform standards only in 1999. It appeared the increased sampling frequency at some stations in 1999 increased the probability for detection of fecal coliform levels in excess of the Wyoming fecal coliform standard. Extensive discussion related to the effects of sampling frequency for reliable estimates of fecal coliform bacteria is presented in Section 8.11.1.

8.9.8 SCCD Tongue River Pesticide and Herbicide Monitoring

SCCD conducted pesticide and herbicide sampling at the Wolf Creek Lower station on August 21, 1996. Analytical results are presented in Appendix Table H-1. Sampling occurred once during the Project due to the high cost associated with sample analyses and negative results from this 1996 sampling event.

A total of nineteen (19) organochlorine pesticides and ten (10) chlorinated herbicides were sampled. Analytical results found no detectable (less than the minimum detection limit) concentrations for herbicides or pesticides. This observation indicated that no evidence of herbicide and pesticide contamination was present in the Wolf Creek water column during this sampling event.

8.9.9 SCCD and WDEQ Wolf Creek Nitrate Nitrogen Monitoring

Total nitrate samples were collected infrequently (N = 3 total samples) at the Wolf Creek Upper station due to Project monitoring budget constraints. Sampling for nitrate nitrogen was concentrated at the Lower station because potential nutrients entering the Tongue River could be best estimated at this station. Summary statistics for nitrate nitrogen are presented in Table 8-50. Average nitrate nitrogen concentrations were low at each station during the Project. The average nitrate concentration at the Upper station was .001 mg/l, and .022 mg/l at the Lower station. Nitrate values at the Upper station based on four (4) samples (including one sample collected by WDEQ in 1995) ranged from .010 mg/1 to .170 mg/l and the range at the Lower station was from .001 mg/l to .130 mg/l.

Average and maximum nitrate values at the Upper and Lower stations were considered low.

Eighteen (18) out of twenty-seven (27) total samples collected at the Upper station were below the minimum detection limit of 0.01 mg/l. Nitrate concentration was well below the Wyoming water quality standard and drinking water human health standard of 10 mg/l for Class 2 surface waters (WDEQ, 1998). Data for nitrate nitrogen indicated that nitrate concentration in Wolf Creek was less than the background concentration of nitrate (about 0.60 mg/L) found in streams in undeveloped areas throughout the United States (USGS, 1999). These observations indicated that nitrate nitrogen was not present in Wolf Creek in concentrations that could pose a human health threat or negatively affect aquatic populations by indirect effects caused by eutrophication. Full support for all Wyoming beneficial uses applicable to nitrate was indicated.

8.9.10 SCCD and WDEQ Wolf Creek Total Phosphorus Monitoring

Total phosphorus samples were collected infrequently by SCCD (N = 3 total samples) at the Wolf Creek Upper station due to Project monitoring budget constraints. WDEQ collected the majority of total phosphorus samples during annual bioassessments. Summary statistics for total phosphorus are presented in Table 8-51. These statistics were based on "censored" values because analytical results from all samples were less than the minimum detection limit (minimum detection limit was 0.10 mg/l for WDEQ analytical method; 0.05 mg/l for SCCD analytical method). The minimum detection limit for the WDEQ analytical method did not provide adequate data needed to address the recommended water quality standard for total phosphorus in water bodies draining to a lake or reservoir (0.05 mg/l; EPA, 1977). Data were thus censored to provide an estimate that could be related to the recommended EPA standard of 0.05 mg/l.

Average total phosphorus concentrations were low at each station during the Project. The average total phosphorus concentration at the Upper station based on three (3) total samples was .018 mg/l, and .027 mg/l at the Lower station. Total phosphorus concentrations at the Upper station ranged from .001 mg/1 to .050 mg/l and from .003 mg/l to .090 mg/l at the Lower station. Average and maximum total phosphorus values at the Upper and Lower stations were based on a low total number of samples. However, total phosphorus values should be considered low. Wyoming has not established surface water quality standards for phosphorus. U.S. EPA (1977) recommended that total phosphorus concentration should not exceed 0.05 mg/l in a stream that enters a lake or reservoir (e.g. Tongue River Reservoir) to prevent development of nuisance algal and plant populations. Mackenthun (1973) suggested a target phosphorus level of less than 0.10 mg/l for streams that did not directly enter lakes or reservoirs. USGS (1999) provided recent information from nationwide NAWQA monitoring and assessment and reported that national background concentrations for total phosphorus from streams in undeveloped (reference - like) areas was about 0.10 mg/L. Because the EPA goal was not attainable, SCCD adopted the finding by USGS for its interpretation of total phosphorus data collected during this Project.

Using the value of $\leq$0.10 mg/l as a target for total phosphorus concentration, no significant amount of total phosphorus was identified in a single sample collected at Wolf Creek stations during this

Project. However, sampling frequency was low at the Upper (N = 3 samples) and Lower station (N = 6 samples) over a four year period and sampling generally occurred during the fall low base flow period when total phosphorus concentration is normally lower. Additional sampling was required to provide a reliable estimate of total phosphorus concentration in Wolf Creek.

8.9.11 WDEQ Wolf Creek Monitoring for Additional Water Chemistry Parameters

WDEQ collected samples for additional monitoring parameters during annual monitoring in 1995 at a station downstream from the SCCD Wolf Creek Upper station. This station was identified as Wolf Creek - Berry's and was located about 3/4 to 1 mile downstream of the Soldier Creek Road bridge crossing. WDEQ also conducted annual monitoring at the Wolf Creek Lower station from 1996 through 1999 in conjunction with benthic macroinvertebrate sampling and habitat assessment. Summary statistics are presented in Table 8-52.

Alkalinity at the Wolf Creek - Berry station based on a single sample was 190 mg/l. Average alkalinity at the Lower station based on four (4) samples was 244 mg/l. The geometric mean was 243 mg/l. The range was from 230 mg/l to 275 mg/l. There was no Wyoming water quality or EPA standard to compare alkalinity values to, but data indicated that water was generally productive for aquatic life and was capable of withstanding sudden changes in pH due to inputs from NPS sources.

Total chloride concentration was low at each station during the limited sampling. There were no samples collected at either Berry's station or the Lower station that had total chloride concentrations greater than 5 mg/l. Total chloride values were well within WDEQ and EPA water quality standards indicating full support for Wyoming beneficial uses applicable to chloride.

Total sulfate concentration was high at Berry's station based on the single sample in 1995. Total sulfate concentration was 779 mg/l which exceeded the WDEQ standard (for groundwater use) and the EPA secondary drinking water standard of 250 mg/l. The EPA standard was not enforceable. Sulfate concentrations were lower at the Lower station. Average total sulfate concentration based on four (4) total samples at the Lower station was 83 mg/l. The range in total sulfate was from 67 mg/l to 101 mg/l. These values were considered moderate and slightly higher than expected even considering samples were collected in the fall during lower base flow when ion concentrations were normally highest. Total sulfate values at the Lower station were within WDEQ standards (for groundwater use) and the EPA secondary drinking water standard of 250 mg/l. This observation indicated full support at the Lower station for Wyoming beneficial uses applicable to sulfate.

Although the high total sulfate concentration at the Berry station was based on a single sample collected during the low flow period, it suggested there was a potential water quality concern that required further investigation. This area may have irrigation return questions affecting sulfate concentration. Because no water quality problems were detected at the Wolf Creek Upper station during this Project, a potential future monitoring station may be sited in the vicinity of the Soldier Creek bridge crossing.

Hardness concentration was relatively high at each station and may be due to the natural limestone geology that predominated much of the upstream Wolf Creek watershed. Hardness at the Berry station based on a single sample was 264 mg/l. Average hardness at the Lower station was 293 mg/l. The range in hardness at the Lower station was from 251 mg/l to 334 mg/l. Water at each station may be termed hard based on the classification found in Table 6-2. There were no Wyoming or EPA water quality standards for hardness, but observed values suggested partial support of the Wyoming beneficial use for Industrial use at the Lower station since some values were greater than 300 mg/l and treatment may be required before industrial use. More year around sampling was required to determine if the relatively high hardness values were due to seasonal sampling artifact during low flow periods, to natural limestone geology in the watershed, or to potential land use influence.

Total Suspended Solids (TSS) concentrations were low at the Berry station and relatively higher at the Lower station. Lower values appeared to be related to the fact that all samples were collected in the fall during lower flow when TSS values were normally lowest. The TSS concentration at the Upper station based on a single sample was <2 mg/l. Average TSS at the Lower station was 7 mg/l with a range from 5 mg/l to 10 mg/l. Results of limited TSS sampling conducted by WDEQ indicated that TSS values at the Lower station were generally higher than at most other stations within the Project area. This observation, coupled with high turbidity values, suggested sediment input from NPS sources was affecting the station. Turbidity should continue to be used as the indicator for TSS unless specific sediment loading questions arise.

8.9.12 SCCD and WDEQ Wolf Creek Benthic Macroinvertebrate Monitoring

SCCD and WDEQ did not sample for benthic macroinvertebrates at the Wolf Creek Upper station during the Project. WDEQ conducted a bioassessment in 1995 at a station identified as Wolf Creek - Berry's. This station was located about four (4) miles downstream from the Upper station (See Figure 5-5, Station Number 17). SCCD and WDEQ sampled benthic invertebrates at the Wolf Creek Lower station annually from 1996 through 1999.

Metric values for the single WDEQ sample collected from Wolf Creek - Berry's are presented in Appendix Table G-2. Metric values for samples collected at the Lower station are presented in Appendix Table G-2.

Lists of benthic taxa identified, density (number per square meter) of taxa and percent contribution of each taxon to the total benthic population are presented for each station in Appendix F. The taxa list for the Wolf Creek - Berry's station is presented in Appendix Table F-35. Taxa lists for the Lower station are presented in Appendix Tables F-36 through F-39.

Biological condition at the Wolf Creek - Berry's station using scoring criteria from the Wyoming Stream Integrity Index (WSII) from Stribling et al. (2000) was **very good** (Table 8-15). This observation indicated full support of aquatic life use and that biological condition was very good when compared to biological condition at other streams in the Northwestern Great Plains ecoregion of Wyoming. The very good biological condition rating was primarily due to the high number of total taxa (N = 41), number of Ephemeroptera (mayfly) taxa (N = 7), number of Plecoptera (stonefly) taxa (N = 5), percent contribution of Plecoptera to the total community (7 percent), number of Trichoptera (caddisfly) taxa (N = 7) and high number of scraper taxa (N = 7).

Grazing management changes implemented in 1994 at Wolf Creek upstream of this station appeared to have dramatic positive effects for habitat improvement (see Figure 6-13 and Figure 6-14). Habitat improvement is often noticeable in plains streams within one year after management changes are implemented. Although the very good biological condition rating was based on a single sampling event in 1995, the management changes continued through the end of this Project suggesting possible further improvement in biological condition. Further, equal or better management of water resources and habitat upstream of this station should result in continued full support of aquatic life use. SCCD water quality sampling at the Wolf Creek Upper station found good to excellent water quality capable of fully supporting aquatic life use. Fish population data in Section 8.9.14 further supports this observation indicating full support for aquatic life use.

Biological condition at the Wolf Creek Lower station using scoring criteria from the Wyoming Stream Integrity Index (WSII) from Stribling et al. (2000) was **good** during each year (Table 8-15). This observation indicated full support for aquatic life use each year. WSII total scores ranged from 62.3 in 1998 to 74.6 in 1999. The lower WSII score in 1998 was primarily due to the lack of Plecoptera (stoneflies) in the benthic community. Stoneflies were present in the benthic community during other years. Good biological condition was indicated by the high number of total taxa, Ephemeroptera taxa, Trichoptera taxa and number of scraper taxa. The high number of scraper taxa was interesting because sediment deposition was high at this station. It appeared that the high number of scraper taxa and percent contribution of scrapers to the total community (ranging from 27% in 1999 to 48% in 1996) was due to the large amount of macroscopic periphyton attached to the top and side of cobbles allowing scrapers adequate habitat and food source.

The benthic community was dominated by the riffle beetle *Microcylloepus*, the caddisflies *Hydropsyche* and *Helicopsyche borealis* and the mayflies *Baetis tricaudatus* and *Tricorythodes minutus* (Table 8-16). The dominant taxa were each generally warm water taxa. *T. minutus* was an indicator of sediment deposition (Winget and Mangum, 1991). Worms were relatively abundant during each year. There were 3, 8, 3 and 5 worm taxa collected in 1996, 1997, 1998 and 1999, respectively. Percent contribution of worms to the total benthic community ranged from one (1) percent in 1996 to eleven (11) percent in 1997. The number and percent of worms were considered low to moderate for Wyoming plains streams. No *Tubifex tubifex* worms were identified from samples indicating low probability for the occurrence of whirling disease. The increased density of worms (Oligochaeta) may be associated with organic pollution (Klemm, 1985), pollution from feedlots (Prophet and Edwards, 1973), and pollutants contained in urban storm water runoff (Lenat et al., 1979; Lenat and Eagleson, 1981). The number of worm taxa and percent contribution did not indicate a severe pollution problem, but rather a low to moderate amount of pollution indicative of animal waste from possible agricultural and wildlife sources. Urban and rural residential land use influence were generally absent at this station. This observation was supported by the violation of the Wyoming water quality standard for fecal coliform bacteria. Further benthic macroinvertebrate monitoring is recommended to track this indicator assemblage as fecal coliform bacteria is reduced through management changes, land treatments and BMP implementation.

8.9.13 SCCD and WDEQ Wolf Creek Habitat Assessment

Qualitative habitat assessments were conducted once by WDEQ in 1995 at the Wolf Creek - Berry's station and annually by SCCD and WDEQ from 1996 through 1999 at the Lower station. Because habitat assessments were subjective, SCCD used caution by providing a conservative interpretation of data.

The total habitat score based on the single 1995 assessment at the Wolf Creek - Berry station was 169 (Table 8-53). The score indicated good to excellent habitat quality. Percent fines (silt and sand) comprising the stream substrate was low (sand = 3 percent, silt = 0 percent) (Table 8-54). The weighted embeddedness (silt covering cobble and gravel substrate) value was 90. This value indicated that a small percentage of cobble and gravel was covered by silt. Riparian condition indicator parameters including bank vegetation stability, riparian zone width and disruptive pressures scored high. However, bank stability scored lower because unstable banks were relatively common. Grazing management changes implemented in 1994 appeared to benefit the riparian condition indicator parameters.

Habitat assessment scores were lower at the Wolf Creek Lower station when compared to Berry's station. Total habitat scores varied from 110 in 1996 to 142 in 1998 (Table 8-53). The reduction in habitat score from Berry's station to the Lower station was due to lower scores for instream cover, embeddedness, pool riffle ratio and width depth ratio. The lower scores for these parameters was related to silt deposition on cobble and gravel, lower discharge and apparent habitat alteration by historic channelization. The low riparian zone width was related to down cutting of the channel and channelization that combined to reduce the size of the riparian zone. Other riparian indicators including bank vegetation protection and disruptive pressures scored high because this stream reach was fenced. Banks were generally stable and scored moderate to high.

The semi-quantitative stream substrate particle size distribution differed between Berry's and the Lower station. Percent cobble was 67 percent at Berry's and the average composition of cobble at the Lower station was 80 percent. Silt deposition was not detected at Berry's and silt deposition was low at the Lower station averaging only 1 percent of the total stream substrate. Sand deposition was minimal at Berry's (3 percent) and at the Lower station (2 percent). The low degree of silt and sand deposition at each station indicated no large scale disruption within the watershed that could contribute sand and silt to the stream channel.

Embeddedness (silt covering cobble and gravel) was low at Berry's and high the Lower station. The weighted embeddedness value at Berry's was 90 and the average weighted embeddedness at the Lower station was about 28. The low value at the Lower station indicated that although there were no deposits of sediment in the channel, the majority of cobble and gravel substrate was covered or surrounded by fine silt. Weighted embeddedness values at the Lower station ranged from 21.2 (almost complete silt coverage) in 1996 to 39.0 in 1999. Silt deposition is controlled by the amount of silt contained in the water mass and by the current velocity. Silt deposition will normally increase as current velocity is decreased provided the water column contains significant fine sediment.

The average current velocity measured at Berry's was 2.3 feet per second (fps) and 1.4 fps at the Lower station (Table 8-54). The lower average current velocity at the Lower station combined with high turbidity appeared to be factors related to the higher embeddedness values because lower current velocity apparently allowed entrained sediment to settle out of the water column.

High embeddedness at the Lower station did not appear to affect the benthic macroinvertebrate community because macroscopic periphyton was abundant on cobble and gravel thus providing adequate alternative habitat to cobble and gravel themselves. However, reduction in turbidity and increase in average discharge should promote gains in biological condition beyond the current good rating.

8.9.14 WGFD Wolf Creek Fish Population Monitoring

WGFD conducted historic and current monitoring of fish populations at various locations within the Wolf Creek watershed over the period from 1959 through 1997. Approximate location of sampling stations are illustrated in Figure 5-1 and Figure 5-2. Results from twelve (12) sampling events are presented in Appendix Tables C-23 through C-34.

Most historic fish sampling occurred at upper stations near Eaton's Ranch, middle stations near the Wolf Creek Ranch and lower stations at Joe Pattersons. Brown trout was the most abundant game fish collected in the watershed followed by rainbow trout. No brook trout and whitefish were reported during fish population sampling within the watershed. Yellow perch and stonecat were collected in 1959 at Wolf Creek Station 1, believed to be near or downstream from the current

SCCD Wolf Creek Lower monitoring station. These two species have not been reported in Wolf Creek since then, but the lower Wolf Creek reaches have been sampled infrequently. The majority of historic sampling in the upper reaches of Wolf Creek identified only game fish and seldom non-game fish. This observation may be due to sampling artifact since early WGFD surveys appeared to concentrate on collection of game species with less effort directed toward capture of non-game species.

Non-game fish species collected in the Wolf Creek watershed included longnose dace, mountain sucker, longnose sucker, white sucker, northern redhorse and creek chub. Longnose Dace appear to be the most abundant non-game fish species in the Tongue River watershed and are distributed throughout the Project area. Longnose dace are widespread in North America and is a native species in Wyoming and common in all but the Green and Little Snake River drainages (Baxter and Simon, 1970). The remaining non-game species were collected in the middle to lower Wolf Creek reaches where conditions were more favorable for their existence. Warmer water temperature, higher turbidity, higher substrate embeddedness and lower summer discharge presented unfavorable conditions for trout species, but more suitable conditions for non-game species.

The only WGFD fish sampling that occurred during this Project was on October 6, 1997 at a location identified as Wolf Creek - Bob Berry's (Appendix Table C-34). This location was near the WDEQ 1995 bioassessment station identified as Wolf Creek - Berry's. The WDEQ bioassessment indicated biological condition was very good based on evaluation of the benthic macroinvertebrate community. WGFD sampling found large numbers of brown trout, one (1) rainbow trout, longnose suckers and white suckers. Sampling indicated that water quality and habitat quality were suitable to maintain a large population of brown trout and other game and non-game fish. Full support for aquatic life use was indicated.

Instream flow studies conducted by WGFD in this vicinity indicated that the lowest summer flow that would maintain habitat quality at its present level between July 1 and September 30 was 8.0 cfs (Annear and Dey, 1998). The flow recommendation to maintain existing physical habitat for brown trout spawning was 7.0 cfs. They reported that the instream flow to maintain existing physical habitat for rainbow trout spawning was 20.0 cfs.

Extrapolating results from the instream flow study to the discharge data collected by SCCD at the Wolf Creek Lower station indicated that instream flow requirements for trout were not achieved due to low summer discharge caused by dewatering. Discharge was less than 8.0 cfs during eleven (11) out of fourteen (14) sampling days (79%) from July 1 through September 30. High projected summer water temperature, high turbidity and substrate embeddedness (Section 8.9.13) probably limited trout habitat, survival and recruitment in the Lower reach.

8.10 Five Mile Creek Lower Station

8.10.1 Five Mile Creek Discharge

Instantaneous discharge measurements were recorded by SCCD and WDEQ during sampling at the Five Mile Creek Lower station. Summary statistics for discharge are presented in Table 8-1. The average and geometric mean discharge during the Project was 9.8 cfs and 4.7 cfs, respectively. Discharge ranged from 0.1 cfs to 52.0 cfs. Figure 8-23 illustrates discharge measurements recorded during the Project.

Discharge generally followed the normal seasonal discharge pattern observed in the Tongue River with the exception of generally greater fluctuation in discharge after spring runoff. These fluctuations were apparently related to diversion of water from Columbus Creek into the Five Mile watershed and controlled release of water from the Five Mile Reservoir for irrigation use.

Five Mile Creek is highly regulated because the primary source of water in the channel originates from Columbus Creek via the Five Mile Ditch. Springs exist in Five Mile Creek, but are believed to not provide adequate flow to sustain game fish populations. The extent to which the springs recharge due to irrigation water influence is unknown. The majority of the length of Five Mile Creek was probably ephemeral prior to its use as an irrigation water conduit in the 1880's. As such, its entire length should be classified by WDEQ as a Class 3 water body. Five Mile Creek is currently not classified by WDEQ, but assumes the classification of the Tongue River (Class 2 cold water) due to the "tributary rule" (WDEQ, 1999). The following three (3) decision criteria are used to determine whether a water body is Class 2 or Class 3:

1. Be presently supporting game fish; or

2. Have the hydrologic and natural water quality potential to support game fish; or

3. Include nursery areas or food sources for game fish.

Criteria number 1 could not be determined because there has been no fish sampling in Five Mile Creek. It is possible that cold water and warm water fish species may seasonally migrate into Five Mile Creek, but fish survival is suspect after irrigation releases are reduced. Criteria number 2 could not be met because Five Mile Creek does not appear to have the hydrologic potential to support either cold water or warm water game fish. However, it is probable that Five Mile Creek could support non-game fish in the isolated pools that were probably characteristic of the Creek (and other ephemeral plains streams) prior to development of irrigation in the watershed. The other element for Criteria number 2, natural water quality potential to support game fish, could not be determined because springs were not sampled for water quality nor could it be determined if existing springs were natural or if they formed due to irrigation water recharge. Criteria number 3 could not be met because lack of perennial discharge would preclude adequate nursery areas for either cold water or warm water game fish. The other element for Criteria 3, food sources for game fish, is difficult to link to nursery areas because food sources for fish may develop in stagnant pools (i.e. pollution tolerant midge larvae (Chironomidae), mosquito larvae (Culicidae) and worms (Oligochaeta) that are unsuitable as nursery areas for game fish. Because of these factors, SCCD proposes that Five Mile Creek be classified as a Class 3 water body for its entire length. Because this proposal does not reclassify the stream, a Use Attainability Analysis would not be required because Five Mile Creek at this time, is not classified nor listed in WDEQ (1998). SCCD will contact WDEQ for guidance to designate Five Mile Creek as a Class 3 water body.

The Five Mile Creek Lower station had a discharge less than 1 cfs on three (3) days which represented about 9 percent of all sampling days. This low discharge value probably represented an estimate for base flow under the current water management system in the Five Mile Creek watershed.

The contribution of discharge from Five Mile Creek to the Tongue River was estimated by comparing discharge at the Five Mile Creek Lower station to discharge measured at the Tongue River Lower station on the same day. This comparison revealed that Five Mile Creek contributed an estimated 1.6 percent of the Tongue River discharge (Appendix Table M-2). This observation indicated that potential pollutants entering the Tongue River from Five Mile Creek would have an insignificant effect on Tongue River water quality.

8.10.2 SCCD and WDEQ Five Mile Creek Temperature Monitoring

Summary statistics for instantaneous water temperature measurements by SCCD and WDEQ at the Five Mile Creek Lower station are presented in Table 8-44. Water quality data for the Lower station is presented in Appendix Tables B-24 and B-25.

The average and geometric mean water temperature during the Project was 14.1^{0}C, and 12.6^{0}C, respectively. The maximum water temperature was 22.6^{0}C and the minimum water temperature was 0.7^{0}C. Highest water temperatures occurred during the summer months of June through August when ambient air temperature was highest. Lowest water temperatures generally occurred during April, May or October when discharge was dominated by snowmelt runoff or seasonally cooler ambient air temperatures.

Based on instantaneous measurements there were no exceedences of the Wyoming water quality standard for water temperature. However, as indicated in Section 8.5.2, sampling conducted by SCCD and WDEQ did not occur during the time of day required to detect maximum daily water temperature. Maximum daily water temperature was estimated during the months of June, July, August and September as described in Section 8.5.3. Projected maximum daily water temperature indicated that there were probably nine (9) exceedences of the Wyoming water quality standard for water temperature during this Project. The number of exceedences represented about 24 percent of total sampling days. Higher water temperatures were not necessarily associated with lower discharge as was often observed at other Tongue River and tributary stations. Some of the projected higher water temperatures were recorded when discharge ranged from about 8 cfs to 46 cfs. This observation suggested that warm water releases from the upstream Five Mile Creek Reservoir may significantly affect water temperature in Five Mile Creek. These observations indicated the need for future continuous water temperature monitoring during warmer summer months at the Lower station to determine frequency of occurrence for exceedence of the Wyoming water quality standard for water temperature. The SCCD proposed stream classification would increase the water temperature standard to 32.2^0C for a Class 3 water body (WDEQ, 1998).

8.10.3 SCCD and WDEQ Five Mile Creek pH Monitoring

Summary statistics for instantaneous pH measurements by SCCD and WDEQ at the Five Mile Creek Lower station are presented in Table 8-45. The average and geometric mean for pH during this Project was 8.0 SU. The maximum pH recorded during the Project was 8.5 SU and the minimum pH was 7.6 SU. There were no samples less than 6.5 SU or greater than 9.0 SU indicating pH was within the Wyoming water quality standard for pH.

8.10.4 SCCD and WDEQ Five Mile Creek Specific Conductivity Monitoring

Summary statistics for specific conductivity are presented in Table 8-46. The average and geometric mean for conductivity during the Project was 819 umhos/cm and 742 umhos/cm, respectively. Conductivity values ranged from a low of 157 umhos/cm to a high of 1824 umhos/cm. Conductivity at Five Mile Lower was compared to conductivity at the Columbus Creek Upper station because Columbus Creek was the source for the majority of water in Five Mile Creek. The average increase in conductivity from Columbus Creek Upper to Five Mile Creek Lower station was 103 percent. The increase in conductivity between stations using the geometric mean was 85 percent. The increase in conductivity was higher than expected and suggested that irrigation return and water released from the irrigation storage reservoirs may be affecting conductivity at the Five Mile Creek Lower station especially during periods of low discharge. Although there was no Wyoming water quality standard for conductivity, values were generally considered low to moderate and within the range required for support of aquatic life.

Conductivity values were affected by stream discharge, but not to the extent that discharge affected conductivity at most other stations in the Project area. The association between conductivity and discharge was present and inverse such that as discharge increased, conductivity decreased. The correlation coefficient between conductivity and discharge at the Five Mile Creek Lower station was -0.370 (Appendix Table L-3). The correlation coefficient was significant ($P<0.05$) indicating there was less than a five (5) percent chance that the association was due to random chance alone. However, the R-Squared value for the correlation was low (13.7%)

indicating that discharge accounted for about 14 percent of the variability observed in conductivity. Weaker correlation coefficients between discharge and conductivity were observed at Smith Creek Upper and Lower, Columbus Creek Lower and Wolf Creek Lower stations. Three of the four stations with lower correlations between conductivity and discharge were highly regulated and their flows appeared to consist of primarily irrigation return during at least a portion of the sampling year.

8.10.5 SCCD and WDEQ Five Mile Creek Dissolved Oxygen Monitoring

SCCD initiated monitoring for dissolved oxygen (DO) in 1999. WDEQ conducted monitoring annually usually in October. Summary statistics for DO are presented in Table 8-47. Average DO during the Project was 9.4 mg/l. DO values ranged from 7.9 mg/l to 11.2 mg/l.

There were no exceedences of the Wyoming water quality standard for DO because no DO values were less than 5 mg/l. The lowest DO value recorded during the Project was 7.9 mg/l measured by WDEQ on October 14, 1998. DO concentrations were sufficient to support diverse populations of aquatic organisms and fish indicating full support for aquatic life use for this physical parameter.

8.10.6 SCCD and WDEQ Five Mile Creek Turbidity Monitoring

Summary statistics for turbidity are presented in Table 8-48. Average turbidity measurements during the Project were high when compared to turbidity at the Columbus Creek Upper station that represented the primary source for water in Five Mile Creek. Average turbidity was 39.4 NTU at Five Mile Lower and 4.8 NTU at Columbus Creek Upper (Table 8-39). The geometric mean was 26.5 NTU at Five Mile Lower and 2.3 NTU at Columbus Creek Upper. Turbidity values at Five Mile Creek Lower ranged from a low of 3.8 NTU to 155 NTU. Turbidity values greater than or equal to 15 NTU (maximum Columbus Creek Upper station value; see Table 8-39) were recorded on twenty-seven (27) different sampling dates representing 72 percent of total sampling events. This observation indicated that there was a significant change in turbidity after Columbus Creek water was diverted into Five Mile Creek.

Turbidity values were strongly associated with discharge. There was a significant positive relationship such that turbidity values increased as discharge increased. The correlation coefficient between turbidity and discharge at the Five Mile Creek Lower station was +0.673 ($P<0.01$). The R-squared value for the regression analysis was 45.3 percent (Appendix Table L-6) indicating that about 45 percent of the variability in turbidity values during the Project was attributed to discharge. Because of the association between turbidity and discharge, lower turbidity values were generally recorded during periods of lower discharge (prior to and after spring runoff) in early April, September and October and higher turbidity values were generally recorded during periods of higher discharge during spring runoff in latter April, May and June. However, turbidity values greater than 30 NTU were sometimes measured when discharge was low during the summer. A portion of the higher turbidity may be related to the natural geology and soil type upstream of this station, but frequent higher turbidity strongly suggested sediment input from unknown upstream sources. This scenario suggested influence from irrigation return water and potential influence from variable fluctuating discharge in response to irrigation demand may resuspend sediment deposited on the stream bed.

The average increase in turbidity between the Five Mile Creek Lower station and Columbus Creek Upper station (the control station) was 34.6 NTU. The increase in turbidity represented an exceedence of the Wyoming water quality standard because an increase up to 10 NTU is allowed for Class 2 cold water, water bodies. An increase in turbidity up to 15 NTU is allowed for Class 3 water bodies, which SCCD proposed for classification. Additional sampling stations are required upstream for future turbidity sampling to identify the source(s) for turbidity affecting the Five Mile Creek Lower station.

8.10.7 SCCD and WDEQ Five Mile Creek Fecal Coliform Bacteria Monitoring

Summary statistics for fecal coliform bacteria are presented in Table 8-49. The geometric mean for fecal coliform bacteria at the Five Mile Creek Lower station during the Project was 185 per 100ml. The geometric mean is a logarithmic transformation of the raw data and provided a more reliable estimate of the mean by smoothing extreme values due to high variability commonly observed for fecal coliform sampling.

Fecal coliform bacteria concentration ranged from 1 per 100ml to 9100 per 100ml. The median fecal coliform bacteria concentration was 190 per 100 ml. The median statistic value is the number at which 50 percent of the observed values are above and 50 percent of the observed values are below.

Fecal coliform bacteria levels at the Five Mile Creek Lower station exceeded the Wyoming water quality standard for fecal coliform bacteria. The geometric mean of five (5) samples collected during the Recreation Season in 1999 was 565 per 100ml which exceeded the standard of 200 per 100ml. During the Project eight (8) samples had fecal coliform levels in excess of 400 ml representing thirty (30) percent of total samples. The exceedence of the standard indicated remedial measures were required to lower fecal coliform levels to bring the Lower station into compliance with the Wyoming water quality standard. The fecal coliform standard is the same for Class 2 and Class 3 water bodies, thus the proposed classification for Five Mile Creek (Class 3) will have no effect upon the effective numeric fecal coliform standard.

There were exceedences of the fecal coliform standard in 1997, 1998 and 1999, but none in 1996. Based on fecal coliform bacteria numbers in 1997 through 1999, it was probable that fecal coliform bacteria levels also exceeded the Wyoming water quality standard in 1996. The lack of an exceedence in 1996 was probably related to the low number of samples collected (N = 3).

SCCD increased the sampling frequency in 1999 from monthly to five (5) samples within a 30 day period during the Recreation Season to provide a better estimate of bacteria contamination and allow direct comparison to the Wyoming water quality standard for fecal coliform bacteria. Some sampling stations within the Project area exceeded Wyoming fecal coliform standards only in 1999. It appeared that the increased sampling frequency in 1999 compared to previous years increased the probability for detection of fecal coliform levels in excess of the Wyoming fecal coliform standard. Extensive discussion related to this finding is presented in Section 8.11.1.

8.10.8 SCCD Five Mile Creek Pesticide and Herbicide Monitoring

SCCD conducted pesticide and herbicide sampling at the Five Mile Creek Lower station on August 21, 1999. Analytical results are presented in Appendix Table H-1. Sampling occurred once during the Project due to the high cost associated with sample analyses and negative results from the 1996 sampling event.

A total of nineteen (19) organochlorine pesticides and ten (10) chlorinated herbicides were sampled. Analytical results found no detectable (less than the minimum detection limit) concentrations for herbicides or pesticides. This observation indicated that no evidence of herbicide and pesticide contamination was present in the Five Mile Creek water column during this sampling event.

8.10.9 SCCD and WDEQ Five Mile Creek Nitrate Nitrogen Monitoring

Summary statistics for nitrate nitrogen are presented in Table 8-50. Average nitrate nitrogen concentrations were high when compared to nitrate concentrations at other monitoring stations within the Project area. The average nitrate concentration at the Five Mile Creek Lower station was 0.526 mg/l. The geometric mean was 0.222 mg/l and the median was 0.260 mg/l. The range in nitrate values was from .005 mg/1 to 5.32 mg/l. Nitrate values of 1.32 mg/l and 1.18 mg/l were recorded on August 26, 1998 and April 29, 1998, respectively. The average, geometric mean and maximum nitrate values were higher at the Five Mile Creek Lower station than at any other station in the Project area.

Although the Five Mile Creek Lower station exhibited the highest nitrate concentrations, the average nitrate value was considered low to moderate. The maximum nitrate concentration (5.32 mg/l) was concerning, but fifty-seven (57) percent of total nitrate samples were less than 0.40 mg/l. The nitrate concentrations were well below the Wyoming water quality standard and drinking water human health standard of 10 mg/l for Class 2 (and Class 3) surface waters (WDEQ, 1998). Data for nitrate nitrogen indicated that the nitrate concentration in Five Mile Creek was generally less than the background concentration of nitrate (about 0.60 mg/L) found in streams in undeveloped areas throughout the United States (USGS, 1999). These observations indicated that nitrate nitrogen levels in Five Mile Creek were similar to natural background levels found throughout the United States, but five (5) of twenty-eight (28) samples representing 18% of total samples were greater than the background level. This suggested occasional influence by anthropogenic (man-caused) influences possibly from urban and agricultural related land use. However, nitrate was not present in Five Mile Creek in concentrations that could pose a human health threat nor were consistently present in moderately high concentration to pose a threat to aquatic populations caused by indirect effects due to eutrophication. Full support for all Wyoming beneficial uses applicable to nitrate was indicated. Future monitoring for nitrate and total phosphorus is recommended. Because the Lower station was sited in the Town of Ranchester, at least one other station upstream of the town limits should be established to separate the potential influence from urban nutrient sources from potential agricultural sources.

8.10.10 SCCD and WDEQ Five Mile Creek Total Phosphorus Monitoring

Total phosphorus samples were collected infrequently by SCCD (N = 3 total samples) at the Five Mile Creek Lower station due to Project monitoring budget constraints. An additional four (4) total phosphorus samples were collected by WDEQ during annual bioassessments. Summary statistics for total phosphorus are presented in Table 8-51. These statistics were based on "censored" values because the majority of analyses (4 samples out of 7 total samples) were less than the minimum detection limit (minimum detection limit was 0.10 mg/l for WDEQ analytical method; 0.05 mg/l for SCCD analytical method). The minimum detection limit for the WDEQ analytical method did not provide data quality needed to address the recommended water quality standard for total phosphorus in water bodies draining to a lake or reservoir (0.05 mg/l; EPA, 1977). Data were thus censored to provide an estimate that could be related to the recommended EPA standard of 0.05 mg/l.

The average total phosphorus concentration based on seven (7) total samples was .055 mg/l. Total phosphorus concentration ranged from .002 mg/1 to .090 mg/l. The median nitrate concentration was .050 mg/l.

The average and maximum total phosphorus values were based on a low total number of samples. However, total phosphorus concentration in Five Mile Creek should be considered low. Wyoming has not established surface water quality standards for phosphorus. U.S. EPA (1977) recommended that total phosphorus concentration should not exceed 0.05 mg/l in a stream that enters a lake or reservoir (e.g. Tongue River Reservoir) to prevent development of nuisance algal and plant populations. Mackenthun (1973) suggested a target phosphorus level of less than 0.10 mg/l for streams that did not directly enter lakes or reservoirs. USGS (1999) provided recent information from nationwide NAWQA monitoring and reported that national background concentrations for total phosphorus from streams in undeveloped (reference - like) areas was about 0.10 mg/L. Because the EPA goal was not attainable, SCCD adopted the finding by USGS for its interpretation of total phosphorus data collected during this Project.

Using the value of ≤0.10 mg/l as a target for total phosphorus concentration, no single sample exceeded the target value. However, because the sampling frequency was low (N = 7 total samples) over a four year period, sampling generally occurred during the fall low base flow period when total phosphorus concentration is normally lower and occasional moderately high nitrate concentrations were present, additional sampling is required to provide a reliable estimate of nutrient concentration in Five Mile Creek.

8.10.11 WDEQ Five Mile Creek Monitoring for Additional Water Chemistry Parameters

WDEQ collected samples for additional water chemistry parameters during annual monitoring at the Five Mile Creek Lower station from 1996 through 1999. Summary statistics are presented in Table 8-52.

Alkalinity averaged 420 mg/l based on four (4) samples. The geometric mean was 396 mg/l. The range was from 210 mg/l to 390 mg/l. Average alkalinity values were highest when compared to average alkalinity values at Tongue River and other tributary stations. There was no Wyoming water quality or EPA standard to compare alkalinity values to, but data indicated that water was moderate to highly alkaline, highly productive for aquatic life and was generally capable of withstanding sudden changes in pH due to inputs from point and NPS sources.

Total chloride concentration at Five Mile Creek Lower was relatively high when compared to other monitoring stations within the Project area. Average chloride based on four (4) samples was 10 mg/l with a range from 2.5 mg/l (censored value) to 17.0 mg/l. Columbus Creek Lower had the same average chloride concentration. Total chloride values were well within WDEQ and EPA water quality standards indicating full support for Wyoming beneficial uses that may be affected by total chloride. However, presence of chloride, although at low levels suggested that irrigation return may have some effect on Five Mile Creek.

Total sulfate concentration at Five Mile Creek Lower was highest when compared to the other monitoring stations within the Project area. The average total sulfate concentration based on four (4) total samples was 392 mg/l. The range in total sulfate was from 131 mg/l to 495 mg/l. These values were higher than expected even considering samples were collected in the fall during lower flow when ion concentrations were normally highest. The primary sources for the higher total sulfate concentration at Five Mile Creek Lower appeared to be natural sources (based on the Columbus Creek Upper control station concentration), urban sources, irrigation return and probable water released from upstream storage reservoirs containing increased sulfate due to evaporative concentration.

Total sulfate values for Five Mile Creek exceeded WDEQ standards (for groundwater use) and the EPA secondary drinking water standard of 250 mg/l. This observation suggested non-support for the Wyoming beneficial use for human consumption although the EPA secondary drinking water standard was not enforceable. Higher sulfate levels may also affect livestock ("blind staggers") especially if animals are moved to Five Mile Creek from a "cleaner" water source without adequate time to acclimate to Five Mile Creek water. Total sulfate sampling is recommended for future monitoring at Five Mile Creek Lower and at other stations upstream not only to further evaluate sulfate, but to evaluate turbidity and fecal coliform levels that exceeded Wyoming water quality standards.

Hardness concentration at Five Mile Creek Lower was highest when compared to the other monitoring stations within the Project area. Average hardness was 392 mg/l. The range in hardness was from 296 mg/l to 663 mg/l. Water may be termed very hard based on the classification found in Table 6-2. There were no Wyoming or EPA water quality standards for hardness, but observed values indicated partial support of the Wyoming beneficial use for Industrial use since the average concentration approached 300 mg/l and treatment may be required before industrial use. More year around sampling was required to determine if the high hardness values were due to seasonal sampling artifact during low flow periods, natural limestone geology in the watershed, probable irrigation water containing hardness due to evaporative concentration from upstream storage reservoirs, urban sources or irrigation return.

Total Suspended Solids (TSS) concentration was relatively high at Five Mile Creek Lower when compared to other monitoring stations within the Project area. Only Columbus Creek Lower had a higher average TSS concentration. Average TSS was 11 mg/l with a range from 5 mg/l to 17 mg/l. These values were considered seasonally high because most stations in the Project area displayed TSS values near or slightly above minimum detection limits during the lower flow season. Results of turbidity sampling (Section 8.10.6) showed high turbidity levels in excess of the Wyoming water quality standard. This suggested that significant amounts of sediment were entering Five Mile Creek. Further sampling for TSS is not recommended at this time unless specific sediment loading questions arise. Turbidity should continue to be used as a surrogate indicator for TSS. As indicated in Section 8.10.6, further turbidity sampling is required at Five Mile Creek.

8.10.12 SCCD and WDEQ Five Mile Creek Benthic Macroinvertebrate Monitoring

The Five Mile Creek Lower station was monitored by SCCD and WDEQ in 1996, 1997 and 1999. There were no benthic macroinvertebrate samples collected in 1998 because beaver activity dammed and inundated the sampling reach. The Five Mile Creek Lower benthic macroinvertebrate station was relocated in 1999 to a station about 100 to 150 yards upstream of the Highway 14 crossing.

Metric values are presented in Appendix Table G-2. Lists of benthic taxa identified, density (number per square meter) of taxa and percent contribution of each taxon to the total benthic population at each station are presented in Appendix Tables F-6 through F-8.

Biological condition at Five Mile Creek Lower using scoring criteria from the Wyoming Stream Integrity Index (WSII) from Stribling et al. (2000) was **poor** in 1996 and 1999 and **fair** in 1997 (Table 8-15). The poor biological condition rating indicated non-support for aquatic life use and the fair biological condition rating indicated partial support for aquatic life use. Both poor and fair ratings for biological condition require improvement in the aquatic resource to restore biological condition to full support for aquatic life use.

The lower biological condition ratings were due to the low number of Ephemeroptera (mayfly) taxa, Plecoptera (stonefly) taxa, Trichoptera (caddisfly) taxa and high percentage of non-insects comprising the total benthic population. The total number of EPT taxa was generally low each year and ranged from four (4) taxa in 1999 to nine (9) taxa in 1997. The number of scraper taxa was low (1 taxa in 1996, 2 taxa in 1997 and 2 taxa in 1999) and percent contribution of scrapers to the total benthic population comprised 0.2% in 1996, 0.3% in 1997 and 1.6% in 1999. The low percentage of scrapers in the benthic population suggested high deposition of sediment covering stream bottom substrate. This observation was confirmed by the average weighted embeddedness value of 21.4 at the Lower station (Table 8-54) that indicated virtually all cobble and gravel were covered by fine silt. The low percentage of shredders in the benthic population suggested upstream riparian disturbance and vegetation removal. Shredders feed on coarse particulate organic material such as leaves and vegetation that enter small stream systems usually from the riparian zone. Shredders comprised 0.4 percent, 0.0 percent and 0.0 percent of the total benthic community during 1996, 1997 and 1999, respectively.

The benthic community was dominated by warm water and generally pollution tolerant taxa indicative of higher water temperature, fair water quality and fair habitat quality. The generalist caddisfly, *Hydropsyche* was the dominant taxon followed in order of decreasing abundance by the mayfly, *Baetis tricaudatus*, the blackfly, *Simulium* and the worms *Nais variabilis* and *Uncinais uncinata* (Table 8-16).

Worms were a significant component in the benthic community especially in 1996 and 1997 when they comprised 36 percent and 32 percent, respectively, of the total population. Increased density of worms (Oligochaeta) may be associated organic pollution (Klemm, 1985), pollution from feedlots (Prophet and Edwards, 1973), and pollutants contained in urban storm water runoff (Lenat et al., 1979; Lenat and Eagleson, 1981). *Nais variabilis* and *Uncinais uncinata* were worm taxa that were among the five most dominant taxa in the benthic population. These taxa and *Ophidonais serpentina*, another abundant worm in Five Mile Creek, are widespread throughout the United States (Hiltunen and Klemm, 1980; Brinkhurst, 1986) and are often associated with sediment and organic deposits (e.g. animal waste). Each have pollution tolerance values of 8 (Table 8-16) indicating they are highly tolerant of pollution.

The percent contribution of Oligochaeta to the total benthic macroinvertebrate community was a reliable predictor for identification of fecal coliform bacteria contamination at monitoring stations within the Project area. Regression analyses using the average percent contribution of Oligochaeta and the average fecal coliform bacteria concentration at each monitoring station were conducted. The correlation coefficient (+0.886) was statistically significant ($P<0.05$) indicating that increase in percent Oligochaeta was associated with increase in fecal coliform bacteria level (Figure 8-24). Although the association was significant and strong, there was no apparent direct cause and effect relationship indicating that increased oligochaetes caused increased fecal coliform bacteria levels. Rather, the association was indirect because environmental conditions required for oligochaete populations to flourish (i.e. organic material from human and animal sources and increased sediment) were similar to conditions expected for the occurrence of higher fecal coliform bacteria levels (i.e. human and animal sources of excrement and generally higher turbidity). The application of this relationship for water quality monitoring should be explored further because general use of oligochaete populations to identify sources of fecal contamination to estimate fecal coliform bacteria levels would represent major savings in manpower and monitoring costs.
The presence of certain worm taxa including *Ophidonais serpentina*, *Eiseniella tetraedra* and Lumbricina may present additional predictive power because these organisms occurred most frequently at stations exceeding the Wyoming water quality standard for fecal coliform bacteria. The use of these worm species as possible fecal coliform bacteria indicators should be explored further. No *Tubifex tubifex* worms were identified from samples. *T. tubifex* is very common in polluted waters (Goodnight, 1959) and is significantly involved in the whirling disease life cycle caused by a parasite (*Myxobolus cerebralis*) that penetrates the head and spinal cartilage of fingerling trout. Whirling disease may eventually cause death in trout and the absence of this worm indicated low probability for the occurrence of whirling disease in the Tongue River watershed within the Project area. These associations further indicated the utility of benthic macroinvertebrates as cost-effective water quality indicators.

The projected higher water temperature, high turbidity and fine sediment deposition, frequent low and irregular discharge appeared to combine with fecal contamination indicative of organic pollution from animal or human origin to result in impairment of biological condition and non-support for aquatic life use. Although SCCD proposed that Five Mile Creek be designated as a Class 3 water body, aquatic life use must still be fully supported for Class 1, Class 2 and Class 3 water bodies. The apparent input of animal or human waste and sediment from suspected agricultural, wildlife and urban land use requires resolution to bring the stream into compliance with Wyoming water quality standards and to fully support aquatic life use. Further, future macroinvertebrate monitoring is recommended at stations upstream of the Town of Ranchester to separate potential impacts from urban land use from potential impacts from agricultural land use.

8.10.13 SCCD and WDEQ Five Mile Creek Habitat Assessment

Qualitative habitat assessments were conducted by SCCD and WDEQ in 1996, 1997 and 1999 in conjunction with benthic macroinvertebrate sampling. As indicated in Section 8.10.12, no sampling occurred in 1998 due to beaver activity that impounded the station. Because habitat assessments were subjective, SCCD used caution by providing a conservative interpretation of data.

Habitat assessment scores were low at the Five Mile Creek Lower station. The average total habitat score was 102. Total habitat scores ranged from 83 in 1996 to 122 in 1997 (Table 8-53). The lower scores indicated poor to moderate habitat. The low total habitat score was due to lack of instream cover for fish, high embeddedness (silt covering cobble and gravel), low velocity/depth and low pool and riffle ratio. Riparian indicators for bank vegetation protection, bank stability and disruptive pressures (vegetation removal) were good. However, riparian zone width was low because the stream channel had significantly down cut isolating the riparian zone from the influence of stream and groundwater. The location of the station downstream of Highway 14 assessed in 1996 and 1997 was highly channelized and had extensive urban development on one bank. Many of the lower scores for individual habitat parameters was related to extensive habitat alteration by channelization that occurred years ago in the Town of Ranchester. Channelization straightened and deepened the stream channel reducing instream habitat for aquatic organisms and fish. The generally unstable soil and apparent irregular, often high discharges also promoted down cutting of the stream channel such that Five Mile Creek resembled a deep ditch. The reduction in habitat coupled with low and irregular discharge due to irrigation demand and probable higher water temperature appeared to place stress on aquatic communities resulting in non-support for aquatic life use.

The semi-quantitative stream substrate particle size distribution indicated that the stream bottom was comprised of silt (35%), cobble (23%), coarse gravel (16%), fine gravel (15%), hard pan clay (6%) and sand (3%) (Table 8-54). This observation suggested that reduction in silt deposition may result in a cobble and gravel dominated substrate that would afford better habitat for macroinvertebrate and fish populations and enhance biological condition.

The high degree of silt deposition was further evidenced by the low average weighted embeddedness value of 21.4 (Table 8-54). The lower the weighted embeddedness value, the higher the percent coverage of cobble and gravel substrate by fine silt. The low weighted embeddedness value indicated virtually all cobble and gravel were covered by silt. Silt deposition was affected by the apparent amount of silt entrained in the water column (i.e. turbidity exceedence of the water quality standard), low and irregular discharge due to irrigation demand, and relatively low current velocity. Silt deposition will normally increase as current velocity is decreased provided adequate sediment is present in the water column.

The average current velocity was 1.4 feet per second (fps) and the range in velocities was from 0.7 fps in 1996 to 1.9 fps in 1999.

8.10.14 WGFD Five Mile Creek Fish Population Monitoring

SCCD could locate no historic or current record of fish sampling in the Five Mile Creek watershed.

8.11 Factors Affecting Fecal Coliform Bacteria Concentration in the Tongue River and Tributaries

Fecal coliform bacteria levels at Little Tongue River Lower, Smith Creek Lower, Columbus Creek Lower, Wolf Creek Lower and Five Mile Creek Lower stations exceeded the Wyoming water quality standard for fecal coliform bacteria. Corrective action will be required to reduce fecal coliform bacteria levels. Technical exceedence of the fecal coliform bacteria standard occurred at Columbus Creek Upper and Tongue River Lower stations based on single high fecal coliform bacteria samples. A sample collected at Columbus Creek Upper in 1998 exceeded the standard, but this sample represented only four (4) percent of total samples collected during the four year Project. Because of the low frequency, SCCD proposed that this stream reach not be placed on the Wyoming Water Quality Limited list (303d list), but rather be monitored to determine if limited, but significant bacterial contamination persisted. The same situation was observed at the Tongue River Lower station. A sample collected at the Tongue River Lower station in 1999 exceeded the standard and this sample represented only four (4) percent of total samples collected during the four year Project. However, because this station was located near the Town of Ranchester Water Treatment Plant, SCCD recommended remedial action due to immediate health and safety concerns and non-support for the Wyoming beneficial use for human consumption.

Fecal coliform bacteria levels at Little Tongue River Upper, Smith Creek Upper, Wolf Creek Upper, Tongue River Upper and Tongue River Middle stations were generally low and within the Wyoming water quality standard for fecal coliform bacteria. This observation indicated that sources for fecal coliform bacteria located between the Upper and Lower stations on the mainstem Tongue River and tributaries were contributing bacteria in sufficient quantities to produce health and safety concerns and non-support for human consumption beneficial use.

Locating sources for fecal coliform bacteria will be required to effectively target limited resources in the most cost-effective manner to remediate and reduce bacterial contamination. SCCD conducted further analysis of the fecal coliform data set by associating bacteria levels to turbidity levels, temperature, discharge, temporal (seasonal) effect and land use data. These variables were evaluated because the literature suggested that they were most frequently associated with variability in fecal coliform bacteria concentration at other water bodies throughout the United States and other countries. The effect that sampling frequency had on the ability to detect significant fecal coliform bacteria levels was also evaluated because inadequate sampling for fecal coliform may not detect bacteria contamination when in fact, a threat to public health and safety may exist.

8.11.1 Effect of Sampling Frequency

Sampling frequency must be sufficient to detect levels of fecal coliform bacteria that pose a risk to public health and safety through direct consumption by primary contact (i.e. swimming) and secondary contact (i.e. boating, fishing and incidental contact).

There were no exceedences of the Wyoming water quality standard for fecal coliform at any station in 1996. This observation suggested that there was no significant bacterial contamination within the Project area. However, it was likely that significant bacteria contamination existed, but was not detected. Lack of detection of significant fecal coliform levels appeared to be directly due to the low sampling frequency in 1996 when only three (3) total samples were collected at each station. As sampling frequency increased to seven (7) total samples in 1997 and 1998, sporadic, but significant contamination was detected at additional stations. When sampling frequency was increased in 1999 to ten (10) samples to incorporate WDEQ water quality standard sampling requirements during the Recreation Season, all tributary stations and the Tongue River Lower station were found to exceed the fecal coliform bacteria standard. There were no large differences in environmental conditions or change in land use in 1999 to account for this observation (See Section 8.11.3).

SCCD conducted further evaluation to determine the effect that sampling frequency had on the ability to detect fecal coliform contamination by combining the fecal coliform data set from this Project collected during the 1999 Recreation Season with the WDEQ fecal coliform data set collected during the Recreation season in 1998 and 1999 at streams in the adjacent Goose Creek watershed (Rogaczewski and Smith, 1999). Sampling by SCCD and WDEQ consisted of collection of 5 samples obtained during separate 24 hour periods for a 30 day period between May 1 and September 30. Only data from those stations with confirmed exceedences of the Wyoming water quality standard for fecal coliform bacteria were evaluated.

Table 8-55 presents summary statistics for the evaluation including the mean (number of fecal coliform colonies per 100 milliliters), geometric mean (number of fecal coliform colonies per 100 milliliters), number of individual daily samples greater than 400 colonies per 100ml, number of individual daily samples with less than 400 colonies per 100ml and the percent of total samples with less than 400 colonies per 100 milliliters (based on the total of 5 samples collected at each station within a 30 day period). SCCD modified the WDEQ data set before analysis. When duplicate (N=2) fecal coliform samples were collected by WDEQ, the mean value was used by SCCD for statistical analysis. This was in contrast to WDEQ treatment of duplicate values where the lower of the two duplicate values and not the mean, was used for calculation of the geometric mean (Rogaczewski and Smith, 1999). This resulted in lower geometric mean values reported by Rogaczewski and Smith when compared to geometric mean values presented by SCCD in Table 8-55.

Results of statistical analyses found that exceedence of the Wyoming water quality standard for fecal coliform bacteria at stations with confirmed violations would not have been detected on average, approximately 48 percent of the time, when a single daily sample was collected during a 30 day (monthly) period. A single instantaneous grab sample for fecal coliform would miss significant fecal coliform bacteria contamination about half the time. However, the greater the level of fecal coliform contamination, the fewer number of daily samples were generally needed to detect an exceedence of the fecal coliform standard with confidence. For example, at stations with high geometric mean fecal coliform bacteria levels greater than 500 per 100ml, samples collected on one to two different days would generally be sufficient to detect an exceedence of the fecal coliform standard (when using the standard of 400 per 100ml based on a single daily sample). Conversely, when fecal coliform bacteria levels were lower (i.e. geometric mean from 200 per 100ml to 300 per 100ml), the minimum number of separate daily samples collected must be increased from three (3) to (5) separate daily samples per 30 day period to reliably detect an exceedence of the fecal coliform standard (Figure 8-25).

Based on this evaluation, a single daily sample collected monthly by SCCD was insufficient to detect significant fecal coliform bacteria contamination except at only the most highly contaminated stations with geometric mean fecal coliform bacteria levels greater than 500 per 100ml. Thus, the single daily sample for fecal coliform collected monthly by SCCD had a probability of about 50 percent of missing an exceedence of the fecal coliform bacteria standard when in fact significant bacteria probably existed. This finding should be considered unacceptable because of the risk to public health and safety.

EPA (1986) found that a statistically sufficient number of samples for fecal coliform sampling was generally not less than 5 samples equally spaced over a 30-day period. MacDonald et al. (1991) cautioned that results from any single fecal coliform sample was of questionable value due to the high variability of fecal coliform bacteria in surface water. They recommended that because of variability associated with fecal coliform bacteria sampling, monitoring should be more regular and intensive than for most other water quality monitoring parameters.

It appeared that the single daily fecal coliform sample collected monthly by SCCD during 1996 through 1998 was inadequate to detect significant fecal coliform bacteria contamination. This sampling frequency should be abandoned for future fecal coliform monitoring in the Tongue River watershed and perhaps, for statewide fecal coliform monitoring by Wyoming Conservation Districts and WDEQ. The fecal coliform sampling frequency based on a minimum of not less than 5 samples obtained during separate 24 hour periods for any 30 day period appeared to provide the most reliable measure to detect significant fecal coliform contamination. Single day sampling may possibly continue due to time and budget considerations, but only at the risk of not detecting significant fecal coliform bacteria contamination on average, about 50 percent of the time which may place undue health and safety risk on the public.

It is recommended that future sampling for fecal coliform bacteria in the Tongue River watershed (and other water bodies) consist of a minimum five (5) samples each collected on separate days during a 30 day period within the Recreation Season (May 1 through September 30) to ensure detection of significant bacterial levels for protection of public health and safety. Single daily sampling, although less time consuming and costly, runs the risk of missing significant fecal coliform bacteria contamination about 50 percent of the time. Sampling for fecal coliform bacteria may also be conducted outside the Recreation Season to identify pollution sources that may be related to seasonal factors such as discharge, turbidity, wildlife use, livestock use and irrigation demand. However, sampling during the Recreation Season must be targeted first since this is the period is when public risk is highest due to primary and secondary contact.

8.11.2 Effect of Seasonal Variability

Fecal coliform bacteria concentrations may fluctuate wildly in wildland streams due to normal fluctuations in discharge and other environmental factors (Bohn and Buckhouse, 1985). Seasonal fluctuations were observed in fecal coliform bacteria levels during this Project and at streams in the Goose Creek watershed (adjacent to the Tongue River watershed) during sampling by WDEQ in 1998 and 1999. Seasonal variability was evaluated by comparing results for fecal coliform samples collected by WDEQ at several stations in the Goose Creek watershed (Rogaczewski and Smith, 1999) during the Recreation Season (May 1 through September 30) to fecal coliform concentrations collected during the Non-Recreation Season in October and November. Both Recreation Season and Non-Recreation Season data sets consisted of collection of 5 instantaneous grab samples obtained during separate 24 hour periods within a 30 day period.

There was a significant difference ($P<0.01$) in fecal coliform bacteria concentration between the Recreation and Non-Recreation seasons (Figure 8-26). Fecal coliform bacteria levels were significantly higher at each station during the Recreation Season than during the Non-Recreation season. The greatest difference observed at a single station was a 31-fold decrease in fecal coliform bacteria during the Non-Recreation Season when compared to fecal coliform bacteria levels during the Recreation Season. Several stations exhibited >15-fold decreases in fecal coliform bacteria during the Non-Recreation Season.

The largest percentage in reduction of fecal coliform bacteria level between seasons was observed at those stations with the highest fecal coliform levels during the Recreation Season. Further evaluation indicated that the lower bacteria levels during the Non-Recreation season appeared to be related to seasonally lower turbidity levels and lower consistent stream discharge (that reduced turbidity levels). Tunnicliff and Brickler (1984) found a statistically significant correlation between turbidity and fecal coliform bacteria concentrations in samples collected during higher discharge storm events, but not for samples collected during base flow. The relationship between fecal coliform bacteria, environmental and land use variables during the SCCD Tongue River Project is discussed further in Section 8.11.4.

The evaluation indicated that sampling for fecal coliform bacteria outside the Recreation Season will provide vastly different results than when sampling during the Recreation Season. A monitoring design that concentrates fecal coliform sampling during the Non-Recreational season should be avoided because significant bacterial contamination of risk to public health and safety would not be detected. Sampling during the Recreation Season must be targeted first because it is the primary period for primary and secondary water body contact and highest public health and safety risk. Sampling for fecal coliform bacteria outside the Recreation Season may be required to identify potential fecal bacterial pollution sources, but the data should be relegated to an secondary role for public health and safety concerns.

Based on this evaluation, the most effective sample design for collection of fecal coliform bacteria samples to protect public health and safety was to collect a minimum of five (5) samples each on separate days during a 30 day period within the Recreation Season (May 1 through September 30). This sampling design is the basis for the current Wyoming water quality standard for fecal coliform bacteria (WDEQ, 1998). Collection of a single instantaneous fecal coliform sample on a monthly basis was insufficient to detect fecal contamination when in fact, significant fecal contamination existed (Section 8.11.1). WDEQ (2000) proposed new fecal coliform standards that remove reference to sampling during the Recreation Season. This change may jeopardize public health and safety because analytical results for fecal coliform bacteria samples collected outside of the Recreation Season may be used to report on the annual status of fecal coliform bacteria levels in a particular water body. Expected lower fecal coliform bacteria levels from samples collected outside the Recreation Season may indicate insignificant fecal coliform bacteria contamination when significant bacteria levels may persist during the Recreation Season.

SCCD recommends future fecal coliform bacteria sampling in the Tongue River Project area and perhaps, statewide by other Conservation Districts, occur during the Recreation Season and at a frequency of a minimum of five (5) samples each collected on separate days during a 30 day period within the Recreation Season (May 1 through September 30). As previously indicated, sampling for fecal coliform bacteria outside the Recreation Season may be required to identify sources for fecal coliform, but the data should be relegated to a secondary role for public health and safety concerns.

8.11.3 Factors Related to Fecal Coliform Bacteria Levels

A series of regression analyses were conducted on the Tongue River Project data set to compare fecal coliform bacteria levels to discharge, temperature and turbidity. Regressions were run for each monitoring station, by year and for total combined data for 1996 through 1999. Results for the regression analyses are presented in Appendix L. Correlation coefficients are presented in Appendix Table L-1 and associated R-squared values are presented in Appendix Table L-2.

With few exceptions, there were no consistent statistically significant associations between fecal coliform bacteria level and discharge, temperature and turbidity at the Tongue River Upper station and at the Upper tributary stations. These stations normally exhibited lower fecal coliform levels during the Project and with the exception of a single high fecal coliform bacteria sample at Columbus Creek Upper, none exceeded Wyoming water quality standards. There was a significant relationship ($P<0.05$) between fecal coliform and discharge at the Tongue River Upper station in 1999, but this association did not hold when all data (1996 through 1999) were combined. There was a significant, but weak association between fecal coliform and temperature at Smith Creek Upper using combined data from 1996 through 1999. Regression analyses revealed no other significant relationships at this station. There was a significant, but weak association between fecal coliform and turbidity at Columbus Creek Upper using combined data from 1996 through 1999. Regression analyses revealed no other significant relationships at Columbus Creek Upper. There was a strong significant association between fecal coliform bacteria and turbidity at Wolf Creek Upper in 1997 and 1998, but the association was insignificant in 1996 (only 1 data point), 1999 and when using combined data from 1996 through 1999.

More consistent and significant associations between fecal coliform bacteria and turbidity were observed at the Tongue river Middle and Lower stations and at the Lower tributary stations where fecal coliform bacteria levels were higher. The association between fecal coliform bacteria and turbidity was significant at the Tongue River Middle Station during 1997, 1998, 1999 ($P<0.05$) and when using combined data from 1996 through 1999 ($P<0.01$). R-squared values for these correlations ranged from 29.4 percent to 68.8 percent indicating that turbidity level explained much of the variability observed in fecal coliform bacteria levels. A significant association between fecal coliform bacteria and turbidity levels was evident at the Tongue River Lower station ($P<0.01$ for combined 1996-1999 data), Five Mile Creek Lower ($P<0.05$ for combined 1996-1999 data), Columbus Creek Lower ($P<0.01$ for combined 1996-1999 data) and Wolf Creek Lower ($P<0.01$ for combined 1996-1999 data).

Discharge and temperature were also closely associated with fecal coliform bacteria level at Columbus Creek Lower based on combined 1996-1999 data. This was the only station where discharge, temperature and turbidity were each significantly associated with fecal coliform indicating interaction between the three physical parameters. Discharge, in addition to turbidity, was also significantly associated ($P<0.01$) with fecal coliform bacteria level at the Wolf Creek Lower station based on combined 1996-1999 data. Temperature was the only variable significantly associated with fecal coliform bacteria levels at Smith Creek Lower when using combined 1996-1999 data.

Significant associations between turbidity, conductivity and discharge observed at the unregulated Tongue River Upstream station and Upper tributary stations were not consistently observed at the Lower tributary stations. The Tongue River Lower station and Lower tributary stations were regulated by irrigation withdrawal and return especially during the Project sampling period from April through September. Dewatering, admixture of ambient water with irrigation return water and variable stream discharge related to irrigation demand appeared to result in the lack of consistent and expected associations between discharge and certain water quality parameters. These factors may be responsible for the lack of consistent associations between fecal coliform bacteria and temperature, discharge and turbidity at the regulated Lower tributary stations.

Turbidity appeared to be the primary physical factor measured during this Project that was regularly and significantly associated with high fecal coliform bacteria levels. However, the association was not consistent at all stations indicating that merely reducing turbidity would not always result in reduction in fecal coliform levels. Discharge, and then temperature, occasionally exhibited statistical significance with fecal coliform bacteria levels usually at the Lower tributary stations where discharge was highly regulated by irrigation demand. There appeared to be more interaction between turbidity, discharge and temperature with fecal coliform bacteria levels at the more highly regulated Lower tributary stations than at the Upper tributary stations that were not regulated by irrigation demand. Some of the conflicting "noise" present in the fecal coliform bacteria - water quality chemical and physical relationships at the Lower tributary stations sited in urban settings (Little Tongue, Smith Creek, Five Mile Creek and Tongue River Lower) may be due to potential fecal coliform contamination from urban sources during low stream discharge in addition to suspected fecal coliform contamination from upstream wildlife and agricultural land use. Future monitoring should establish stations upstream of the Towns of Dayton and Ranchester to separate urban fecal coliform bacteria sources levels from potential wildlife and agricultural sources.

The association between turbidity and fecal coliform bacteria level may be related to the fact that bacteria appear to survive longer in sediment than when in the water column. This poses additional problems for tracking fecal coliform sources in the Tongue River Project area since fecal coliform bacteria may survive up to sixty (60) days in stream sediment. Davies et al. (1995) found survival of fecal coliform bacteria in freshwater sediment for up to 60 days. The number of bacteria was reduced by from 2 to 3-fold after 29 days. Bacteria numbers then remained relatively constant after that. Sherer et al. (1992) found in the laboratory that the half life of fecal coliform bacteria ranged from 11 to 30 days in fine and coarse sediment and the half life of fecal coliform bacteria in the water column above the sediment was about 3 days. Marino and Gannon (1991) found that fecal bacteria could survive in sediment in storm drains up to 6 days during dry weather conditions.

Marino and Gannon (1991) suggested that an important factor affecting bacterial levels was the resuspension of bacteria accumulated in bottom sediment. Sherer et al. (1988) and Stephenson and Rychert (1982) found that fecal coliform bacteria were resuspended into the water column after physical disturbance of stream bed sediment. Sherer et al. (1992) reported that once stream sediment was disturbed, bacteria could be re-suspended causing increased, but short term bacteria levels. They found that survival of fecal coliform bacteria was longer in fine sediments than in coarse sediments. Fecal bacteria entrained in water survives longer when attached to sediment because of protection from ultraviolet light and other environmental deterrents. Other investigators have found a close association between turbidity and fecal coliform bacteria. Grimes (1980) found a high correlation between turbidity and indicators of fecal contamination in the Mississippi River below a dredging operation that stirred up river bottom sediment. Because of the close association between turbidity and fecal bacteria, Kay and Wyer (1997) suggested that turbidity may be considered as a general indicator for bacteria contamination because it provided "real time" data compared to the normal 24 hour incubation period to acquire accurate bacteria counts. Gerba and McLeod (1976) found that the longer survival of *E. coli* in sediment than in water was related to the higher amount of organic material in the sediment.

The significant relationship between fecal coliform bacteria and turbidity observed at Tongue River Project stations with the highest bacterial levels suggested a strong link to stream bed sediment. The apparent association between increase in aquatic Oligochaeta (associated with sediment and organic pollution) and increase in fecal coliform bacteria contamination (see Section 8.10.12) added more evidence to suggest the link between fecal bacteria in sediment with fecal coliform bacteria detected in the water column.

Overland runoff, direct defecation and discharge containing fecal bacteria are believed to be the primary avenues for fecal bacteria contamination in streams (Miner, et al., 1992). Upon entering the water body, fecal bacteria may survive for several days in stream bed sediment only to be released later by physical disturbance of stream substrate. Sources of fecal material must be reduced or eliminated to restore water quality and meet the Wyoming water quality standard for fecal coliform bacteria

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8.11.4 Fecal Coliform Bacteria and Land Use Relationships

Each land use within the Tongue River Project area had the potential to contribute fecal coliform bacteria to the Tongue River and major tributaries. However, evaluation of the data suggested that certain land uses were related to high fecal coliform bacteria concentration more than other land uses.

Fecal coliform bacteria concentration was generally low at the Tongue River Upper and Middle stations and at each of the four Upper tributary stations. With the exception of the Columbus Creek Upper station (one daily exceedence), there were no exceedences of the Wyoming water quality standard for fecal coliform bacteria during the four year Project. Primary land use in the watershed at and upstream of these stations included wildlife, recreation and seasonal livestock grazing. This observation indicated that wildlife, recreation and limited seasonal livestock grazing land use had no significant effect on fecal coliform bacteria levels. The generally low fecal coliform bacteria concentration at the Tongue River Middle station and data collected by WDEQ in the vicinity of the Town of Dayton WWTF, indicated potential bacteria sources were not affecting the Middle stream reach and the Dayton WWTF was not a significant contributor of bacteria. Comparison of historic fecal coliform data with current fecal coliform data colleted during this Project indicated a reduction in fecal coliform bacteria in this reach over the years (See Section 8.5.11). Upgrade and effective operation and maintenance of the Dayton WWTF was believed to be the reason for reduced fecal coliform bacteria levels over the years.

Water quality and fecal coliform bacteria concentration changed significantly from the Upper to Lower tributary stations. Each Lower tributary station exceeded the Wyoming water quality standard for fecal coliform bacteria. Accordingly, primary land use changed significantly from the Upper to Lower stations. Primary land uses at and upstream of the Lower stations in relative order of importance included irrigated hayland, livestock grazing (more intensive, some year around), wildlife habitat, dryland pasture, recreation and urban. The Little Tongue River Lower and Smith Creek Lower stations were sited in urban settings (i.e. Town of Dayton); Five Mile Creek Lower and the mainstem Tongue River Lower stations were sited in the Town of Ranchester. It was not possible to separate the potential influence of fecal coliform bacteria from wildlife and agricultural land use from the potential influence of fecal coliform bacteria from urban land use at these stations. Although wildlife land use was not an important source of fecal coliform bacteria at the Upper stations, changes in the stream channel morphology from the higher gradient Upper stations in the foothills to the lower gradient and meandering Lower stations in the plains provided better habitat for increased utilization by waterfowl and small mammals. Thus, the role that waterfowl may exert on fecal coliform bacteria levels further complicated the search for fecal bacteria sources.

Wolf Creek Lower and Columbus Creek Lower stations were probably not affected by urban land use because these stations were not sited near urban development. Agricultural land use dominated the watersheds upstream of these stations especially in Columbus Creek where a Confined Animal Feeding Operation was located. The number and duration of livestock grazing significantly increased from the Upper to Lower stations. Potential fecal bacteria contamination from the large feedlot upstream of the Columbus Creek Lower station should be further evaluated. Ancillary effects for irrigation water delivery and return may promote fecal coliform bacteria contamination by transporting bacteria, contributing sediment and creating variable discharges resulting in the instability of stream bottom sediment and resuspension of fecal bacteria.

Watersheds with cattle grazing may show increased concentrations of bacterial indicator organisms (e.g. fecal coliform bacteria) in streams although effects may be variable and detectable only for short distances downstream (Milne, 1976). Deposition of fecal material along water ways contributed a major share of bacteria from grazed watersheds. Howell et al. (1996) reported that fecal coliform bacteria levels increased in stream sediments when cattle had direct access to streams. Stephenson and Street (1978) and Jawson (1982) found fecal bacteria levels increased once cattle entered a pasture. Bacterial levels remained high after cattle were removed. Once deposited, fecal bacteria may survive for periods up to one year in cow feces (Bohn and Buckhouse, 1985). If exposed, bacteria from feces may wash into streams, enter stream bottom sediment and survive only to be resuspended in the water column when bottom substrates are disturbed. Maule (1997) in laboratory experiments found the verotoxic strain of *Escherichia coli* 0157:H7 to survive and remain infective for long periods of time in cattle feces and in soil. Despite seemingly logical rationale linking livestock grazing to fecal coliform bacteria concentration in streams, it is often difficult to show the relationship because of varying livestock management practices and seasonal transient use by wildlife and waterfowl. Doran et al. (1981) and Dixon (1983) found that effects from cattle were often indistinguishable from effects due to wildlife.

Recent advances in biotechnology have allowed water quality investigators to more readily discern sources of fecal contamination through DNA testing. DNA testing is relatively expensive (about $5,000 per station) and time consuming (50 samples per station) and results may be inconclusive about 20 percent to 60 percent of the time (1999 Personal Communication, Dr. Somadpour, University of Washington, Seattle). Identification of fecal bacteria sources increases as the reference source material (i.e. human, cattle, ducks, beaver fecal material) database increases for the watershed under study. Although expensive in the short term, DNA testing may realize long term benefits and cost savings by more effectively directing restoration funds to suspect sources of fecal contamination. SCCD may explore use of DNA testing for future monitoring in the Project area.

Although livestock grazing was suspected as a potential source for significant bacterial contamination at some of the Lower tributary stations, certain best management practices may be implemented to ensure livestock grazing has no significant effect on bacteria levels. Likewise, suspect urban, recreational and agricultural land use practices should be re-evaluated throughout the Tongue River watershed within the Project area.

BMP's that may be implemented within the Tongue River watershed Project area to reduce bacterial contamination to streams include:

1. Locating pollutant sources away from streams. Placement of small and large livestock confinements in areas which reduce the potential for transport of fecal material during flooding and heavy rain periods to reduce the probability that contaminated runoff will reach surface water;

2. Reduction of direct animal contact with surface water by removing high concentrations of animals, strategic fencing of streams, or use of stream bank entrance ramps to allow watering while minimizing direct defecation into surface

water;

3. Improved management of waste disposal techniques and design of disposal areas to include use of riparian buffer strips between application sites and surface water and minimize manure spreading under conditions conducive to runoff and overland flow such as saturated soils, surface channeling and on frozen ground;

4. Improvement of animal waste storage facilities at larger operations to reduce leakage and drainage directly into surface water;

5. Relocating poorly planned septic systems;

6. Proper waste disposal by recreational users;

7. Effective regulatory oversight by WDEQ to ensure effective municipal and large feedlot wastewater treatment through the NPDES program; and

8. Consideration of wildlife and waterfowl population management should they cause significant fecal coliform contamination.

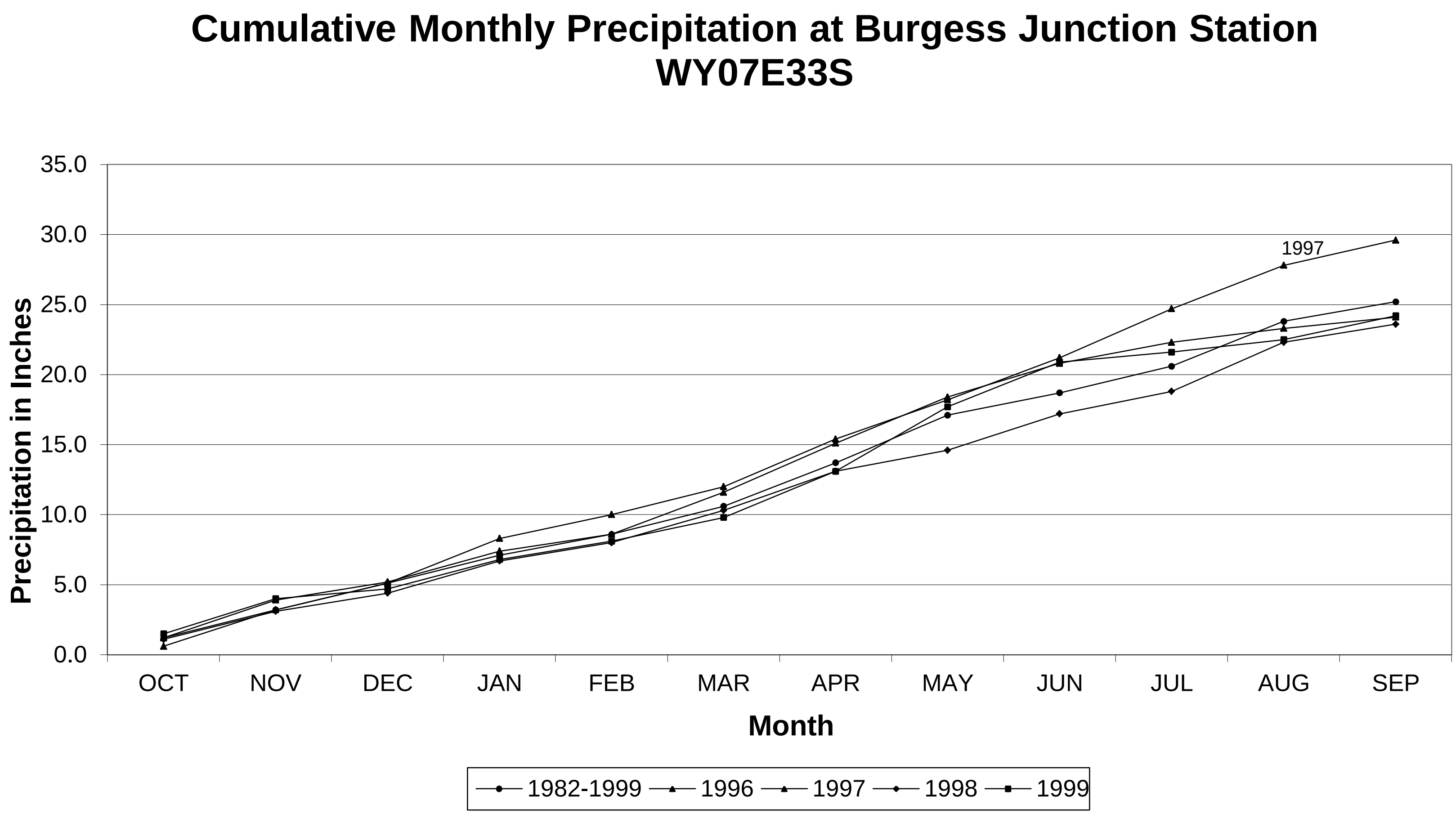

FIGURE 8-1. Cumulative monthly precipitation at Burgess Junction Meteorological Station WY07E33S operated by NRCS, Sheridan County, Wyoming.

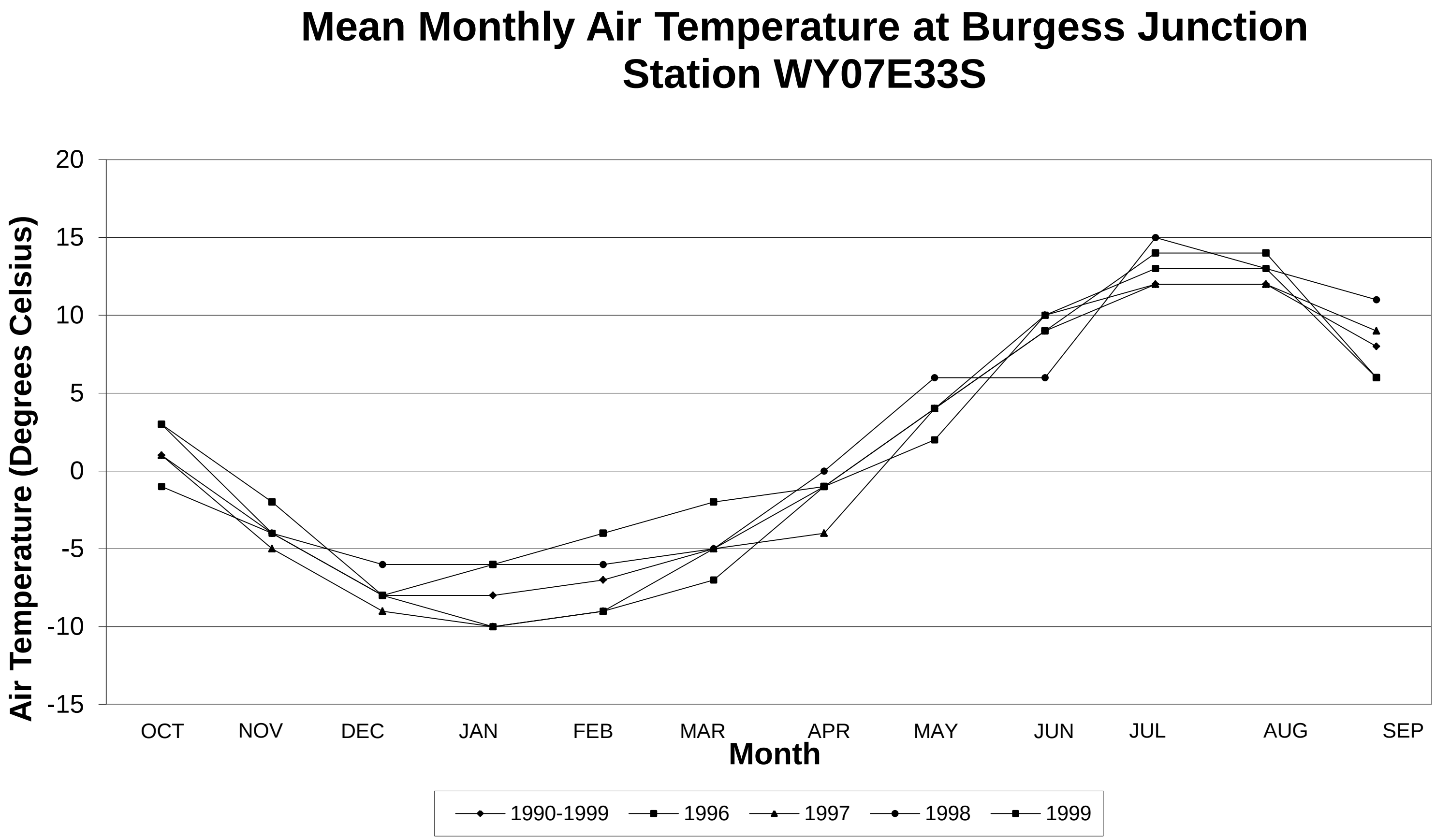

FIGURE 8-2. Monthly air temperature at Burgess Junction Meteorological Station WY07E33S operated by NRCS, Sheridan County, Wyoming.

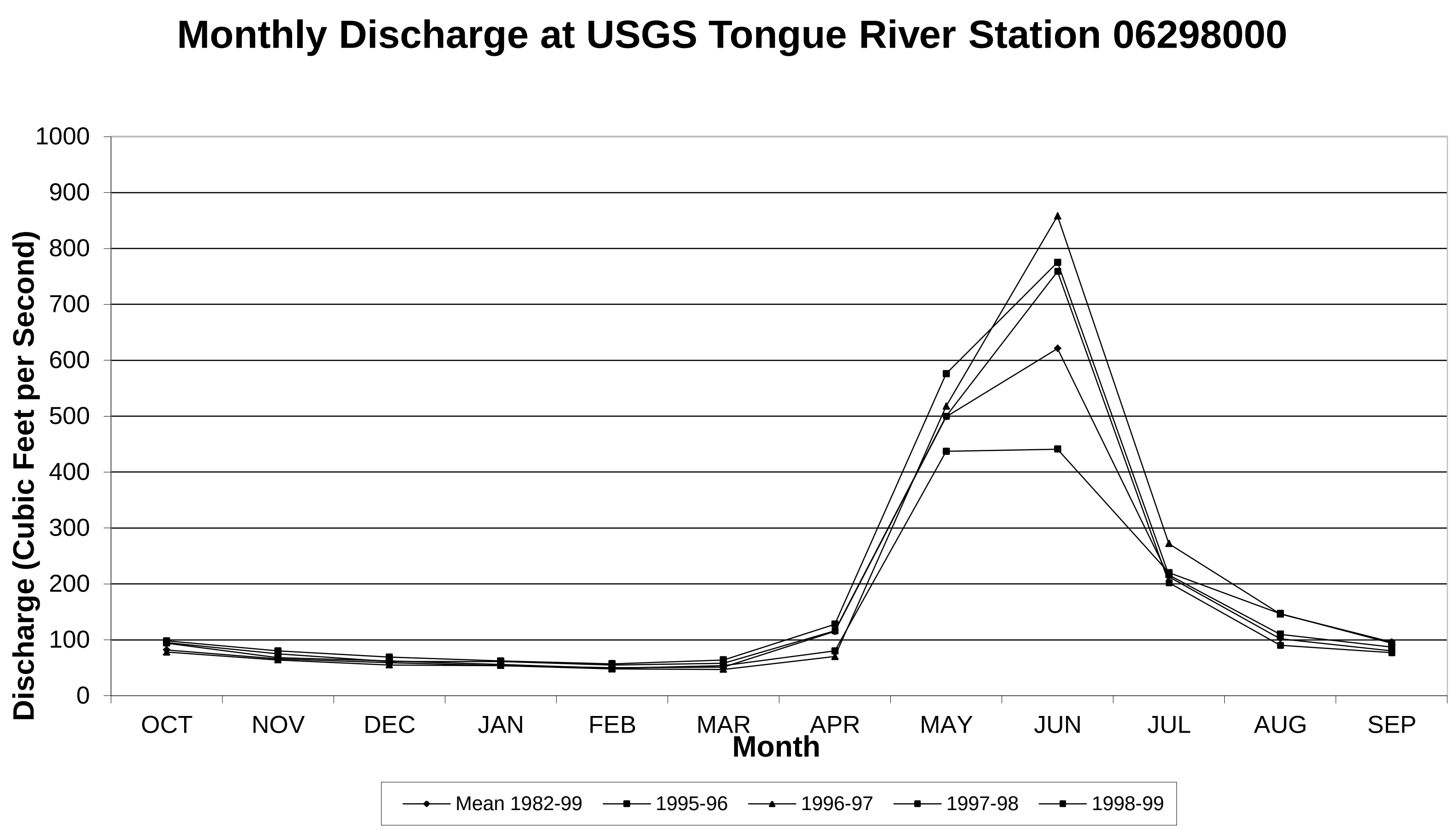

FIGURE 8-3. Monthly discharge at USGS Tongue River Station 06298000, Sheridan County, Wyoming

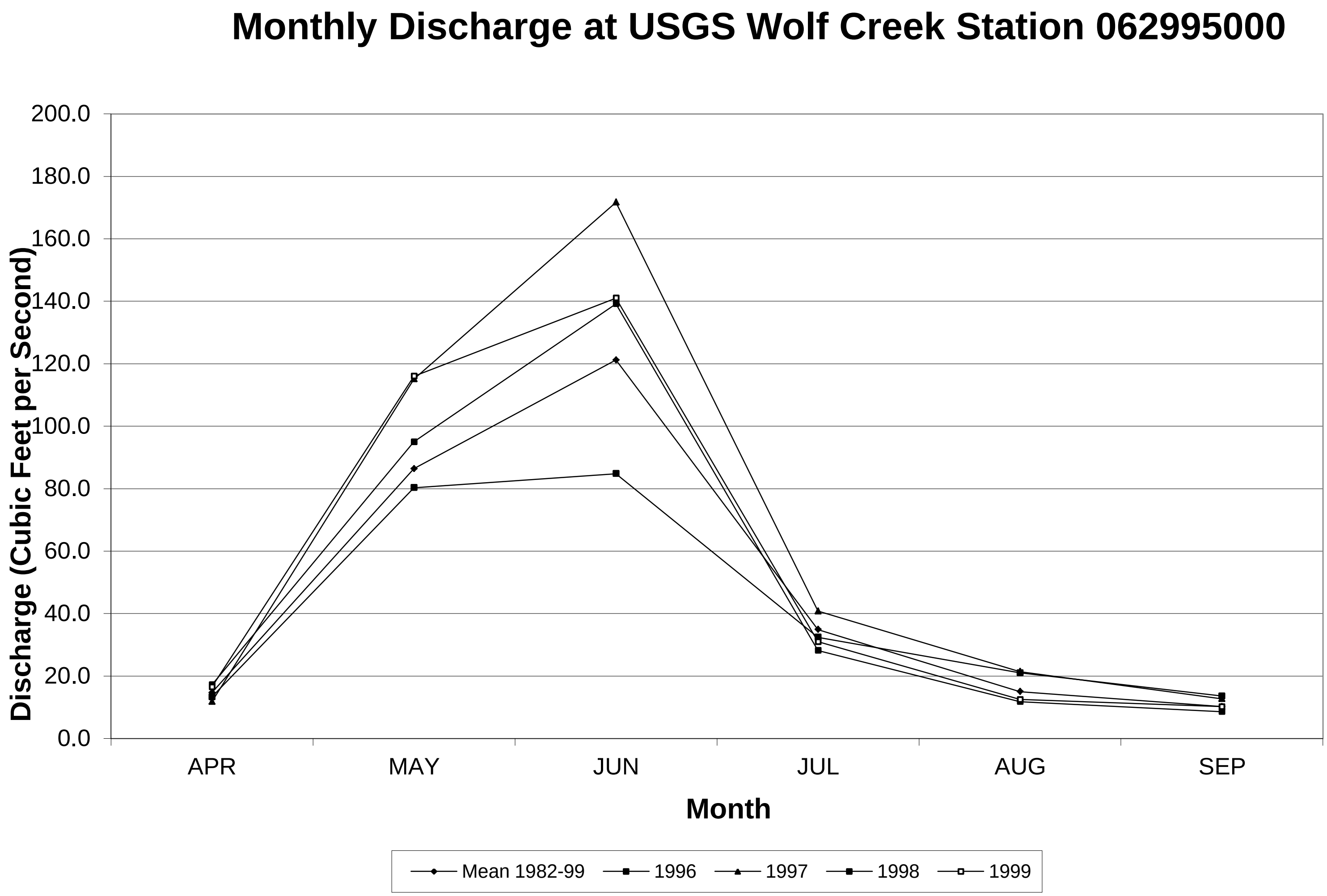

FIGURE 8-4. Monthly discharge from April through September at USGS Wolf Creek Station 06299500, Sheridan County, Wyoming.

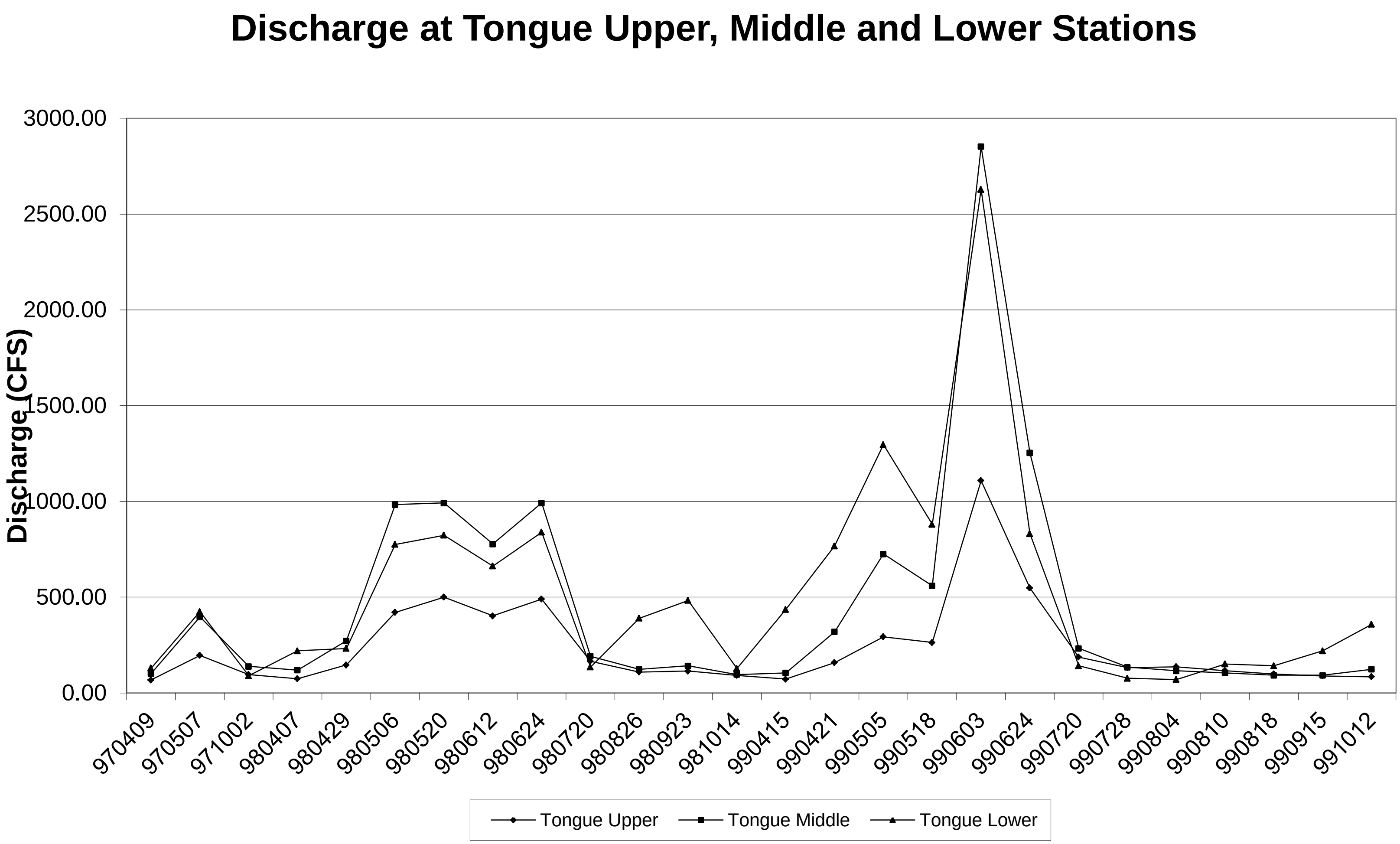

FIGURE 8-5. Comparison of discharge measurements recorded same day at Tongue River Upper, Middle and Lower stations collected by SCCD and WDEQ, 1996-1999, Sheridan County, Wyoming.

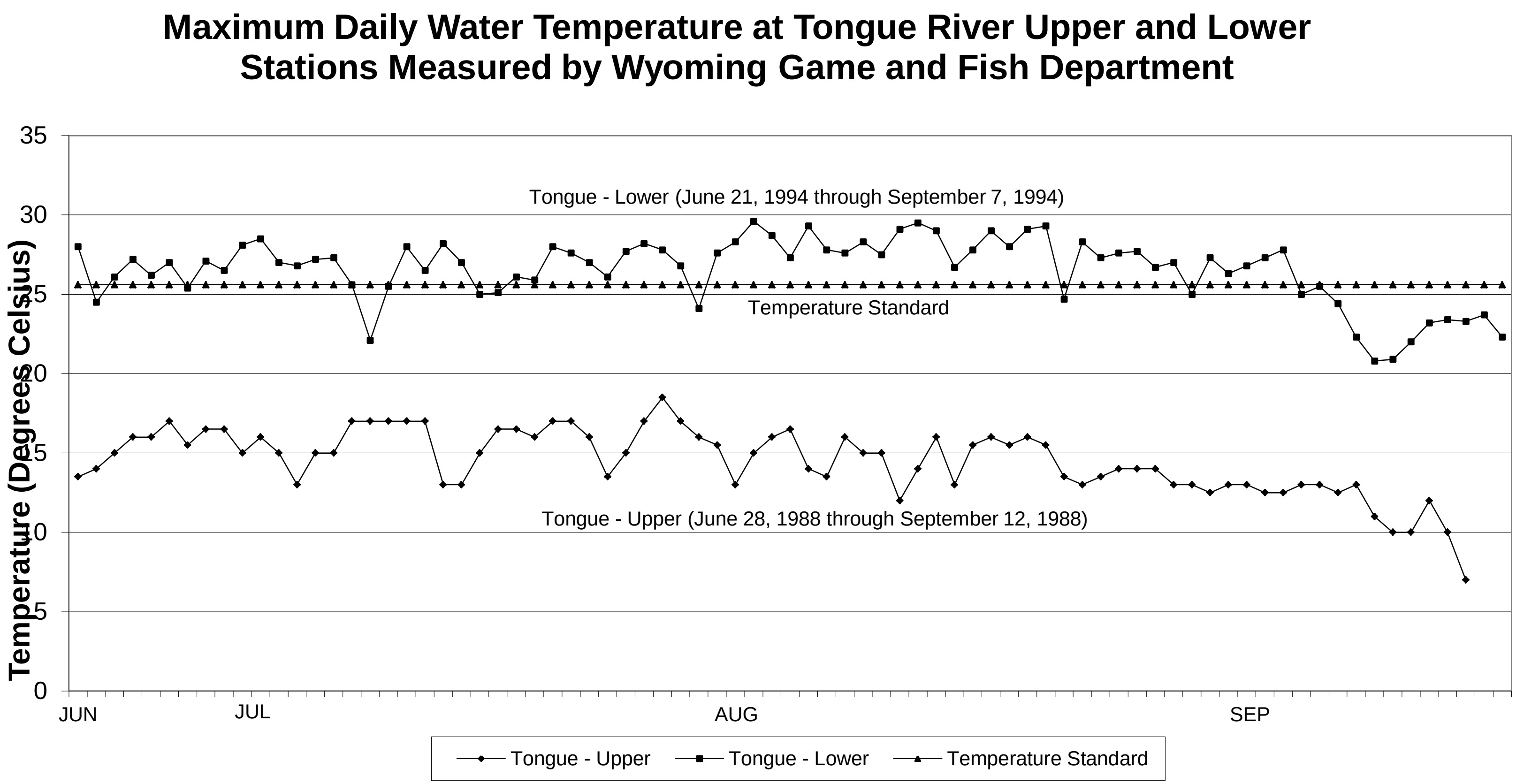

FIGURE 8-6. Maximum daily water temperature recorded at Tongue River - Upper and Tongue River - Lower (Ranchester) by Wyoming Game and Fish Department during 1988 (Upper Station) and Lower Station (1994) in comparison to the Wyoming water quality standard (25.6 degrees centigrade), Sheridan County, Wyoming.

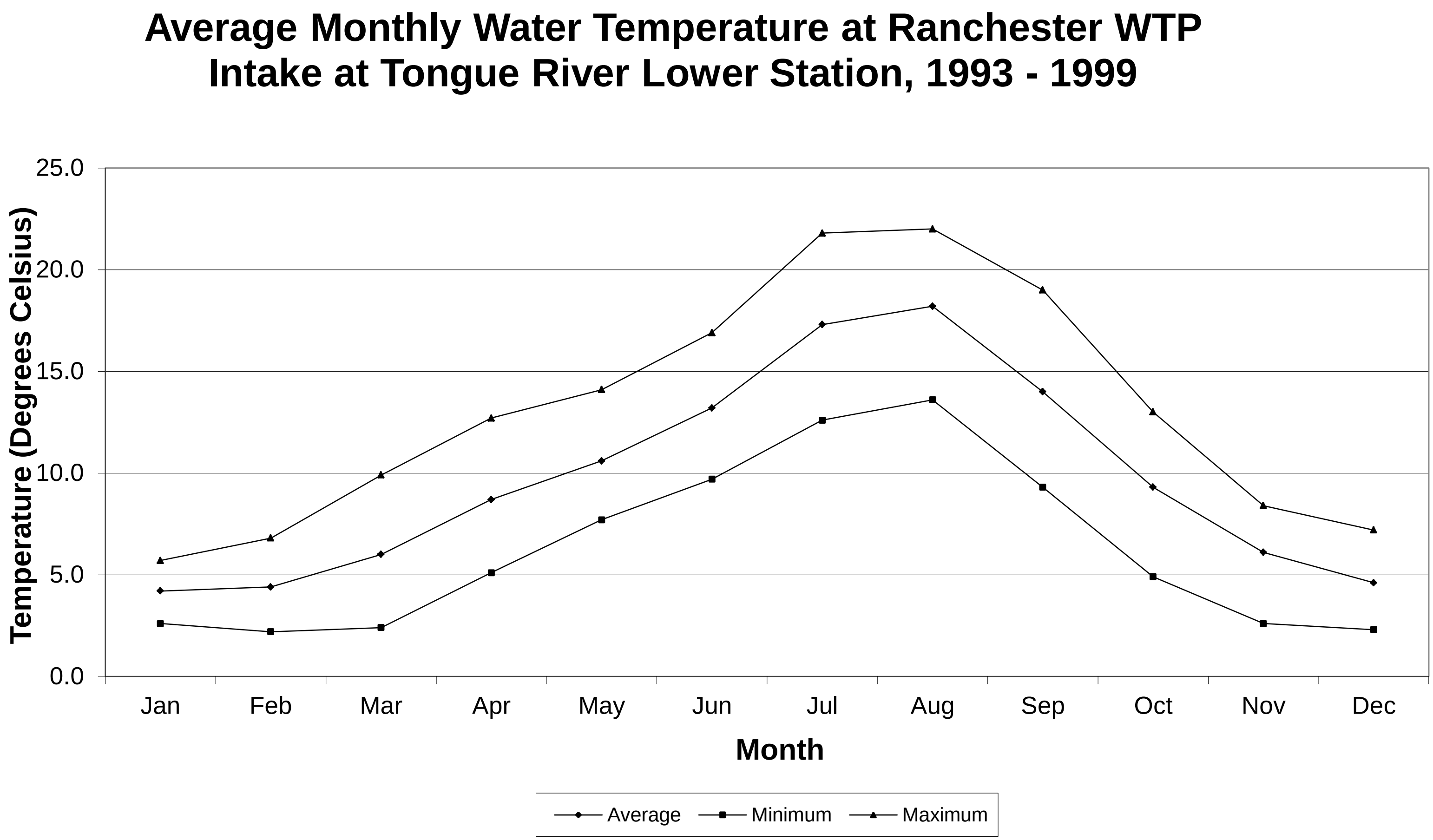

FIGURE 8-7. Average monthly water temperature (based on daily temperature measurements) at the City of Ranchester Water Treatment Plant raw water intake at Tongue River Lower station, 1993 - 1999, Sheridan County, Wyoming.

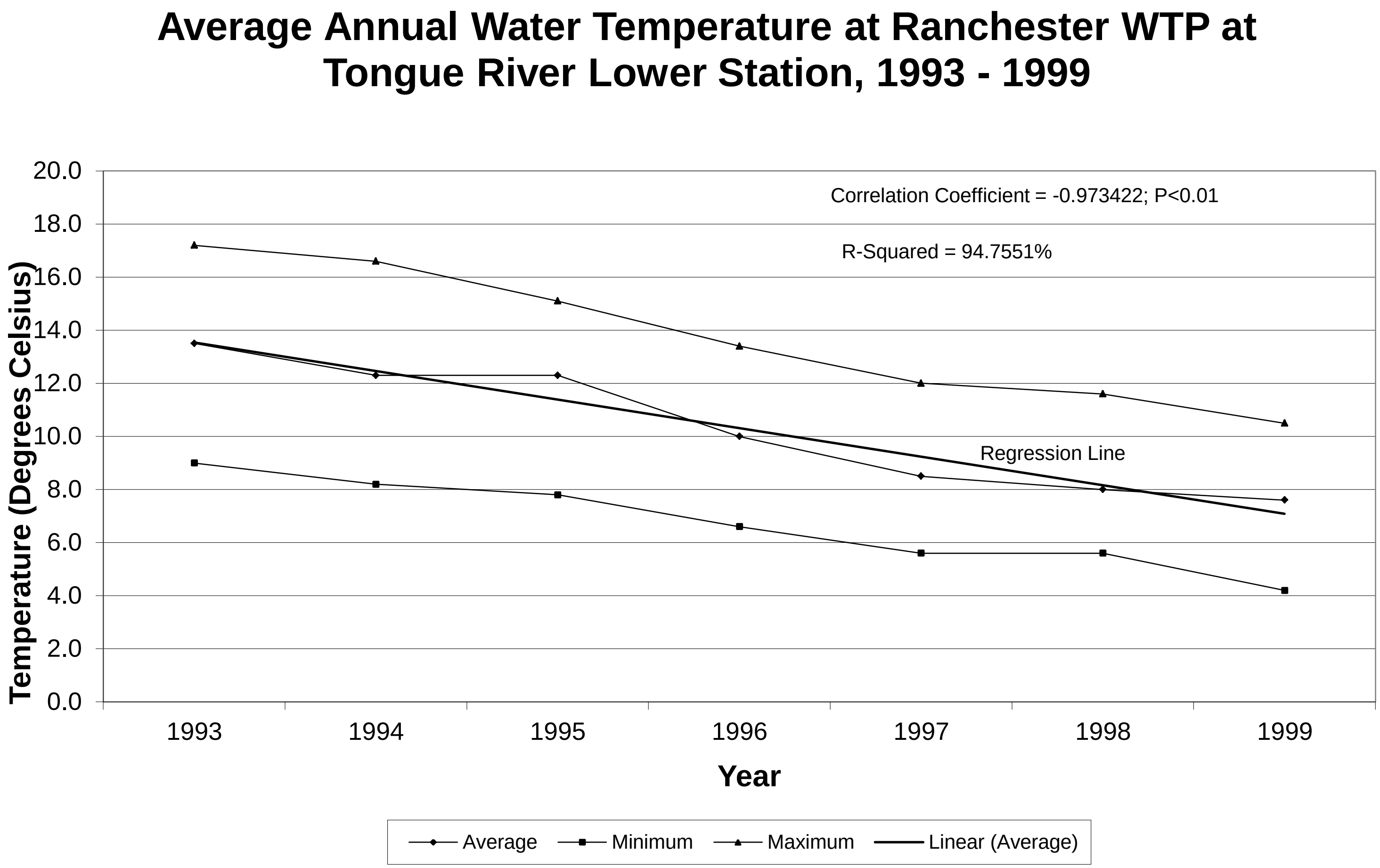

FIGURE 8-8. Time series analysis for average annual water temperature (based on daily temperature measurements) at the City of Ranchester Water Treatment Plant raw water intake at Tongue River Lower station, 1993 - 1999, Sheridan County, Wyoming.

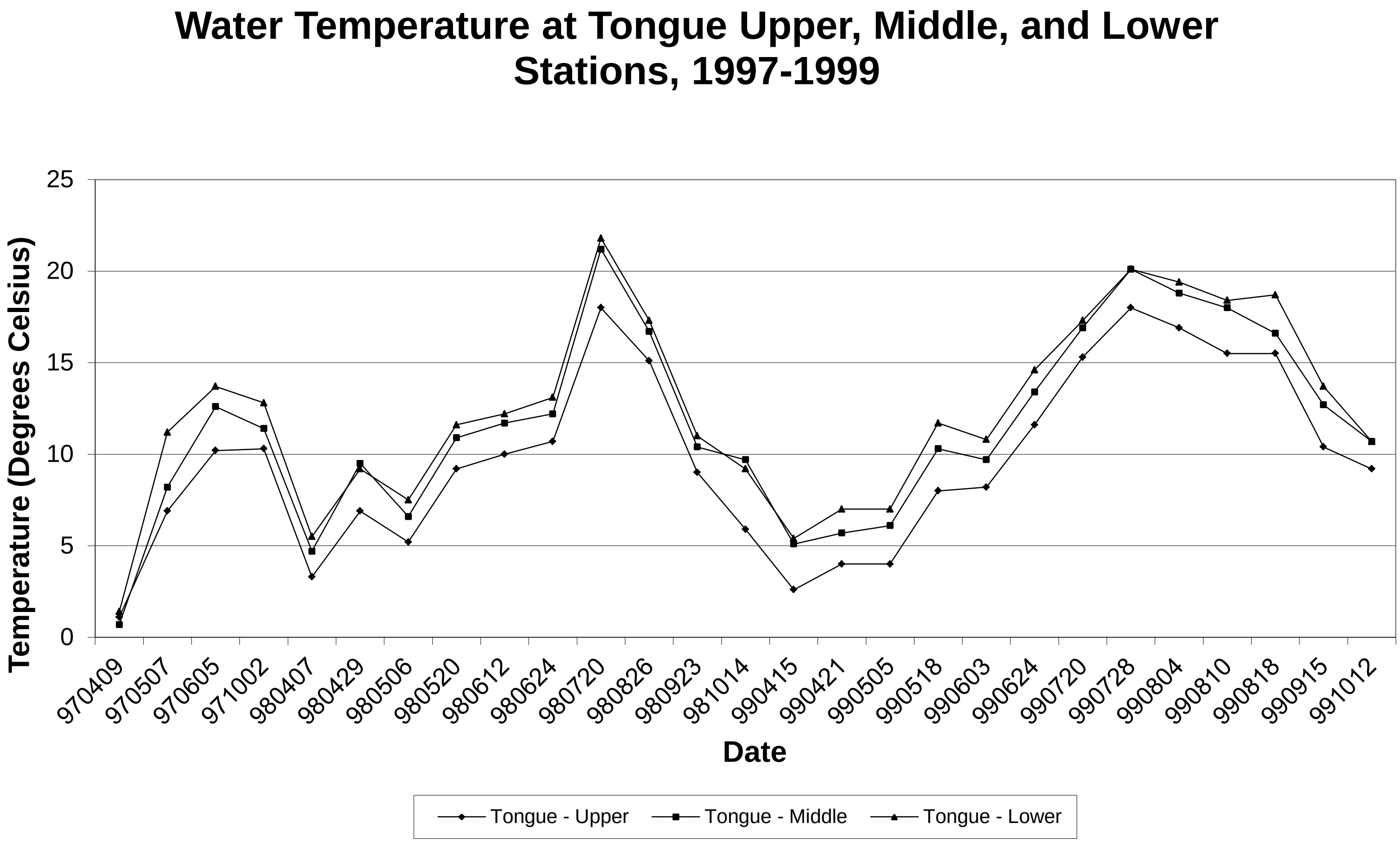

FIGURE 8-9. Comparison of water temperature at Tongue River Upper, Middle and Lower stations on comparable days, 1997-1999, Sheridan County, Wyoming.

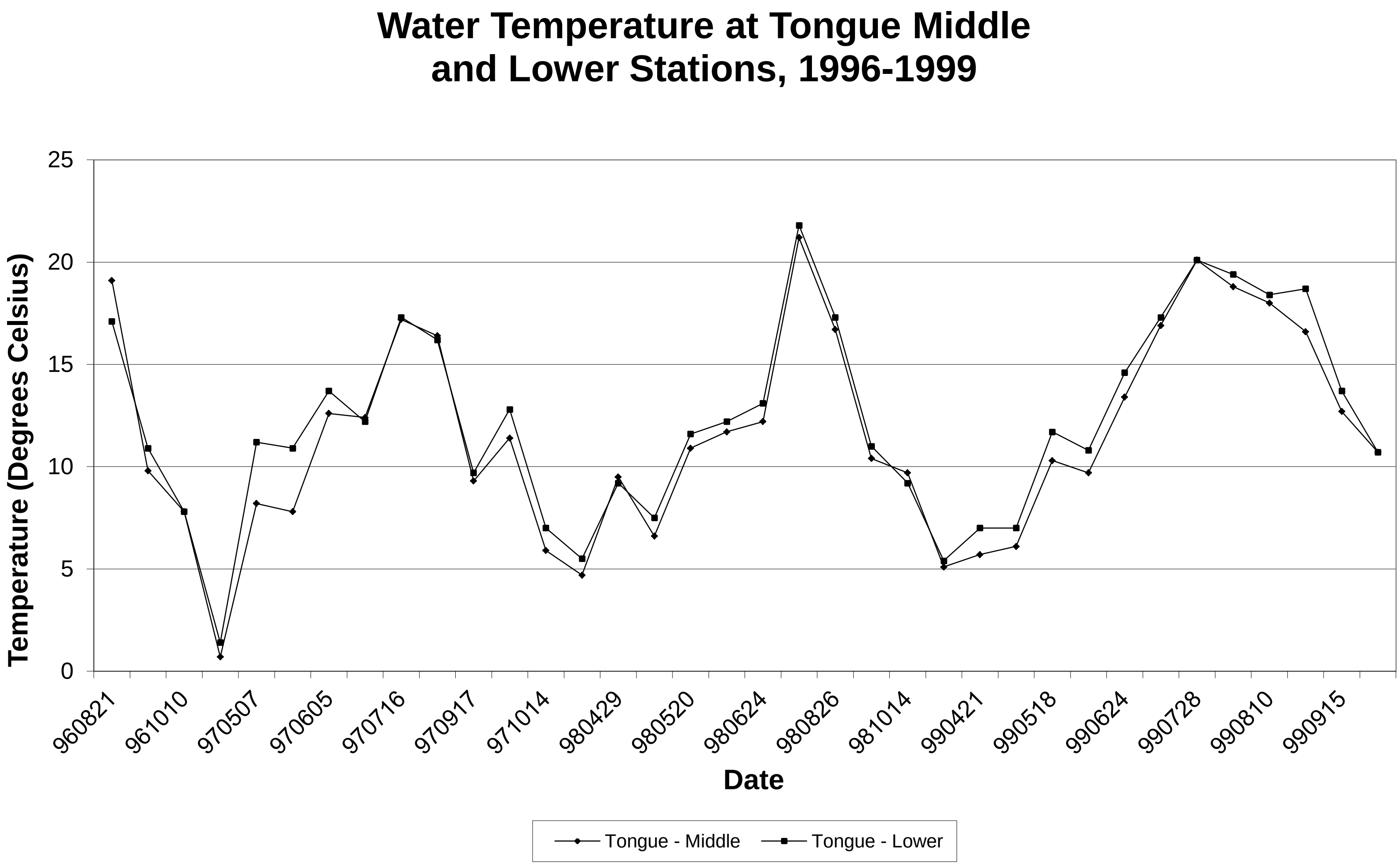

FIGURE 8-10. Comparison of water temperature at Tongue River Middle and Lower stations on comparable days, 1996-1999, Sheridan County, Wyoming.

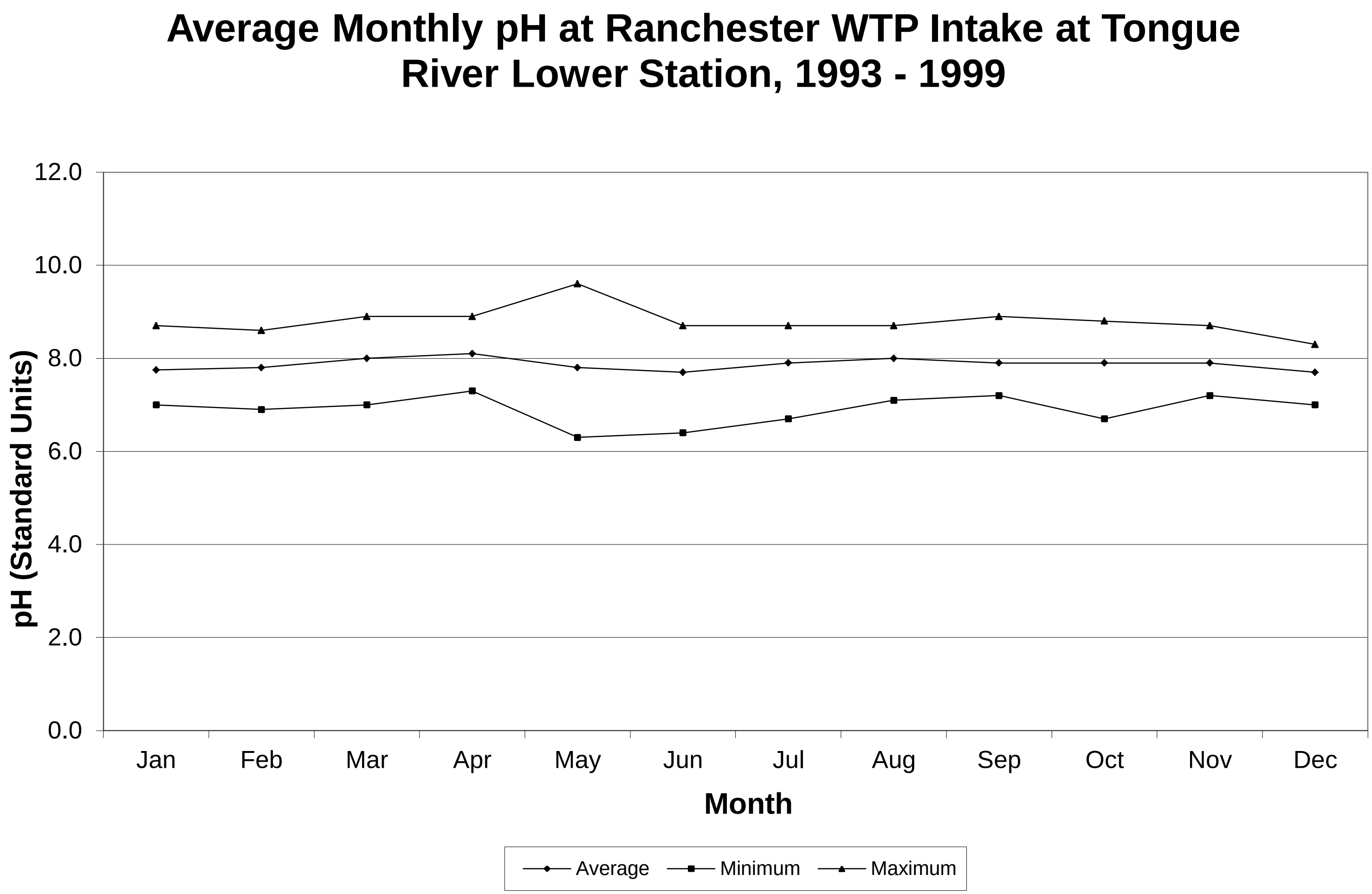

FIGURE 8-11. Average monthly pH (based on daily pH measurements) at the City of Ranchester Water Treatment Plant raw water intake at Tongue River Lower station, 1993 - 1999, Sheridan County, Wyoming.

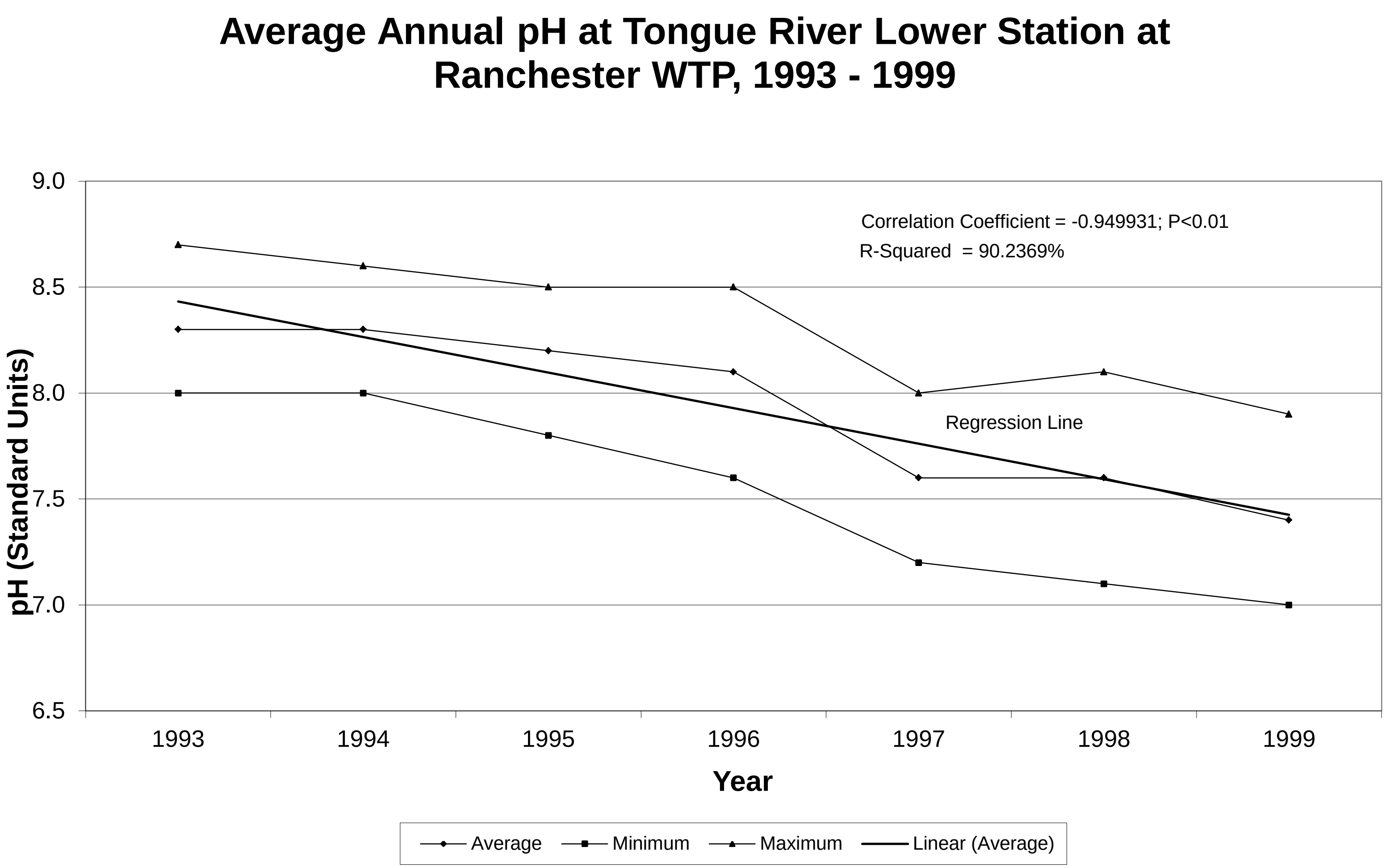

FIGURE 8-12. Time series analysis for average annual pH (based on daily pH readings) at the Town of Ranchester Water Treatment Plant raw water intake at Tongue River Lower station, 1993 - 1999, Sheridan County, Wyoming.

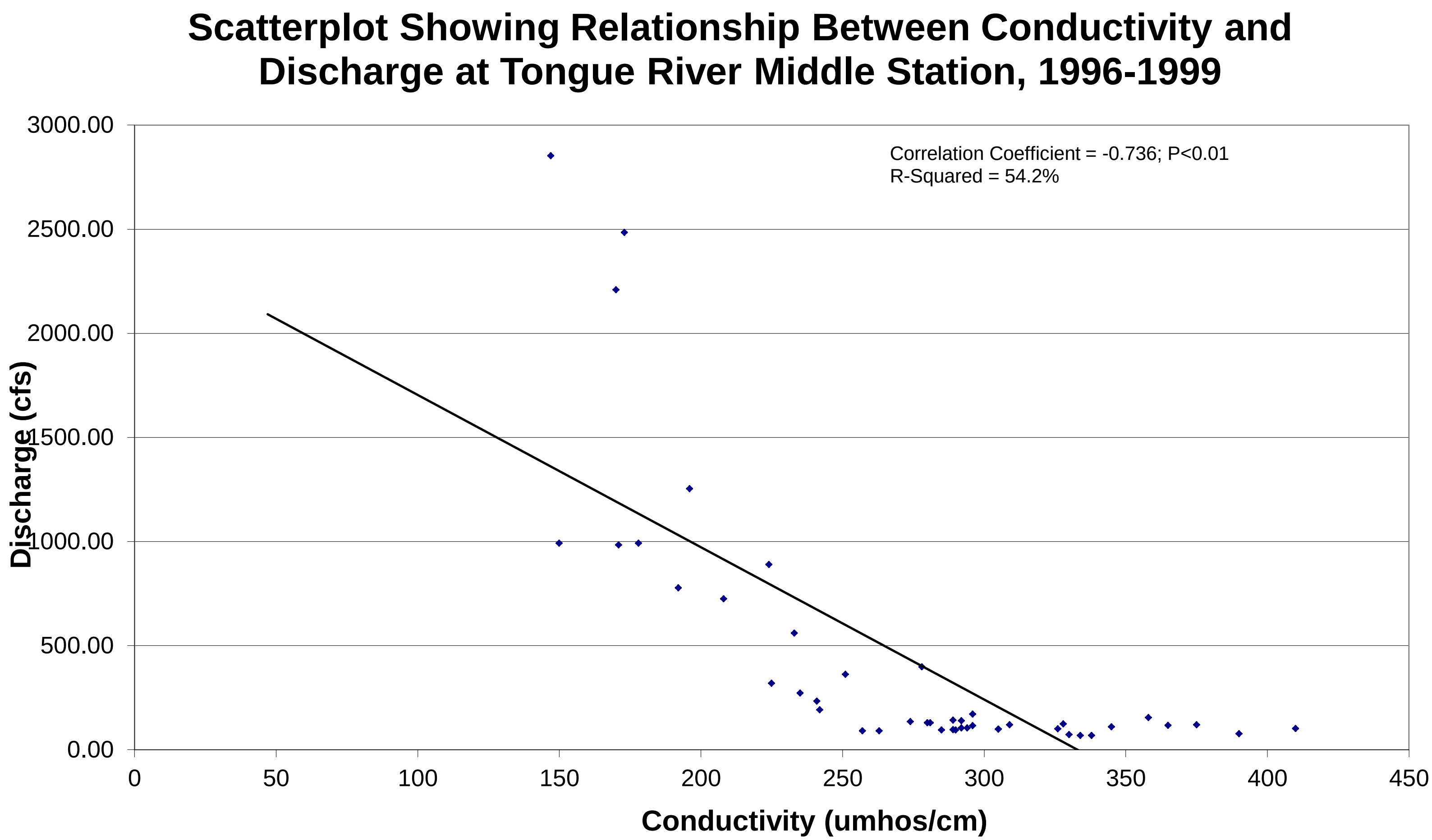

FIGURE 8-13. Scatterplot showing association between conductivity and discharge at Tongue River Middle station, 1996 - 1999, Sheridan County, Wyoming.

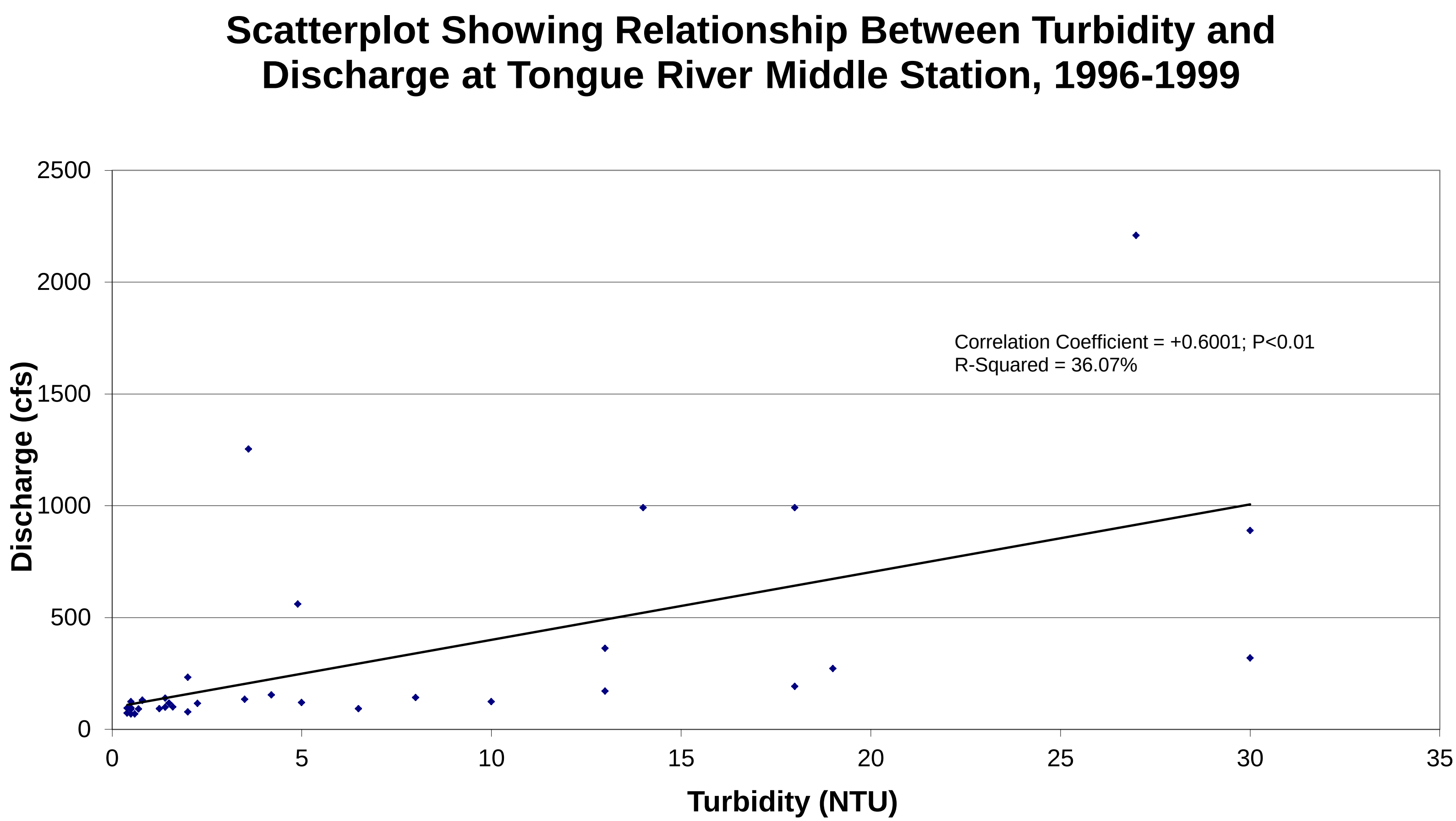

FIGURE 8-14. Scatterplot showing association between turbidity and discharge at Tongue River Middle Station, 1996-1999, Sheridan County, Wyoming.

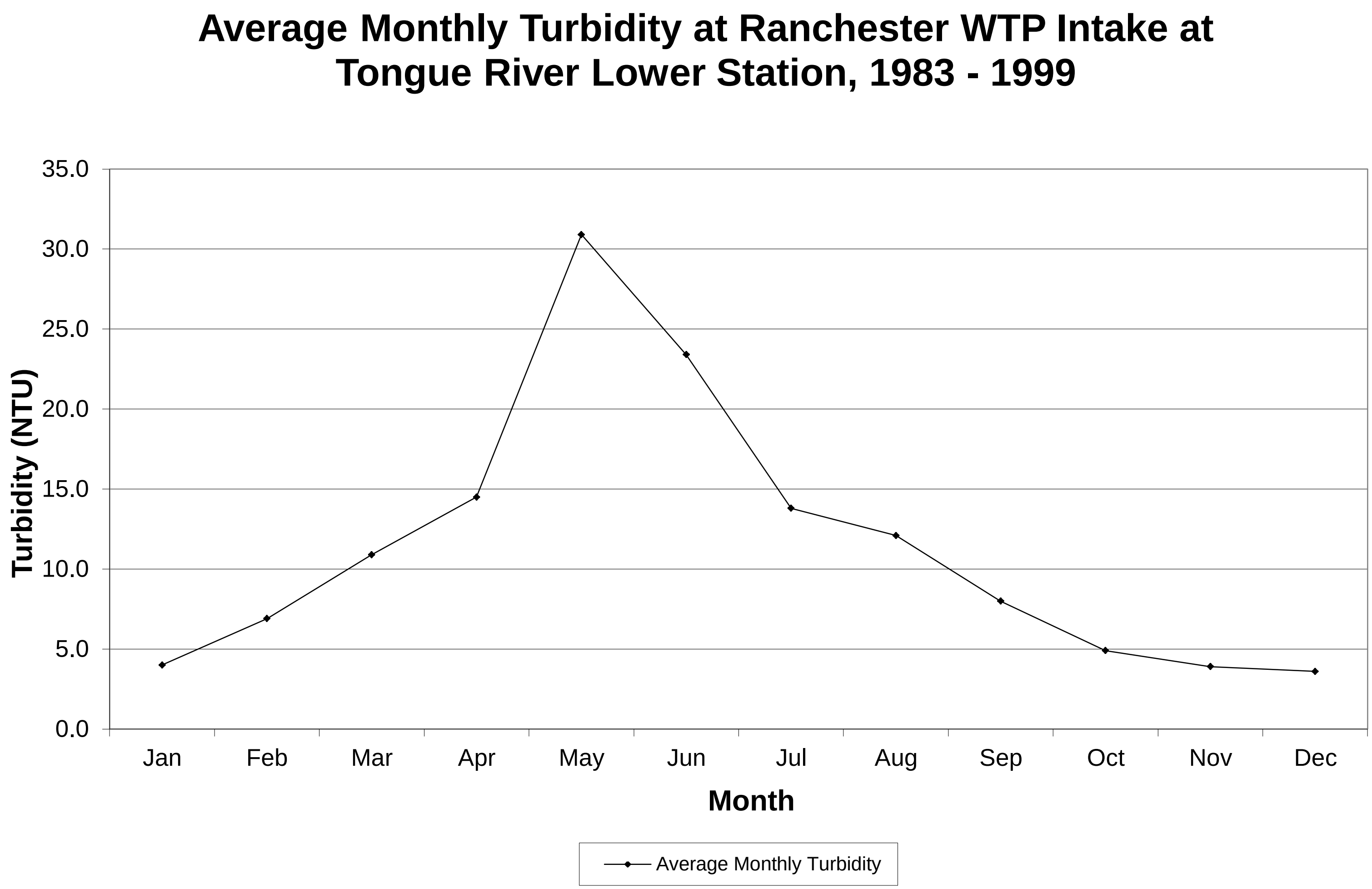

FIGURE 8-15. Average monthly turbidity (based on daily turbidity measurements) at the Town of Ranchester Water Treatment Plant raw water intake at Tongue River Lower station, 1983 - 1999, Sheridan County, Wyoming.

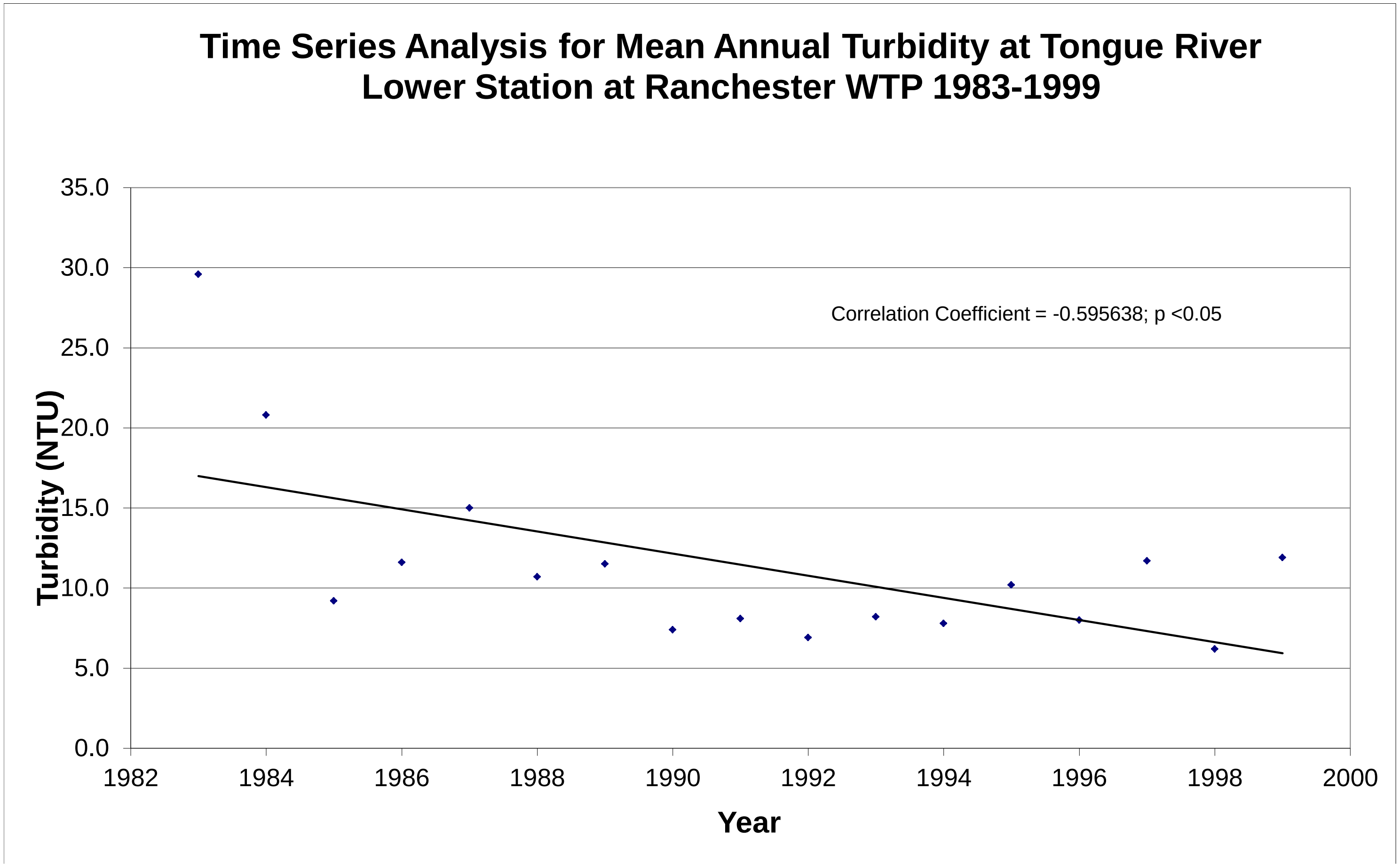

FIGURE 8-16. Time series analysis for mean annual turbidity (based on daily turbidity measurements) at the Town of Ranchester Water Treatment Plant raw water intake at Tongue River Lower station, 1983 - 1999, Sheridan County, Wyoming.

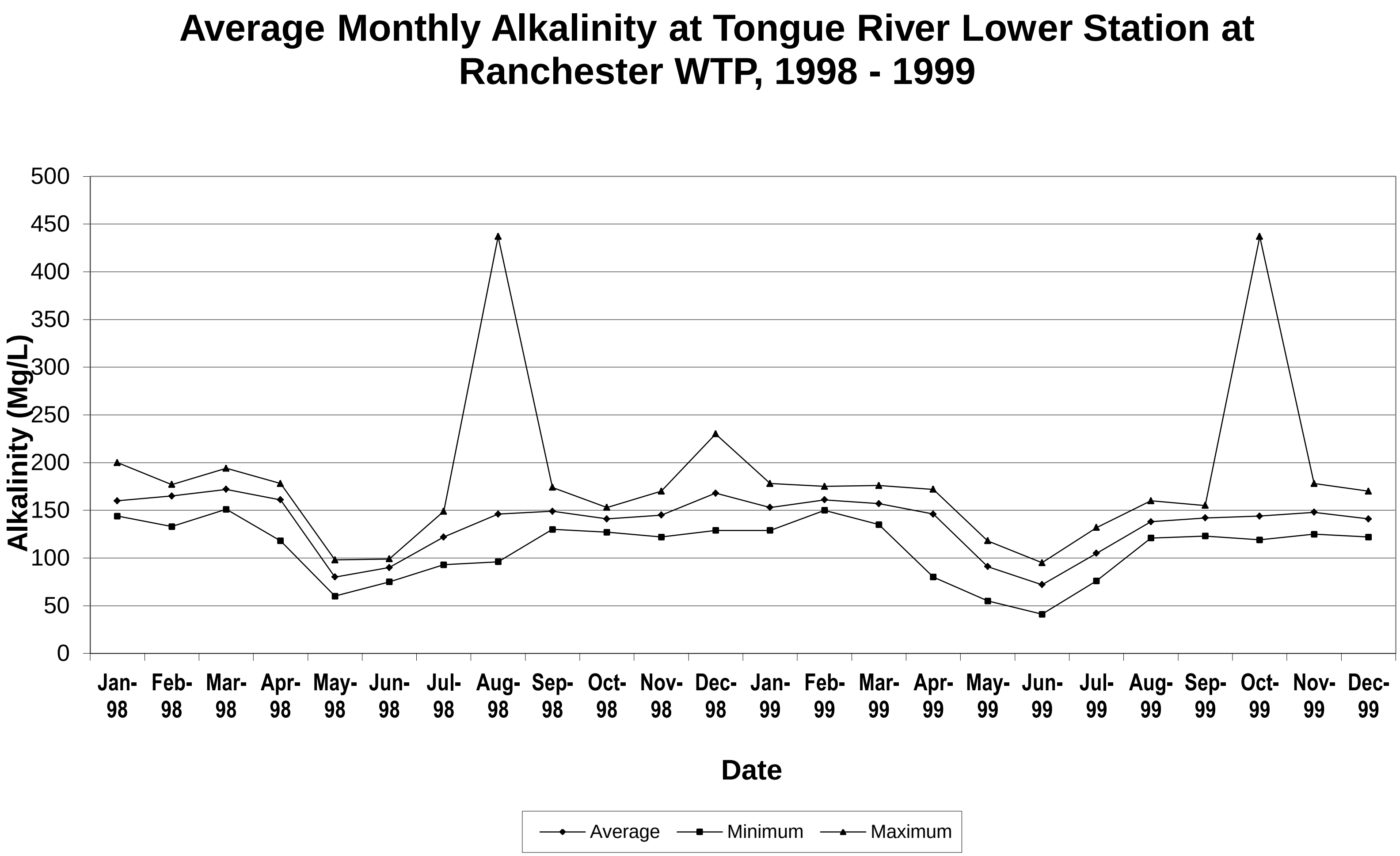

FIGURE 8-17. Mean monthly alkalinity (based on daily alkalinity measurements) analyses at the Town of Ranchester Water Treatment Plant raw water intake at Tongue River Lower station, 1983 - 1999, Sheridan County, Wyoming.

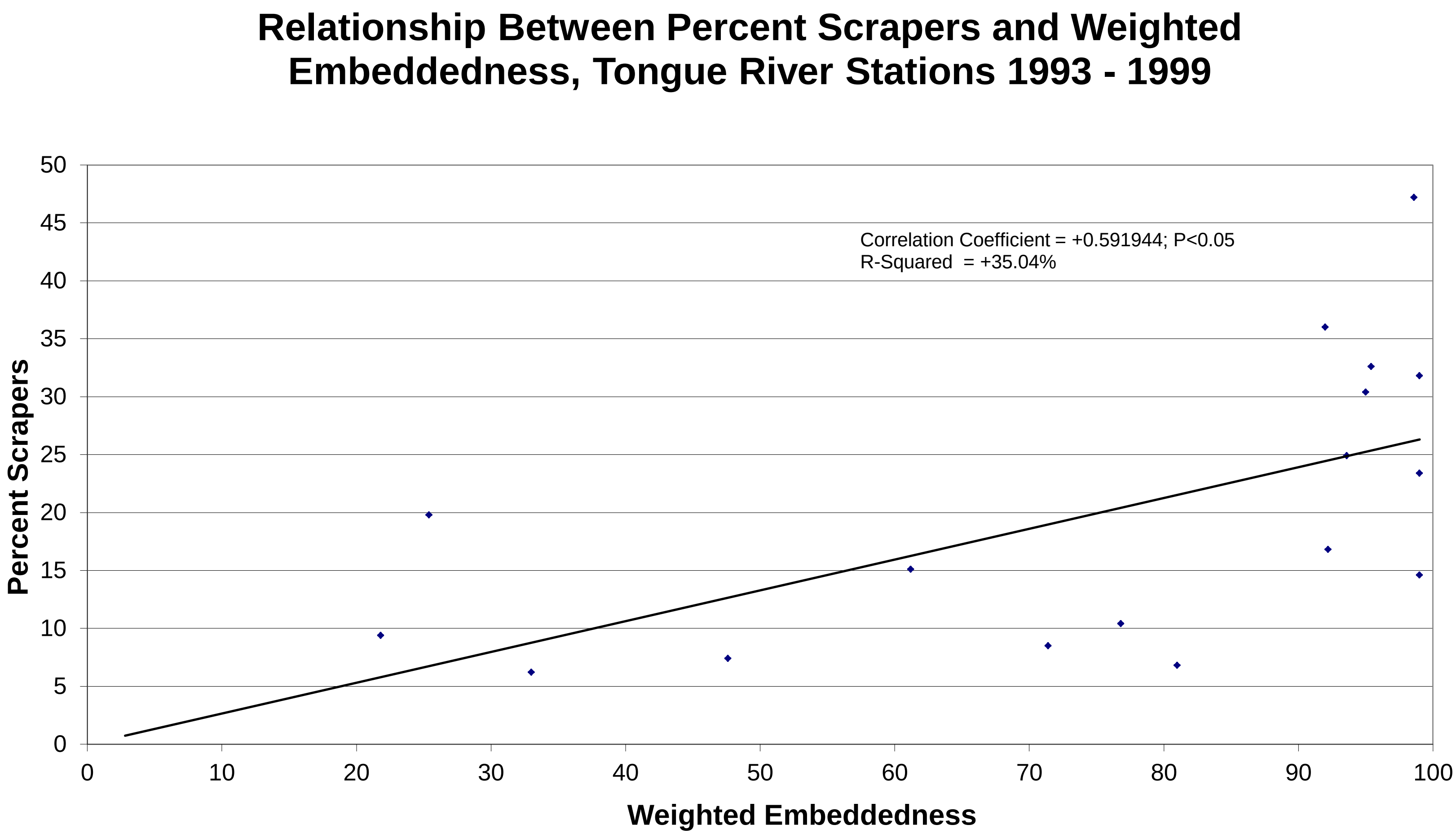

FIGURE 8-18. Scatterplot showing relationship between percent scrapers and Weighted Embeddedness (substrate silt cover) at Tongue River biomonitoring stations, 1993 through 1999, Sheridan County, Wyoming.

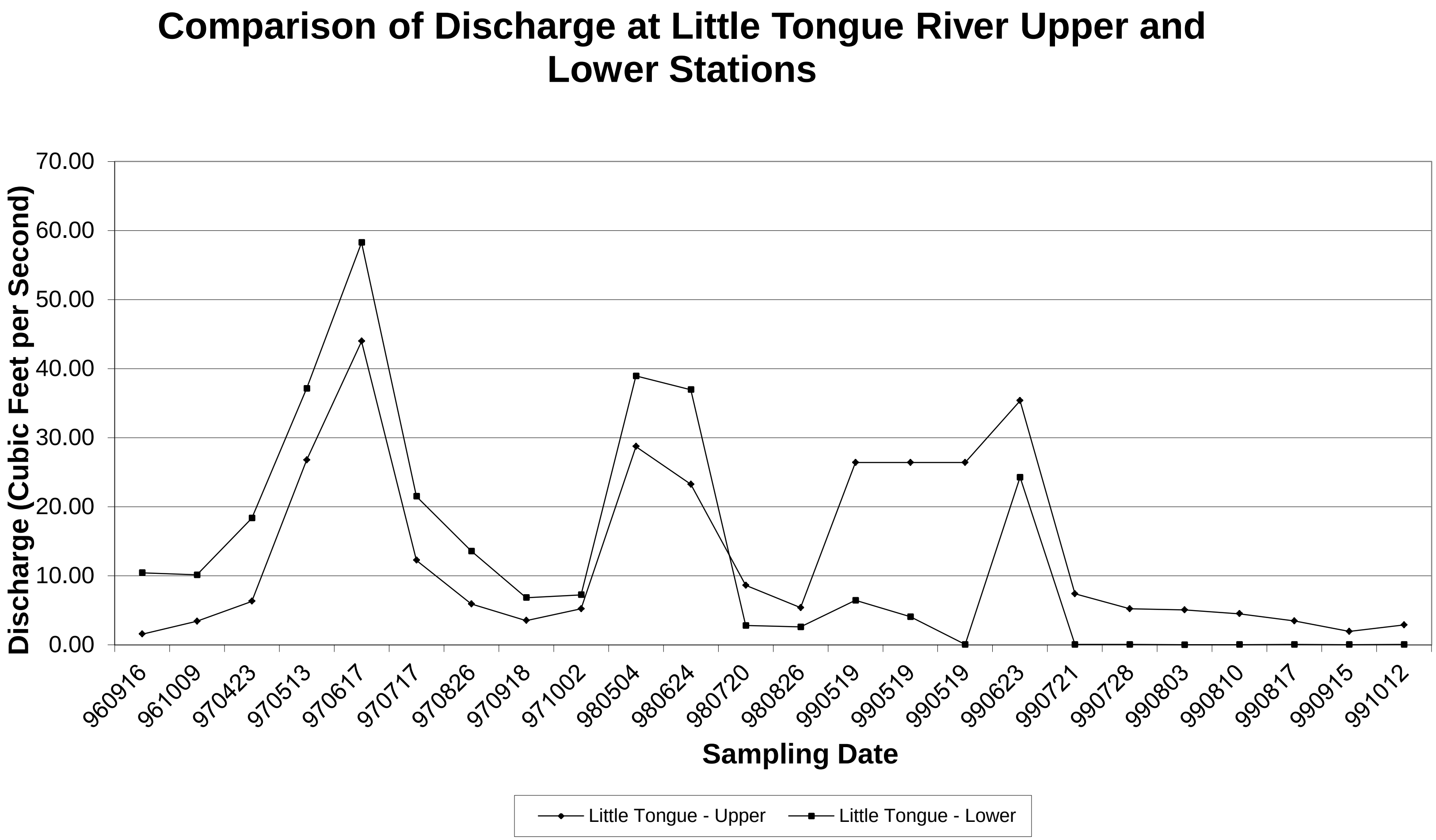

FIGURE 8-19. Comparison of discharge measurements recorded same day at Little Tongue River Upper and Lower stations collected by SCCD and WDEQ, 1996-1999, Sheridan County, Wyoming.

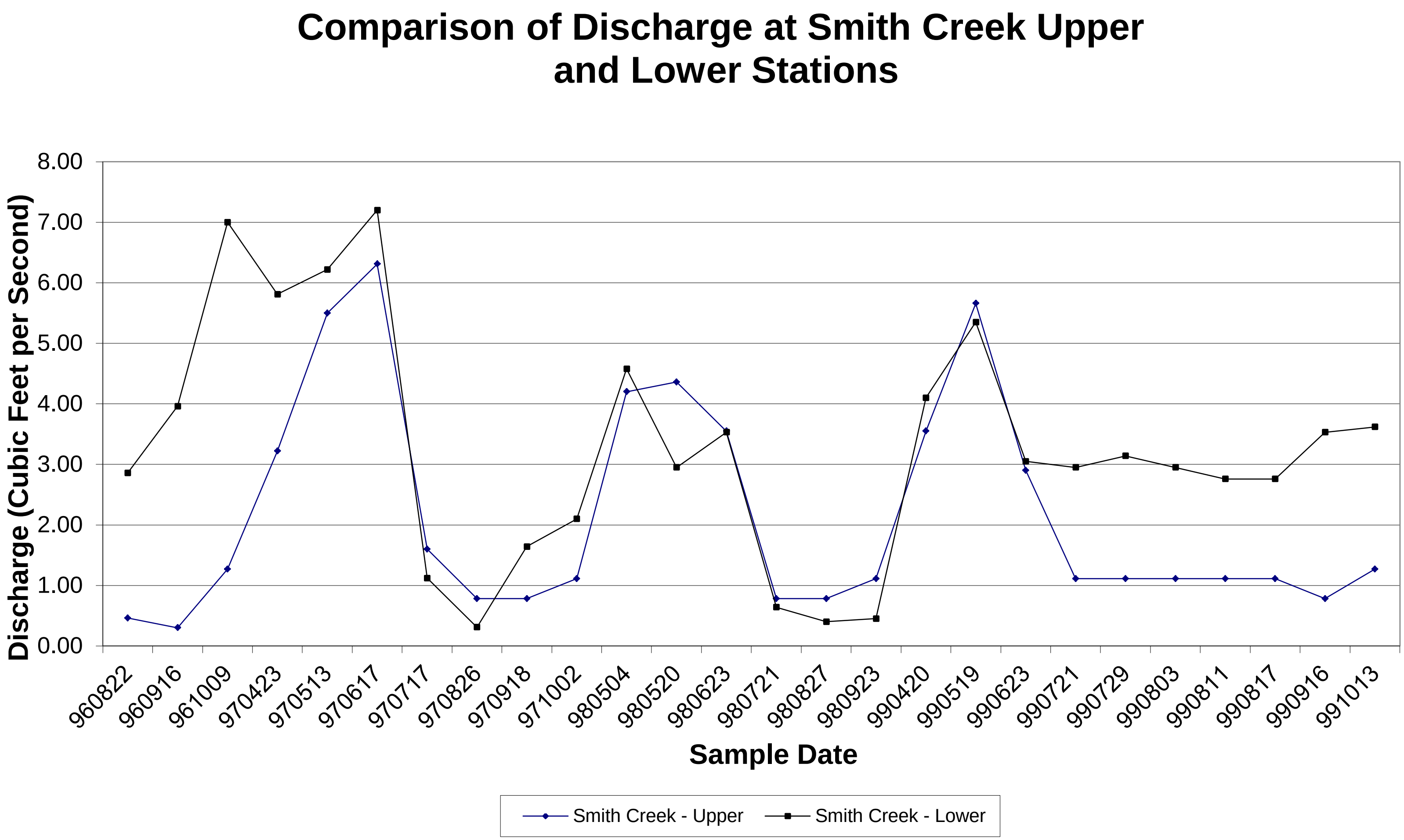

FIGURE 8-20. Comparison of discharge measurements recorded same day at Smith Creek Upper and Lower stations collected by SCCD and WDEQ, 1996-1999, Sheridan County, Wyoming.

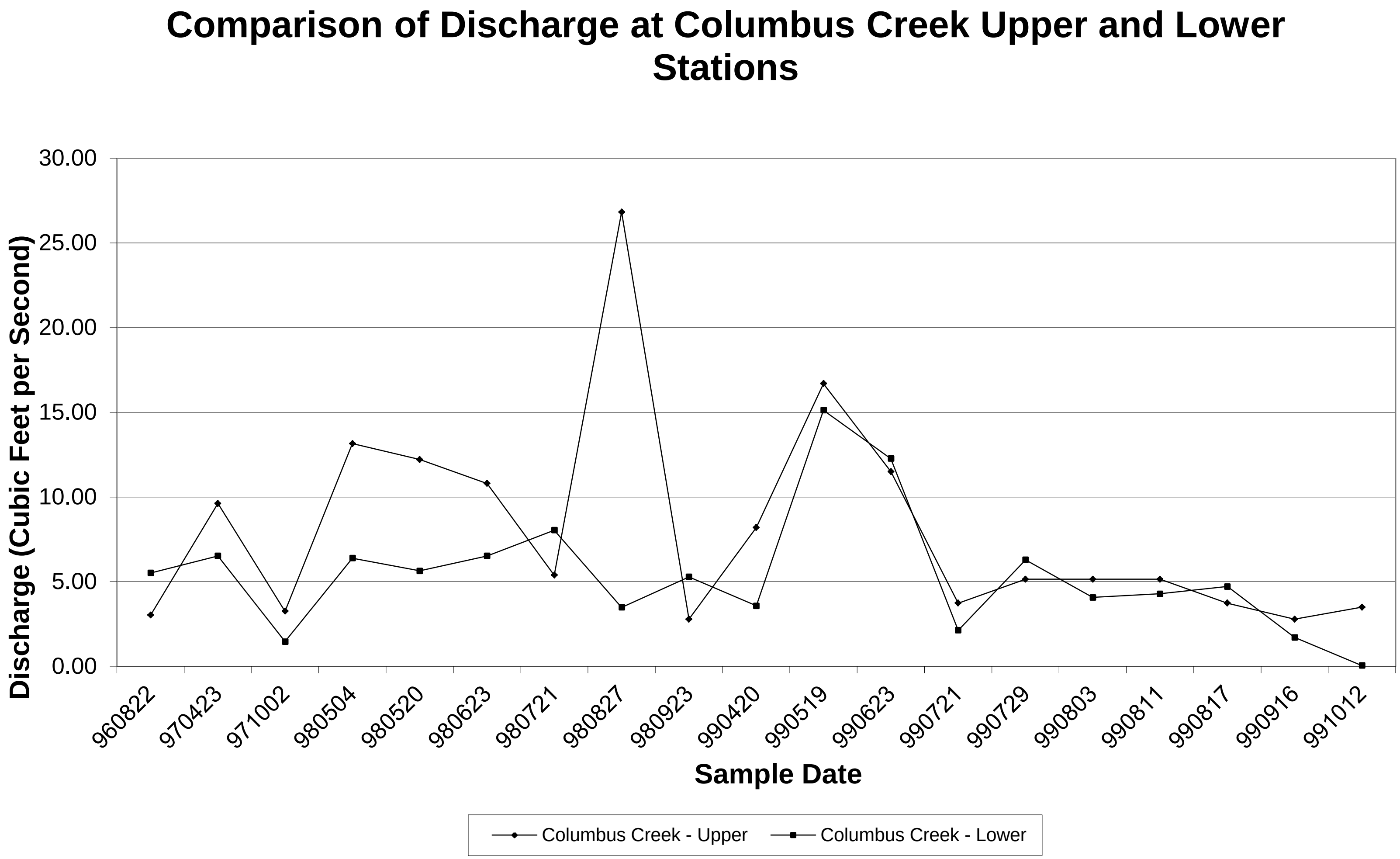

FIGURE 8-21. Comparison of discharge measurements recorded same day at Columbus Creek Upper and Lower stations collected by SCCD and WDEQ, 1996-1999, Sheridan County, Wyoming.

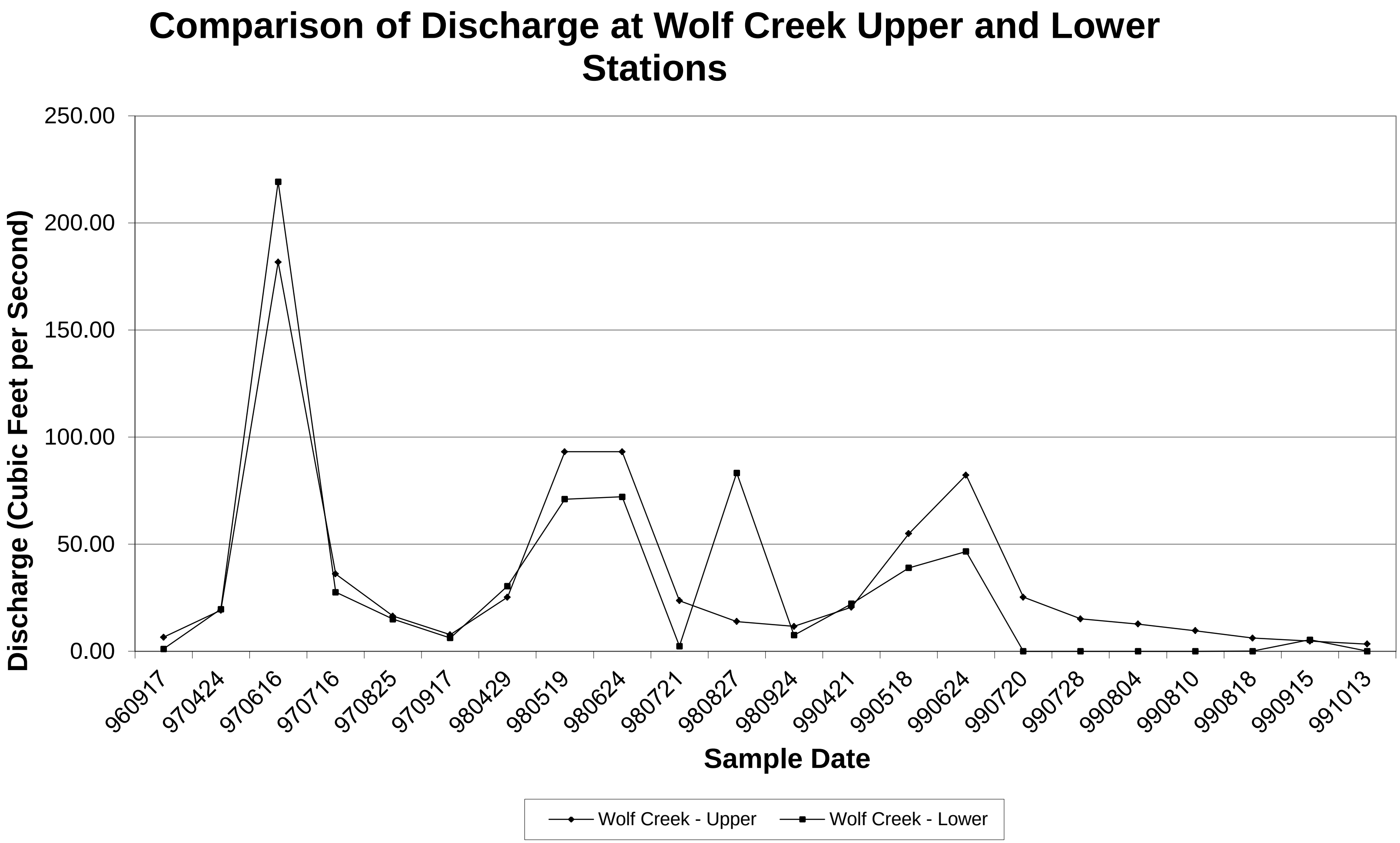

FIGURE 8-22. Comparison of discharge measurements recorded same day at Wolf Creek Upper and Lower stations collected by SCCD and WDEQ, 1996-1999, Sheridan County, Wyoming.

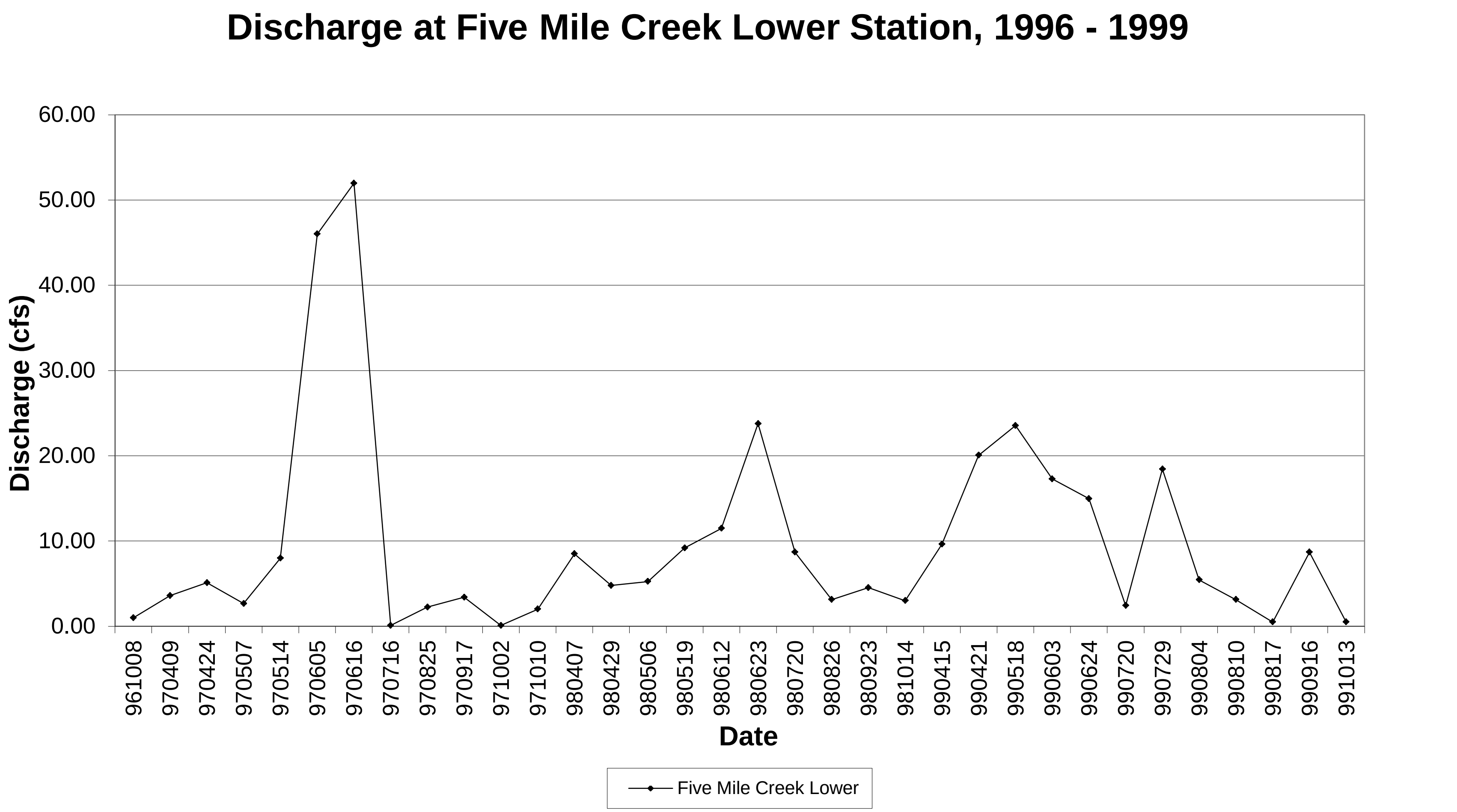

FIGURE 8-23. Discharge measurements at Five Mile Creek Lower station collected by SCCD and WDEQ, 1996-1999, Sheridan County, Wyoming.

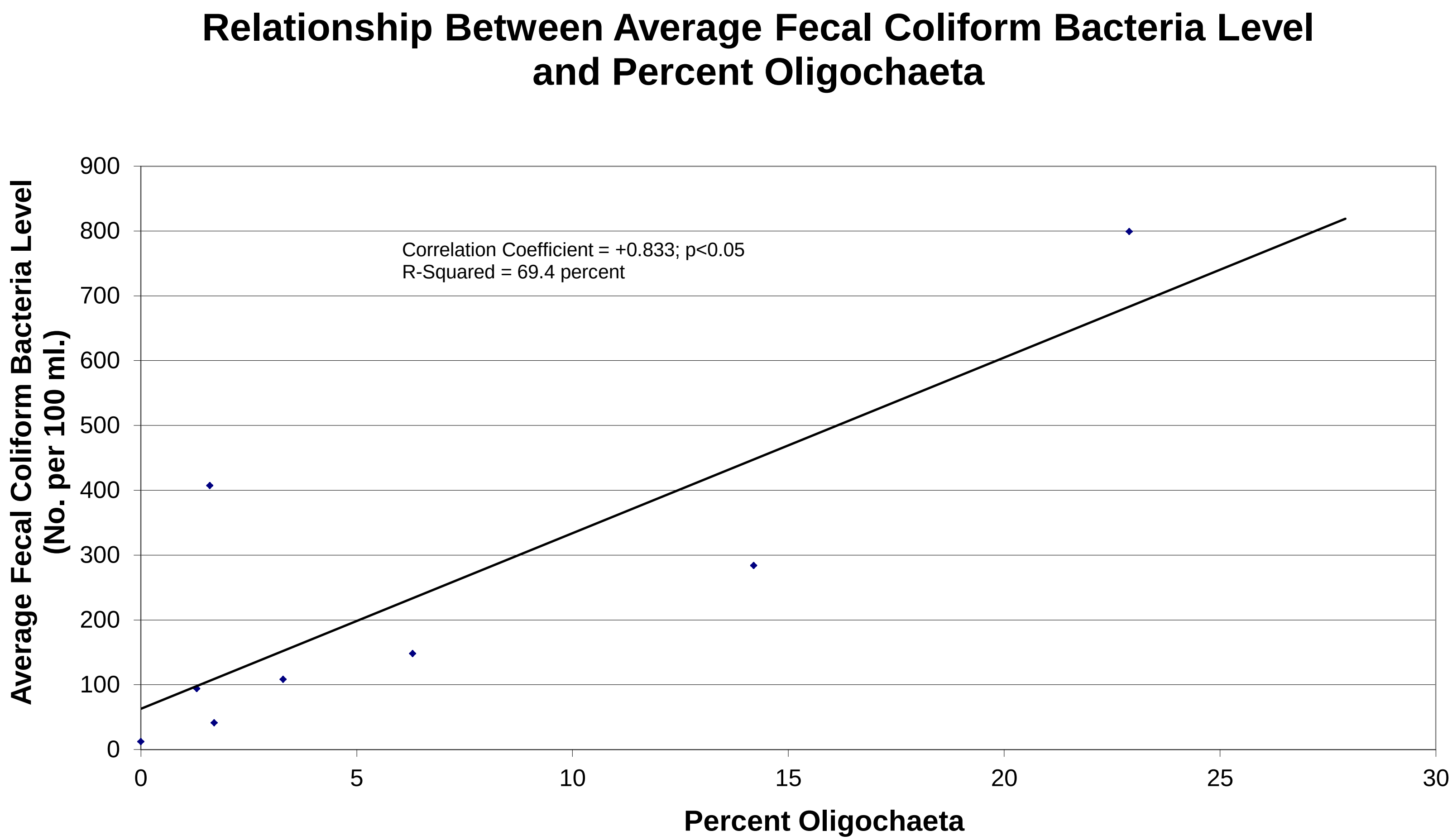

FIGURE 8-24. Scatterplot showing the relationship between the average fecal coliform bacteria level and percent Oligochaeta at mainstem Tongue River stations and Lower Tributary stations, 1996-1999, Sheridan County, Wyoming.

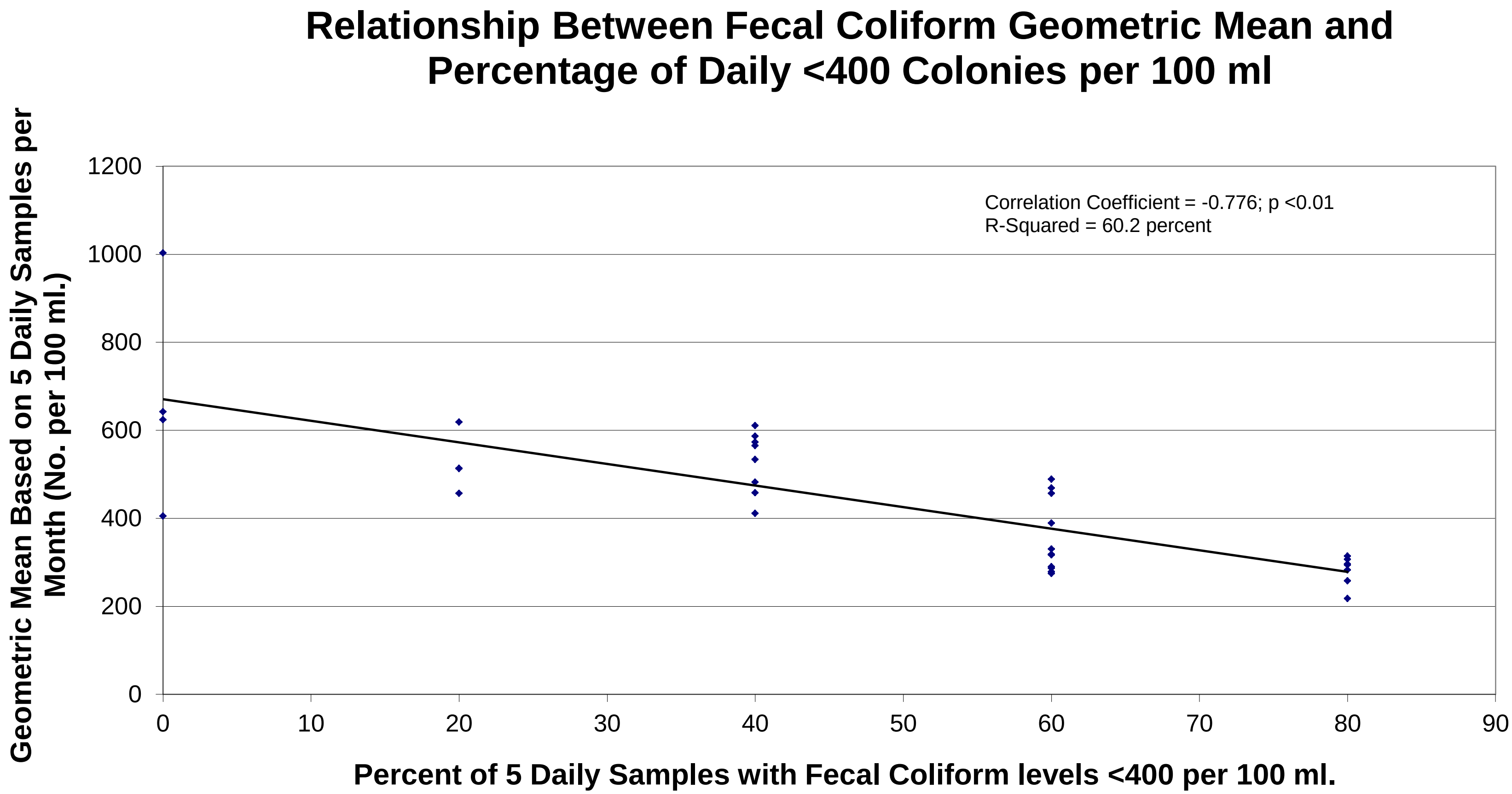

FIGURE 8-25. Scatterplot showing the relationship between the geometric mean and the number of five daily samples collected per month with fecal coliform bacteria levels <400 per 100 ml at stations exceeding the Wyoming fecal coliform standard in the Tongue River and Goose Creek watersheds, 1998 and 1999, Sheridan County, Wyoming.

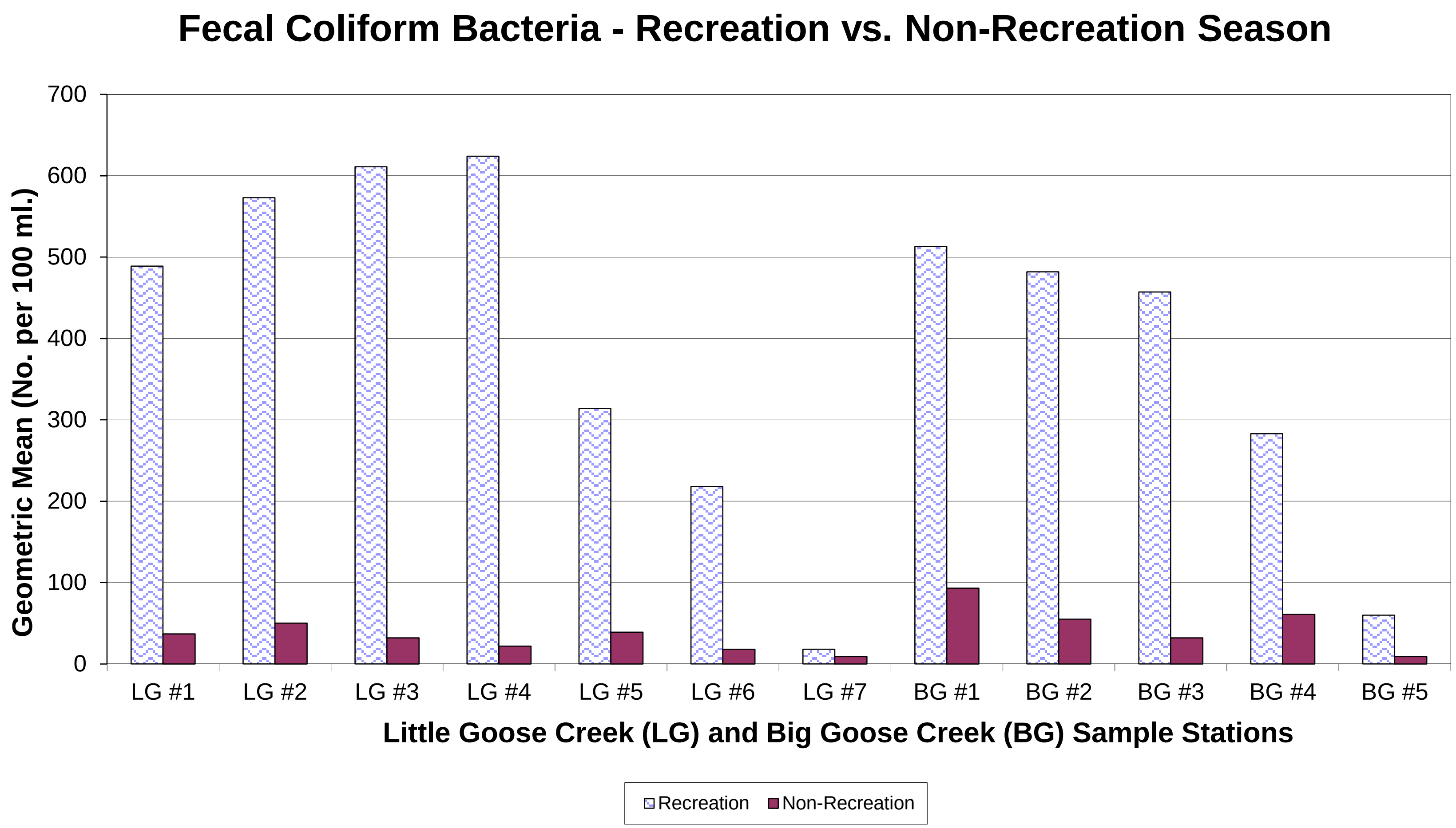

FIGURE 8-26. Comparison of fecal coliform bacteria levels at Little Goose Creek and Big Goose Creek stations during the Recreation (May 1 to September 30) and Non-Recreation seasons, 1998, Sheridan County, Wyoming.

TABLE 8-1. Summary Statistics for Discharge (cfs) Measured at Tongue River Upper, Middle and Lower Stations, Wolf Creek Upper and Lower Stations and Five Mile Creek Lower Stations During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	**Tongue River - Upper**					**Tongue River - Middle**					**Tongue River - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	7	11	10	13	41	4	11	20	12	47	4	11	10	15	40
Average	77	303	251	251	236	94	648	283	552	421	80	646	469	572	517
Median	86	113	156	137	114	94	171	121	184	129	85	204	437	358	226
Minimum	45	68	74	70	45	72	100	68	93	68	41	68	127	70	41
Maximum	88	1061	500	1108	1108	117	2484	992	2852	2852	110	2556	839	2629	2629
Geometric Mean	75	185	196	174	158	92	316	141	278	212	74	288	377	337	285

Summary Statistic	**Wolf Creek - Upper**					**Wolf Creek - Lower**					**Fivemile Creek - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	3	6	7	10	26	4	11	10	13	38	1	11	10	12	34
Average	5.7	55.8	40.7	23.5	33.5	6.3	59.2	43.7	28.7	39.2	1.0	11.4	8.2	10.4	9.8
Median	5.5	27.7	23.7	14.0	17.8	5.1	19.7	48.2	5.4	16.5	1.0	3.4	6.9	9.2	5.2
Minimum	5.0	7.8	11.7	3.4	3.4	1.1	4.6	2.4	0.04	0.04	1.0	0.1	3.0	0.5	0.1
Maximum	6.6	182	93.2	82.3	182	14.0	221	83.3	203	221	1.0	52.0	23.8	23.5	52.0
Geometric Mean	5.6	32.5	29.6	14.6	19.0	4.4	27.7	28.0	1.7	8.7	1.0	2.9	6.8	5.9	4.7

TABLE 8-2. Comparison of Average Daily Total Discharge (cfs), Average Daily Discharge during Primary Low-Irrigation Months (April, May, September and October) and Average Daily Discharge during Primary Irrigation Months (June, July and August) Measured Same Day During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Discharge Period	**Tongue River Upper versus Tongue River Middle**		
	Upper	**Middle**	**Percent Difference**
All Days (N = 29)	255	510	+100
Non-Irrigation Days (N = 17)	168	320	+90
Irrigation Days (N = 12)	380	780	+105
	Tongue River Middle versus Tongue River Lower		
	Middle	**Lower**	**Percent Difference**
All Days (N = 36)	518	550	+6
Non-Irrigation Days (N = 20)	323	422	+31
Irrigation Days (N = 16)	761	710	-7
	Little Tongue River Upper versus Little Tongue River Lower		
	Upper	**Lower**	**Percent Difference**
All Days (N = 24)	13.3	12.5	-6
Non-Irrigation Days (N = 12)	13.3	11.6	-13
Irrigation Days (N = 12)	13.4	13.4	0
	Smith Creek Upper versus Smith Creek Lower		
	Upper	**Lower**	**Percent Difference**
All Days (N = 26)	2.1	3.3	+57
Non-Irrigation Days (N = 13)	2.5	4.0	+60
Irrigation Days (N = 13)	1.7	2.6	+53
	Columbus Creek Upper versus Columbus Creek Lower		
	Upper	**Lower**	**Percent Difference**
All Days (N = 19)	8.0	5.4	-32
Non-Irrigation Days (N = 9)	8.0	5.1	-36
Irrigation Days (N = 10)	8.0	5.7	-29

TABLE 8-2. Con’t

Discharge Period	Wolf Creek Upper versus Wolf Creek Lower		
	Upper	Lower	Percent Difference
All Days (N = 11)	24.1	12.1	-50
Non-Irrigation Days (N = 5)	23.1	16.8	-27
Irrigation Days (N = 6)	25.0	8.2	-68

TABLE 8-3. Summary Statistics for Maximum Daily Water Temperature (C^0) Measured by Wyoming Game and Fish Department at Tongue River Canyon and Tongue River @ Ranchester Stations Using Continuous Recording Thermographs, Sheridan County, Wyoming

Summary Statistic	Tongue River - Canyon	Tongue River - Ranchester
	JUNE 28, 1988 - SEPT 12, 1988	JUNE 21, 1994 - SEPT 07, 1994
Number Samples	77	79
Average	14.5	26.5
Median	15.0	27.0
Minimum	7.0	20.8
Maximum	18.5	29.6
Geometric Mean	14.3	26.5
No. samples > 25.6 C^0	0	57 **WQV**
% of samples > 25.6 C^0	0	72.2 **WQV**

WQV = Violation of Wyoming Surface Water Quality Standards for Temperature

TABLE 8-4. Projected Number of Days Wyoming Water Quality Standard for Water Temperature was Exceeded at the Ranchester Water Treatment Plant, 1993 through 1999, Sheridan County, Wyoming

	Year						
Month	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
June	0	4	0	0	0	0	0
July	3	14	11	26	7	4	0
August	9	24	16	23	4	1	4
September	0	0	3	6	5	1	0
Total Days	12	42	30	55	16	6	4

TABLE 8-5. Summary Statistics for Water Temperature (C^0) Measured at Tongue River Upper, Middle and Lower Stations During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	**Tongue River - Upper**					**Tongue River - Middle**					**Tongue River - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	7	11	11	13	42	4	11	20	13	48	6	11	10	15	42
Average	8.3	8.7	10.1	10.7	9.6	12.0	10.1	7.2	12.6	9.8	9.2	10.9	11.8	13.3	11.7
Median	7.5	10.2	9.2	10.4	9.2	10.6	9.6	4.2	12.7	9.7	9.4	11.2	11.3	13.7	11.4
Minimum	3.2	1.1	3.3	2.6	1.1	7.8	0.7	0.5	5.1	0.5	2.5	1.4	5.5	5.4	1.4
Maximum	15.0	16.3	18.0	18.0	18.0	19.1	17.2	21.2	20.1	21.2	17.1	17.3	21.8	20.1	21.8
Geometric Mean	7.3	6.8	9.0	9.2	8.1	11.4	8.2	4.6	11.5	7.3	7.7	9.4	11.0	12.4	10.5
No. samples > 25.6 C^0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
% of samples > 25.6 C^0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 8-6. Summary Statistics for pH (Standard Units) Measured at Tongue River Upper, Middle and Lower Stations During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	**Tongue River - Upper**					**Tongue River - Middle**					**Tongue River - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	7	11	11	13	42	4	11	20	13	48	6	11	10	15	42
Average	8.3	8.2	8.0	8.2	8.2	8.2	8.1	8.0	8.1	8.0	8.0	8.1	7.9	8.0	8.0
Median	8.3	8.2	8.1	8.3	8.3	8.2	8.1	8.1	8.2	8.1	8.0	8.1	8.2	8.2	8.1
Minimum	7.9	7.9	6.9	7.6	6.9	7.9	7.7	6.9	7.5	6.9	7.4	7.8	6.8	7.1	6.8
Maximum	8.6	8.6	8.5	8.5	8.6	8.4	8.6	8.4	8.4	8.6	8.3	8.6	8.6	8.4	8.6
Geometric Mean	8.3	8.2	8.0	8.2	8.2	8.1	8.1	8.0	8.1	8.0	8.0	8.1	7.9	8.0	8.0
No. samples <6.5 or >9.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
% of samples <6.5 or >9.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 8-7. Summary Statistics for Conductivity (Micromhos per Centimeter) Measured at Tongue River Upper, Middle and Lower Stations During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	**Tongue River - Upper**					**Tongue River - Middle**					**Tongue River - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	7	11	11	13	42	4	11	20	13	48	6	11	10	15	42
Average	283	195	193	193	209	358	281	269	260	277	293	324	271	304	300
Median	240	207	201	201	207	355	292	283	274	289	376	333	275	338	322
Minimum	223	137	139	119	119	330	170	150	147	147	90	171	161	155	90
Maximum	530	232	254	250	530	390	410	375	346	410	414	495	460	363	495
Geometric Mean	270	193	190	189	202	357	271	262	254	269	242	310	259	296	282
No. Samples >7500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
% Samples >7500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 8-8. Summary Statistics for Dissolved Oxygen (Mg/l) Measured at Tongue River Upper, Middle and Lower Stations During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	**Tongue River - Upper**					**Tongue River - Middle**					**Tongue River - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	4	1	1	8	14	1	1	10	8	20	1	1	1	10	13
Average	10.4	12.0	11.1	9.6	10.2	10.0	12.1	12.1	9.6	11.0	9.0	12.2	11.5	9.6	9.9
Median	10.6	12.0	11.1	9.6	10.0	10.0	12.1	12.4	9.6	10.6	9.0	12.2	11.5	9.9	9.9
Minimum	9.1	12.0	11.1	8.1	8.1	10.0	12.1	10.6	8.1	8.1	9.0	12.2	11.5	7.9	7.9
Maximum	11.4	12.0	11.1	11.0	12.0	10.0	12.1	13.6	11.0	13.6	9.0	12.2	11.5	10.5	12.2
Geometric Mean	10.4	12.0	11.1	9.6	10.2	10.0	12.1	12.0	9.6	10.9	9.0	12.2	11.5	9.5	9.8
No. Samples < 5 mg/l	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
No. Samples < 4 mg/l	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 8-9. Summary Statistics for Turbidity (NTU) Analyses for Samples Collected at Tongue River Upper, Middle and Lower Stations, Wolf Creek Upper and Lower Stations and Five Mile Creek Lower Station During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	**Tongue River - Upper**					**Tongue River - Middle**					**Tongue River - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	7	11	11	13	42	4	11	20	13	48	6	11	10	15	42
Average	1.1	10.2	13.0	3.3	7.3	1.3	12.8	8.3	9.4	9.0	2.4	15.7	18.0	13.3	13.5
Median	1.0	6.0	10.0	1.5	3.4	1.4	13.0	1.5	3.5	3.6	2.0	11.0	16.0	4.0	5.8
Minimum	0.2	1.1	0.6	0.8	0.2	0.4	1.0	0.4	0.5	0.4	1.3	1.2	1.7	1.1	1.0
Maximum	2.0	24.0	26.0	15.0	26.0	2.0	30.0	33.0	33.0	33.0	5.3	41.0	40.0	61.0	61.0
Geometric Mean	0.8	6.4	10.0	2.1	3.6	1.1	7.9	2.8	4.4	3.7	2.1	9.4	13.9	6.1	7.1

Summary Statistic	**Wolf Creek - Upper**					**Wolf Creek - Lower**					**Five Mile Creek - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	4	6	7	10	27	4	11	10	13	38	5	11	10	11	37
Average	1.4	8.2	8.1	1.5	4.7	5.9	22.2	21.0	24.6	21.0	6.6	30.9	36.7	65.2	39.4
Median	1.2	8.0	7.0	0.6	2.1	7.0	19.0	17.5	6.5	15.5	6.5	27.0	36.0	50.0	34.0
Minimum	0.6	0.9	5.0	0.5	0.5	1.9	3.4	3.6	4.2	1.9	6.0	4.5	3.8	30.0	3.8
Maximum	2.6	17.0	15.0	7.5	17.0	7.9	48.0	41.0	125	125	7.6	100	90	155	155
Geometric Mean	1.2	5.0	7.6	0.9	2.4	5.2	15.1	17.6	12.6	13.2	6.6	21.5	28.1	58.0	26.5

TABLE 8-10. Summary Statistics for Fecal Coliform Bacteria (Number per 100 Milliliters) Analyses for Samples Collected at Tongue River Upper, Middle and Lower Stations During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	**Tongue River - Upper**					**Tongue River - Middle**					**Tongue River - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	3	7	7	10	27	3	7	17	10	37	3	7	7	10	27
Average	1	29	7	7	12	2	47	19	84	41	1	80	71	148	94
Median	1	20	4	4	5	1	43	9	84	16	1	64	14	60	25
Minimum	1	1	1	1	1	1	1	2	4	1	1	6	11	1	1
Maximum	1	90	21	20	90	5	100	126	200	200	2	270	260	1060	1060
Geometric Mean	1	15	4	5	5	2	28	10	44	15	1	41	29	38	25
Geometric Mean (Recreation Season)	NC[A]	NC	NC	7	NC	NC	NC	NC	90	NC	NC	NC	NC	63	NC
No. samples > 400/100ml	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
% of samples > 400/100ml	0	0	0	0	0	0	0	0	0	0	0	0	0	**10**[WQV]	4

NC[A] = Not calculated; less than 5 samples were collected during separate 24 periods within a 30 day period.

WQV = Violation of Wyoming Surface Water Quality Standard.

TABLE 8-11. Comparison of Summary Statistics for Fecal Coliform Bacteria (Number per 100 Milliliters) Analyses for Historical Samples and Samples Collected During Current Study at Tongue River Upper, Middle, and Lower Stations, Sheridan County, Wyoming

Summary Statistic	**Tongue-Upper**		**Tongue- Middle**		**Tongue - Lower**	
	Historical (1976-88)	**Current**	**Historical (1985-89)**	**Current**	**Historical (1968-90)**	**Current**
Number Samples	21	27	9	37	57	27
Average	15	12	233	41	137	94
Median	9	5	80	16	70	25
Minimum	1	1	14	1	1	1
Maximum	65	90	1028	200	1600	1060
Variance	274	354	11611	2705	49925	42560
Std. Deviation	16.6	18.8	340.8	52.0	223.4	206
Geometric Mean	6	5	94	15	71	25
No. samples > 400/100ml	0	0	2	0	2	1
% of samples > 400/100ml	0	0	**22**[WQV]	0	4	4

WQV = Violation of Wyoming Surface Water Quality Standard.

TABLE 8-12. Summary Statistics for Total Nitrate Nitrogen (Mg/l) Measured at Tongue River Upper, Middle and Lower Stations During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	**Tongue River - Upper**					**Tongue River - Middle**					**Tongue River - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	6	8	8	9	31	4	8	17	8	37	6	8	7	10	31
Average	.041	.038	.015	.022	.028	.028	.021	.043	.012	.030	.012	.027	.013	.021	.019
Median	.035	.008	.010	.010	.010	.025	.007	.040	.004	.020	.006	.010	.004	.005	.006
Minimum	.006	.001	.006	.001	.001	.010	.003	.004	.001	.001	.002	.006	.002	.003	.002
Maximum	.080	.130	.060	.090	.130	.050	.070	.100	.070	.100	.050	.070	.050	.120	.120
Geometric Mean	.027	.013	.011	.011	.013	.023	.011	.029	.005	.015	.007	.016	.006	.008	.009
No. Samples >10 mg/l)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 8-13. Summary Statistics for Total Phosphorus (Mg/l) Measured at Tongue River Upper, Middle and Lower Stations During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	**Tongue River - Upper**					**Tongue River - Middle**					**Tongue River - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	5	2	1	2	10	2	1	11	2	16	4	2	1	3	10
Average	.056	.028	.050	.028	.044	.029	.050	.050	.007	.041	.043	.029	.040	.005	.028
Median	.050	.028	.050	.028	.050	.029	.050	.050	.007	.045	.042	.029	.040	.004	.022
Minimum	.040	.006	.050	.007	.006	.008	.050	.020	.006	.006	.006	.008	.040	.004	.004
Maximum	.080	.050	.050	.050	.080	.050	.050	.090	.008	.090	.080	.050	.040	.006	.080
Geometric Mean	.054	.017	.050	.019	.035	.020	.050	.043	.007	.031	.030	.020	.040	.005	.016
No. Samples >0.10 mg/l	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
% Samples >0.10 mg/l	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 8-14. Summary Statistics for Alkalinity, Total Chloride, Total Hardness, Total Sulfate, and Total Suspended Solids Analyses for Samples Collected by WDEQ at Tongue River Upper (1993-1999), Middle and Lower Stations (1996-1999) During Tongue River 205j Project, Sheridan County, Wyoming

Summary Statistic	**Tongue River - Upper**					**Tongue River - Middle**					**Tongue River - Lower**				
	ALK	CL	HARD	SULF	TSS	ALK	CL	HARD	SULF	TSS	ALK	CL	HARD	SULF	TSS
Number Samples	7	7	7	7	7	14	14	14	14	14	4	4	4	4	4
Average	122	<5	209	<10	3	145	<5	176	23	2	174	<5	202	33	3
Median	125	<5	146	<10	2	140	<5	180	22	1	178	<5	201	32	3
Minimum	90	<5	124	<10	1	120	<5	149	17	1	160	<5	173	28	1
Maximum	140	<5	616	<10	6	170	<5	200	33	4	180	<5	235	40	6
Geometric Mean	121	<5	174	<10	2	144	<5	176	23	1	174	<5	201	32	2

TABLE 8-15. Scoring and assessment of biological condition for Tongue River Watershed 205j Project benthic macroinvertebrate communities based on the Wyoming Stream Integrity Index (WSII; from Stribling et al., 2000) and the Wyoming Biological Condition Index (WBCI; from Barbour et al., 1994) developed for streams less than 6,500 feet elevation in the Middle Rockies Central ecoregion of Wyoming

	WSII				**WBCI (Total Score Middle Rockies Streams)**	
	Middle Rockies		**Northwestern Great Plains**			
Sampling Station and Year	**Score**	**Rank**	**Score**	**Rank**	**Score**	**Rank**
Tongue River Upper (1993)	75.2	Good	NA[A]	NA[A]	43	Good
Tongue River Upper (1994)	75.5	Good	NA	NA	43	Good
Tongue River Upper (1995)	74.9	Good	NA	NA	41	Good
Tongue River Upper (1996)	78.0	Good	NA	NA	39	Good
Tongue River Upper (1997)	72.2	Good	NA	NA	43	Good
Tongue River Upper (1998)	71.5	Good	NA	NA	41	Good
Tongue River Upper (1999)	73.8	Good	NA	NA	41	Good
Tongue River @ USGS 06298000 (1999)	77.5	Good	NA	NA	39	Good
Tongue River ab Dayton WWTF (1998)	NA	NA	86.7	Very Good	NA	NA
Tongue River be Dayton WWTF (1998)	NA	NA	84.2	Very Good	NA	NA
Tongue River Middle (1996)	NA	NA	86.7	Very Good	NA	NA
Tongue River Middle (1997)	NA	NA	92.2	Very Good	NA	NA
Tongue River Middle (1998)	NA	NA	79.7	Very Good	NA	NA
Tongue River Middle (1999)	NA	NA	97.9	Very Good	NA	NA
Tongue River Lower (1996)	NA	NA	83.3	Very Good	NA	NA
Tongue River Lower (1997)	NA	NA	82.4	Very Good	NA	NA
Tongue River Lower (1998)	NA	NA	85.2	Very Good	NA	NA
Tongue River Lower (1999)	NA	NA	80.4	Very Good	NA	NA
Little Tongue River Upper (1993)	59.1	Fair	NA	NA	33	Fair

TABLE 8-15. Con't

	WSII				WBCI (Total Score Middle Rockies Streams)	
	Middle Rockies		North West Great Plains			
Sampling Station and Year	Score	Rank	Score	Rank	Score	Rank
Little Tongue River Lower (1996)	51.0	Fair	NA	NA	35	Fair
Little Tongue River Lower (1997)	66.5	Fair	NA	NA	35	Fair
Little Tongue River Lower (1998)	40.6	Fair	NA	NA	27	Fair
Little Tongue River Lower (1999)	42.9	Fair	NA	NA	29	Fair
Smith Creek Lower (1996)	NA	NA	57.1	Good	NA	NA
Smith Creek Lower (1997)	NA	NA	74.0	Good	NA	NA
Smith Creek Lower (1998)	NA	NA	68.4	Good	NA	NA
Smith Creek Lower (1999)	NA	NA	64.0	Good	NA	NA
Columbus Creek Upper	61.5	Fair	NA	NA	39	Good
Columbus Creek Lower (1996)	NA	NA	42.5	Fair	NA	NA
Columbus Creek Lower (1997)	NA	NA	58.6	Good	NA	NA
Columbus Creek Lower (1998)	NA	NA	53.1	Fair	NA	NA
Columbus Creek Lower (1999)	NA	NA	57.9	Good	NA	NA
Wolf Creek Upper @ Berry's	NA	NA	89.9	Very Good	NA	NA
Wolf Creek Lower (1996)	NA	NA	68.3	Good	NA	NA
Wolf Creek Lower (1997)	NA	NA	69.8	Good	NA	NA
Wolf Creek Lower (1998)	NA	NA	62.3	Good	NA	NA
Wolf Creek Lower (1999)	NA	NA	74.6	Good	NA	NA
Five Mile Creek Lower (1996)	NA	NA	30.8	Poor	NA	NA
Five Mile Creek Lower (1997)	NA	NA	47.5	Fair	NA	NA
Five Mile Creek Lower (1999)	NA	NA	34.6	Poor	NA	NA

NA[A] = Scoring and ranking not applicable to this ecoregion.

TABLE 8-16. Five Most Dominant Macroinvertebrate Taxa Based on Mean Abundance, Tolerance Value (TV) and Functional Feeding Group (FFG) Designation by Station Within the Tongue River Watershed Project Area, 1996 Through 1999

Tongue River - Upper				**Tongue River - Middle**			
Scientific Name	**Group**	**TV**	**FFG***	**Scientific Name**	**Group**	**TV**	**FFG**
Baetis tricaudatus	Mayfly	6	CG	*Hydropsyche*	Caddisfly	4	CF
Glossosoma	Caddisfly	1	SC	*Lepidostoma* - sand case larvae	Caddisfly	1	SH
Hydropsyche	Caddisfly	4	CF	*Brachycentrus occidentalis*	Caddisfly	1	OM
Ephemerella inermis/infrequens	Mayfly	1	CG	*Drunella grandis/spinifera*	Mayfly	0	CG
Drunella doddsi	Mayfly	0	CG	*Optioservus*	Riffle Beetle	4	SC

Tongue River - Lower				**Little Tongue River - Lower**			
Scientific Name	**Group**	**TV**	**FFG**	**Scientific Name**	**Group**	**TV**	**FFG**
Hydropsyche	Caddisfly	4	CF	*Cleptelmis*	Riffle Beetle	4	CG
Ephemerella inermis/infrequens	Mayfly	1	CG	*Paraleptophlebia*	Mayfly	4	CG
Baetis tricaudatus	Mayfly	6	CG	*Optioservus*	Riffle Beetle	4	SC
Tricorythodes minutus	Mayfly	4	CG	*Zaitzevia*	Riffle Beetle	4	CG
Microcylloepus	Riffle Beetle	7	SC	*Hydropsyche*	Caddisfly	4	CF

TABLE 8-16. Con't

Smith Creek - Lower				Columbus Creek - Lower			
Scientific Name	**Group**	**TV**	**FFG**	**Scientific Name**	**Group**	**TV**	**FFG**
Hydropsyche	Caddisfly	4	CF	*Hydropsyche*	Caddisfly	4	CF
Helicopsyche borealis	Caddisfly	7	SC	*Baetis tricaudatus*	Mayfly	6	CG
Optioservus	Riffle Beetle	4	SC	*Ophidonais serpentina*	Worm	8	CG
Paraleptophlebia	Mayfly	4	CG	*Uncinais uncinata*	Worm	8	CG
Baetis tricaudatus	Mayfly	6	CG	*Cheumatopsyche*	Caddisfly	8	CF

Wolf Creek - Lower				Five Mile Creek - Lower			
Scientific Name	**Group**	**TV**	**FFG**	**Scientific Name**	**Group**	**TV**	**FFG**
Microcylloepus	Riffle Beetle	7	SC	*Hydropsyche*	Caddisfly	4	CF
Hydropsyche	Caddisfly	4	CF	*Baetis tricaudatus*	Mayfly	6	CG
Helicopsyche borealis	Caddisfly	7	SC	*Simulium*	Black Fly	6	CF
Baetis tricaudatus	Mayfly	6	CG	*Nais variabilis*	Worm	8	CG
Tricorythodes minutus	Mayfly	4	CG	*Uncinais uncinata*	Worm	8	CG

FFG* = CG = Collector Gatherer; SC = Scraper; CF = Collector Filterer; SH = Shredder; OM = Omnivore.

TABLE 8-17.Habitat Assessment Scores for Tongue River 205j Project Stations, 1993 Through 1999

Habit Descriptor	Tongue River @ Canyon								Tongue above Dayton WWTF	Tongue below Dayton WWTF
	1993	1994	1995	1996	1997	1998	1999	Mean	1998	1998
Substrate / Percent Fines	19	16	18	18	17	19	19	18	20	19
Instream Cover	16	18	18	19	18	19	19	18	17	14
Embeddedness	18	19	17	19	20	20	20	19	20	20
Velocity / Depth	18	18	18	18	18	19	16	18	16	15
Channel Flow Status	18	18	18	19	19	18	19	18	14	12
Channel Shape	9	11	11	11	11	9	9	10	8	8
Pool Riffle Ratio	11	14	14	13	12	13	14	13	10	9
Channelization	15	15	15	14	14	15	15	15	8	8
Width Depth Ratio	7	9	13	13	11	11	6	10	6	7
Bank Vegetation Protection	8	9	9	9	9	9	10	9	8	8
Bank Stability	10	9	9	9	9	9	10	9	8	8
Disruptive Pressures	10	10	10	10	10	10	10	10	10	10
Riparian Zone Width	6	7	8	9	9	2	6	7	7	6
TOTAL SCORE	165	173	178	181	177	173	173	174	152	144

TABLE 8-18. Habitat Assessment Scores for Tongue River 205j Project Stations, 1996 Through 1999

Habit Descriptor	**Tongue River - Middle**					**Tongue River - Lower (@ Ranchester)**				
	1996	1997	1998	1999	Mean	1996	1997	1998	1999	Mean
Substrate / Percent Fines	19	20	19	17	19	20	19	20	20	20
Instream Cover	15	14	17	17	16	12	13	19	16	15
Embeddedness	11	19	16	13	15	1	7	4	2	4
Velocity / Depth	19	19	19	7	16	14	16	17	19	16
Channel Flow Status	14	15	14	10	13	15	16	15	15	15
Channel Shape	3	7	8	6	6	8	8	10	9	9
Pool Riffle Ratio	14	13	13	13	13	12	13	14	14	13
Channelization	10	10	9	11	10	11	9	9	11	10
Width Depth Ratio	8	8	8	4	7	5	2	2	3	3
Bank Vegetation Protection	8	9	8	8	8	8	7	8	7	8
Bank Stability	4	7	6	3	5	6	8	6	8	7
Disruptive Pressures	7	9	6	6	7	6	10	9	8	8
Riparian Zone Width	8	8	4	1	5	9	9	2	2	6
TOTAL SCORE	140	158	147	116	140	127	137	135	134	134

TABLE 8-19. Mean Percent Stream Substrate Composition, Percent Embeddedness and Current Velocity for Tongue River 205j Project Stations,1993 Through 1999

SUBSTRATE TYPE	Tongue River - Upper @ Canyon								Tongue above Dayton WWTF	Tongue below Dayton WWTF
	1993	1994	1995	1996	1997	1998	1999	Mean	1998	1998
Cobble	72	64	68	83	81	82	62	73	85	76
Coarse Gravel	15	18	11	7	9	10	16	12	12	16
Fine Gravel	7	10	7	4	3	4	19	8	3	6
Silt	0	1	0	0	0	0	0	1	0	0
Sand	6	8	4	5	7	3	3	5	1	2
Clay	0	0	0	0	0	0	0	0	0	0
EMBEDDEDNESS RATING Weighted Value	92.0	95.0	92.2	95.4	99.0	99.0	98.6	95.9	100	99
CURRENT VELOCITY (Feet Per Second)	2.4	1.7	2.2	2.3	1.7	2.4	1.9	2.1	2.5	2.5

TABLE 8-20. Mean Percent Stream Substrate Composition, Percent Embeddedness and Current Velocity for Tongue River 205j Project Stations,1996 Through 1999

SUBSTRATE TYPE	Tongue River - Middle					Tongue River - Lower (@ Ranchester)				
	1996	1997	1998	1999	Mean	1996	1997	1998	1999	Mean
Cobble	59	75	72	63	67	72	66	42	69	62
Coarse Gravel	23	14	17	7	15	18	24	51	18	28
Fine Gravel	15	11	8	24	14	9	7	7	14	9
Silt	0	0	0	0	0	0	1	0	0	1
Sand	3	0	3	6	3	1	2	0	0	1
Clay	0	0	0	0	0	0	0	0	0	0
EMBEDDEDNESS RATING Weighted Value	61.2	93.6	81.0	71.4	76.8	21.8	47.6	33.0	25.4	32.0
CURRENT VELOCITY (Feet Per Second)	2.3	2.4	2.4	2.1	2.3	3.2	2.3	2.3	2.6	2.6

TABLE 8-21. Summary Statistics for Discharge (cfs) Measured at Little Tongue River Upper, and Lower Stations, Smith Creek Upper and Lower Stations and Columbus Creek Upper and Lower Stations During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	**Little Tongue River - Upper**					**Little Tongue River - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	4	7	6	10	27	4	11	10	13	38
Average	2.0	14.8	17.2	10.2	11.7	8.0	23.9	18.9	7.5	15.3
Median	1.5	6.3	15.9	5.1	5.9	8.8	18.4	19.1	0.1	8.8
Minimum	1.4	3.5	5.4	1.9	1.4	4.0	4.8	0.5	<.1	<.1
Maximum	3.4	44.0	30.8	35.4	44.0	10.4	58.3	38.9	42.9	58.3
Geometric Mean	1.8	10.0	13.4	6.6	7.1	7.5	17.9	10.1	0.4	3.7

Summary Statistic	**Smith Creek - Upper**					**Smith Creek - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	3	7	6	10	26	4	11	10	13	38
Average	0.7	2.8	2.5	2.0	2.1	4.5	4.7	3.0	3.9	3.9
Median	0.5	1.6	2.3	1.1	1.1	4.0	5.8	3.2	3.5	3.8
Minimum	0.3	0.8	0.8	0.8	0.3	2.9	0.3	0.4	2.8	0.3
Maximum	1.3	6.3	4.4	5.7	6.3	7.0	11.0	5.4	7.2	11.0
Geometric Mean	0.6	2.0	1.9	1.6	1.6	4.2	3.3	2.1	3.7	3.1

Summary Statistic	**Columbus Creek - Upper**					**Columbus Creek - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	5	7	6	10	28	4	11	10	13	38
Average	2.6	9.0	11.9	6.6	7.6	2.2	8.4	5.4	9.2	7.2
Median	2.1	6.8	11.5	5.1	5.1	1.6	6.5	5.5	4.3	5.1
Minimum	1.8	3.2	2.8	2.8	1.8	0.0	1.0	1.5	0.05	0.0
Maximum	4.0	19.3	26.8	16.7	26.8	5.5	21.2	8.0	33.6	33.6
Geometric Mean	2.4	7.0	9.4	5.6	5.7	1.0	5.7	5.0	4.4	4.6

TABLE 8-22. Summary Statistics for Water Temperature (C^0) Measured at Little Tongue River Upper and Lower and Smith Creek Upper and Lower Stations During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	**Little Tongue River - Upper**					**Little Tongue River - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	4	7	6	7	24	2	11	10	12	35
Average	9.2	10.3	11.3	11.1	10.7	15.4	11.0	10.9	12.4	11.7
Median	9.6	10.9	11.2	10.6	10.8	15.4	11.1	10.7	12.2	11.3
Minimum	4.6	5.1	7.7	7.1	4.6	13.4	1.2	5.3	4.7	1.2
Maximum	15.9	14.7	15.6	15.5	15.9	17.5	18.9	19.0	20.8	20.8
Geometric Mean	8.9	9.7	11.0	10.6	10.1	15.3	9.3	10.2	11.5	10.6
No. samples > 25.6 C^0	0	0	0	0	0	0	0	0	0	0
% of samples > 25.6 C^0	0	0	0	0	0	0	0	0	0	0

Summary Statistic	**Smith Creek - Upper**					**Smith Creek - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	3	7	6	10	26	4	11	10	13	38
Average	11.3	9.1	10.2	10.7	10.2	12.3	11.8	12.0	13.8	12.6
Median	10.9	9.3	9.3	11.2	9.5	12.2	11.4	11.8	13.8	12.8
Minimum	8.6	4.8	6.4	6.4	4.8	9.5	0.5	5.3	4.7	0.5
Maximum	14.5	12.6	14.4	13.9	14.5	15.3	19.5	17.8	21.1	21.1
Geometric Mean	11.1	8.7	9.9	10.4	9.8	12.1	9.2	11.3	12.7	11.2
No. samples > 25.6 C^0	0	0	0	0	0	0	0	0	0	0
% of samples > 25.6 C^0	0	0	0	0	0	0	0	0	0	0

TABLE 8-23. Summary Statistics for pH (Standard Units) Measured at Little Tongue River Upper and Lower and Smith Creek Upper and Lower Stations During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	**Little Tongue River - Upper**					**Little Tongue River - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	4	7	6	10	27	4	11	10	13	38
Average	8.2	7.9	7.9	8.1	8.0	8.3	8.2	8.0	8.0	8.1
Median	8.3	7.9	8.0	8.0	8.0	8.3	8.2	8.2	8.1	8.2
Minimum	7.8	7.6	7.1	7.9	7.1	8.0	7.8	7.4	7.6	7.4
Maximum	8.6	8.3	8.3	8.3	8.6	8.5	8.5	8.4	8.4	8.5
Geometric Mean	8.2	7.9	7.9	8.1	8.0	8.3	8.2	8.0	8.0	8.1
No. samples <6.5 or >9.0	0	0	0	0	0	0	0	0	0	0
% of samples <6.5 or >9.0	0	0	0	0	0	0	0	0	0	0

Summary Statistic	**Smith Creek - Upper**					**Smith Creek - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	3	7	6	10	26	4	11	10	13	38
Average	8.2	8.1	8.0	8.2	8.1	8.3	8.3	8.1	8.2	8.2
Median	8.2	8.1	8.1	8.2	8.1	8.2	8.3	8.2	8.2	8.2
Minimum	7.9	7.8	7.1	7.8	7.1	8.1	8.1	6.8	7.8	6.8
Maximum	8.4	8.4	8.3	8.8	8.8	8.5	8.6	8.6	8.7	8.7
Geometric Mean	8.2	8.1	8.0	8.2	8.1	8.3	8.3	8.1	8.2	8.2
No. samples <6.5 or >9.0	0	0	0	0	0	0	0	0	0	0
% of samples <6.5 or >9.0	0	0	0	0	0	0	0	0	0	0

TABLE 8-24. Summary Statistics for Conductivity (Micromhos per Centimeter) Measured at Little Tongue River Upper and Lower and Smith Creek Upper and Lower Stations During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	**Little Tongue River - Upper**					**Little Tongue River - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	4	7	6	10	27	4	11	10	13	48
Average	405	190	176	233	234	576	453	371	428	436
Median	358	195	158	244	227	573	383	314	471	408
Minimum	324	102	95	124	95	380	197	197	214	197
Maximum	580	293	277	327	580	780	706	829	745	829
Geometric Mean	394	175	163	222	212	552	410	330	396	395
No. Samples >7500	0	0	0	0	0	0	0	0	0	0
% Samples >7500	0	0	0	0	0	0	0	0	0	0

Summary Statistic	**Smith Creek - Upper**					**Smith Creek - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	3	7	6	10	26	4	11	10	13	38
Average	502	362	345	353	371	500	648	551	550	574
Median	435	360	352	362	360	497	608	476	515	546
Minimum	380	329	303	295	295	420	494	375	383	375
Maximum	690	414	363	387	690	585	910	943	703	943
Geometric Mean	485	361	345	351	366	494	636	524	542	557
No. Samples >7500	0	0	0	0	0	0	0	0	0	0
% Samples >7500	0	0	0	0	0	0	0	0	0	0

TABLE 8-25. Summary Statistics for Dissolved Oxygen (Mg/l) Measured at Little Tongue River Upper and Lower and Smith Creek Upper and Lower Stations During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	**Little Tongue River - Upper**					**Little Tongue River - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	1	NC*	NC	8	9	1	1	1	8	11
Average	9.7	NC	NC	9.6	9.6	8.9	10.0	9.8	9.6	9.5
Median	9.7	NC	NC	9.8	9.7	8.9	10.0	9.8	9.7	9.7
Minimum	9.7	NC	NC	7.8	7.8	8.9	10.0	9.8	7.2	7.2
Maximum	9.7	NC	NC	10.7	10.7	8.9	10.0	9.8	10.4	10.4
Geometric Mean	9.7	NC	NC	9.5	9.6	8.9	10.0	9.8	9.5	9.5
No. Samples < 5 mg/l	0	NC	NC	0	0	0	0	0	0	0
No. Samples < 4 mg/l	0	NC	NC	0	0	0	0	0	0	0

Summary Statistic	**Smith Creek - Upper**					**Smith Creek - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	NC*	NC	NC	8	8	1	1	1	8	11
Average	NC	NC	NC	9.3	9.3	9.1	9.7	10.1	9.0	9.2
Median	NC	NC	NC	9.2	9.2	9.1	9.7	10.1	9.0	9.1
Minimum	NC	NC	NC	7.9	7.9	9.1	9.7	10.1	7.9	7.9
Maximum	NC	NC	NC	10.4	10.4	9.1	9.7	10.1	10.1	10.1
Geometric Mean	NC	NC	NC	9.3	9.3	9.1	9.7	10.1	9.0	9.2
No. Samples < 5 mg/l	NC	NC	NC	0	0	0	0	0	0	0
No. Samples < 4 mg/l	NC	NC	NC	0	0	0	0	0	0	0

NC* = No samples collected.

TABLE 8-26. Summary Statistics for Turbidity (NTU) Analyses for Samples Collected at Little Tongue River Upper and Lower and Smith Creek Upper and Lower Stations During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	**Little Tongue River - Upper**					**Little Tongue River - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	4	7	6	10	27	4	11	10	13	38
Average	1.3	9.2	11.1	1.8	5.8	1.3	10.4	16.3	3.1	8.5
Median	1.4	8.0	9.5	1.5	2.5	1.2	6.0	13.5	1.0	4.6
Minimum	0.1	1.7	8.0	0.5	0.1	0.6	0.6	0.3	0.5	0.3
Maximum	2.4	19.0	20.0	3.5	20.0	2.3	25.0	36.0	16.0	36.0
Geometric Mean	0.8	6.8	10.6	1.5	3.2	1.2	5.7	10.4	1.4	3.5

Summary Statistic	**Smith Creek - Upper**					**Smith Creek - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	3	7	6	10	26	4	11	10	13	38
Average	0.9	5.7	9.3	1.0	4.2	4.3	18.2	26.0	19.0	19.0
Median	1.0	6.0	8.0	1.0	1.5	4.1	10.0	20.5	9.6	10.0
Minimum	0.3	1.2	7.0	0.5	0.3	2.5	1.8	6.1	5.2	1.8
Maximum	1.5	11.0	14.0	1.5	14.0	6.4	43.0	79.0	53	79
Geometric Mean	0.8	4.4	9.1	1.0	2.4	4.0	12.1	19.0	14.2	12.8

TABLE 8-27. Summary Statistics for Fecal Coliform Bacteria (Number per 100 Milliliters) Analyses for Samples Collected at Little Tongue River Upper and Lower Stations During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	**Little Tongue River - Upper**					**Little Tongue River - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	2	7	6	10	25	3	7	7	10	27
Average	2	1	6	33	15	1	72	40	214	108
Median	2	1	2	11	2	1	82	23	126	62
Minimum	1	1	1	1	1	1	6	1	11	1
Maximum	2	3	23	98	98	1	100	110	770	770
Geometric Mean	1	1	3	11	4	1	57	17	92	32
Geometric Mean (Recreation Season)	NC[A]	NC	NC	55	NC	NC	NC	NC	**290**[WQV]	NC
No. samples > 400/100ml	0	0	0	0	0	0	0	0	2	2
% of samples > 400/100ml	0	0	0	0	0	0	0	0	**20**[WQV]	7

NC[A] = Not calculated; less than 5 samples were collected during separate 24 periods within a 30 day period.

WQV = Violation of Wyoming Surface Water Quality Standard.

TABLE 8-28. Summary Statistics for Total Nitrate Nitrogen (Mg/l) Analyses for Samples Collected at Little Tongue River Upper and Lower and Smith Creek Upper and Lower Stations During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	**Little Tongue River - Upper**					**Little Tongue River - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	3	NC*	NC	1	4	2	8	7	10	27
Average	.090	NC	NC	.020	0.01	.042	.027	.026	.011	.022
Median	.070	NC	NC	.020	0.01	.042	.009	.005	.008	.008
Minimum	.030	NC	NC	.020	0.03	.005	.005	.001	.002	.001
Maximum	.170	NC	NC	.020	0.17	.080	.130	.110	.050	.130
Geometric Mean	.071	NC	NC	.020	0.08	.020	.013	.009	.007	.010
No. Samples >10 mg/l	0	NC	NC	0	0	0	0	0	0	0

Summary Statistic	**Smith Creek - Upper**					**Smith Creek - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	1	NC*	NC	1	2	4	8	7	8	27
Average	.170	NC	NC	.140	.155	.068	.061	.020	.010	.036
Median	.170	NC	NC	.140	.155	.065	.030	.010	.006	.020
Minimum	.170	NC	NC	.140	.140	.004	.002	.004	.001	.001
Maximum	.170	NC	NC	.140	.170	.140	.190	.060	.030	.190
Geometric Mean	.170	NC	NC	.140	.154	.036	.030	.014	.006	.016
No. Samples >10 mg/l	0	NC	NC	0	0	0	0	0	0	0

NC* = No samples collected.

TABLE 8-29. Summary Statistics for Total Phosphorus (Mg/l) Analyses for Samples Collected at Little Tongue River Upper and Lower and Smith Creek Upper and Lower Stations During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	**Little Tongue River - Upper**					**Little Tongue River - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	2	NC*	NC	1	3	1	1	1	3	6
Average	.045	NC	NC	.020	.037	.020	.050	.090	.030	.042
Median	.045	NC	NC	.020	.040	.020	.050	.090	.020	.035
Minimum	.040	NC	NC	.020	.020	.020	.050	.090	.020	.020
Maximum	.050	NC	NC	.020	.050	.020	.050	.090	.050	.090
Geometric Mean	.045	NC	NC	.020	.034	.020	.050	.090	.027	.035
No. Samples >0.10 mg/l	0	NC	NC	0	0	0	0	0	0	0
% Samples >0.10 mg/l	0	NC	NC	0	0	0	0	0	0	0

Summary Statistic	**Smith Creek - Upper**					**Smith Creek - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	1	NC*	NC	1	2	2	1	1	2	6
Average	.020	NC	NC	.006	.013	.065	.080	.060	.065	.067
Median	.020	NC	NC	.006	.013	.065	.080	.060	.065	.065
Minimum	.020	NC	NC	.006	.006	.050	.080	.060	.060	.050
Maximum	.020	NC	NC	.006	.020	.080	.080	.060	.070	.080
Geometric Mean	.020	NC	NC	.006	.011	.063	.080	.060	.065	.066
No. Samples >0.05 mg/l	0	NC	NC	0	0	0	0	0	0	0
% Samples >0.05 mg/l	0	NC	NC	0	0	0	0	0	0	0

NC* = No samples collected.

TABLE 8-30. Summary Statistics for Alkalinity, Total Chloride, Total Hardness, Total Sulfate, and Total Suspended Solids Analyses for Samples Collected by WDEQ at Little Tongue River Upper (1993) and Lower (1996-1999) and Smith Creek Upper and Lower Stations (1996-1999) During Tongue River 205j Project, Sheridan County, Wyoming

Summary Statistic	**Little Tongue River - Upper**					**Little Tongue River - Lower**				
	ALK	CL	HARD	SUL F	TSS	ALK	CL	HARD	SULF	TSS
Number Samples	1	1	1	1	1	4	4	4	4	4
Average	180	<5	205	<10	<2	220	<5	380	201	2
Median	180	<5	205	<10	<2	220	<5	391	206	1
Minimum	180	<5	205	<10	<2	200	<5	346	153	1
Maximum	180	<5	205	<10	<2	240	<5	392	238	3
Geometric Mean	180	<5	205	<10	<2	220	<5	379	198	1

Summary Statistic	**Smith Creek - Upper**					**Smith Creek - Lower**				
	ALK	CL	HARD	SUL F	TSS	ALK	CL	HARD	SULF	TSS
Number Samples	NC*	NC	NC	NC	NC	4	4	4	4	4
Average	NC	NC	NC	NC	NC	271	<5	361	151	10
Median	NC	NC	NC	NC	NC	265	<5	353	137	9
Minimum	NC	NC	NC	NC	NC	235	<5	281	113	1
Maximum	NC	NC	NC	NC	NC	320	<5	456	216	20
Geometric Mean	NC	NC	NC	NC	NC	269	<5	355	146	6

NC* = No samples collected at this station

TABLE 8-31. Habitat Assessment Scores for Columbus Creek and Little Tongue River 205j Project Stations, 1993 Through1999

Habit Descriptor	**Columbus Cr. Upper**	**Columbus Cr. Lower**					**Little Tongue Upper**	**Little Tongue Lower**				
	1993	1996	1997	1998	1999	Mean	1993	1996	1997	1998	1999	Mean
Substrate / Percent Fines	11	8	5	11	6	8	19	20	19	19	16	18
Instream Cover	15	1	3	4	4	3	15	10	6	5	10	8
Embeddedness	12	1	0	1	1	1	2	13	13	12	7	11
Velocity / Depth	15	1	14	10	7	8	14	10	9	9	9	9
Channel Flow Status	17	16	17	17	8	14	9	14	16	15	8	13
Channel Shape	12	8	7	7	7	7	11	9	7	7	7	8
Pool Riffle Ratio	12	4	6	6	2	4	14	5	7	6	5	6
Channelization	14	9	9	9	10	9	15	9	10	10	6	9
Width Depth Ratio	10	9	8	10	9	9	11	1	1	3	9	4
Bank Vegetation Protection	8	1	2	8	2	3	8	8	9	8	9	8
Bank Stability	6	0	4	6	2	3	9	7	9	8	8	8
Disruptive Pressures	6	4	6	8	8	6	10	8	6	8	8	8
Riparian Zone Width	9	4	4	0	0	2	10	3	1	2	1	2
TOTAL SCORE	147	66	85	97	66	77	147	117	113	112	103	112

TABLE 8-32. Mean Percent Stream Substrate Composition, Percent Embeddedness and Current Velocity for Columbus Creek and Little Tongue River 205j Project Stations,1993 Through 1999

SUBSTRATE TYPE	**Columbus Cr. Upper**	**Columbus Cr. Lower**					**Little Tongue Upper**	**Little Tongue Lower**				
	1993	1996	1997	1998	1999	Mean	1993	1996	1997	1998	1999	Mean
Cobble	64	33	38	29	42	36	95	59	58	69	56	60
Coarse Gravel	10	16	3	28	12	15	4	30	24	17	14	21
Fine Gravel	8	18	1	24	2	11	10	9	16	12	22	15
Silt	3	26	46	0	43	29	0	0	0	0	0	0
Sand	16	8	0	19	1	7	0	1	2	2	8	3
Clay	0	0	12	0	0	3	0	0	0	0	0	0
EMBEDDEDNESS RATING Weighted Value	81	23.2	20.0	22.4	21.8	21.8	27	71.8	68.6	66.0	45.2	62.9
CURRENT VELOCITY (Feet Per Second)	2.6	0.6	0.6	0.6	0.05	0.5	0.8	1.3	0.7	1.2	0.7	1.0

TABLE 8-33. Summary Statistics for Fecal Coliform Bacteria (Number per 100 Milliliters) Analyses for Samples Collected at Smith Creek Upper and Lower Stations During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	**Smith Creek - Upper**					**Smith Creek - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	2	7	6	10	25	3	7	7	10	23
Average	1	38	22	62	41	8	603	87	459	407
Median	1	11	20	54	15	8	160	80	305	160
Minimum	1	3	1	1	1	1	50	8	65	8
Maximum	1	180	47	160	180	14	2790	184	2150	2790
Geometric Mean	1	14	8	23	12	5	222	61	278	176
Geometric Mean (Recreation Season)	NC[A]	NC	NC	57	NC	NC	NC	NC	**534**[WQV]	NC
No. samples > 400/100ml	0	0	0	0	0	0	2	0	3	5
% of samples > 400/100ml	0	0	0	0	0	0	**29**[WQV]	0	**30**[WQV]	**11**[WQV]

NC[A] = Not calculated; less than 5 samples were collected during separate 24 periods within a 30 day period.

WQV = Violation of Wyoming Surface Water Quality Standard.

TABLE 8-34. Summary Statistics for Discharge (CFS) Measured at Columbus Creek Upper and Lower Stations During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	Columbus Creek - Upper					Columbus Creek - Lower				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	5	7	6	10	28	4	11	10	13	38
Average	2.6	9.0	11.9	6.6	7.6	2.2	8.4	5.4	9.2	7.2
Median	2.1	6.8	11.5	5.1	5.1	1.6	6.5	5.5	4.3	5.1
Minimum	1.8	3.2	2.8	2.8	1.8	0.0	1.0	1.5	0.05	0.0
Maximum	4.0	19.3	26.8	16.7	26.8	5.5	21.2	8.0	33.6	33.6
Geometric Mean	2.4	7.0	9.4	5.6	5.7	1.0	5.7	5.0	4.4	4.6

TABLE 8-35. Summary Statistics for Water Temperature (C^0) Measured at Columbus Creek Upper and Lower Stations During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	Columbus Creek - Upper					Columbus Creek - Lower				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	5	7	6	10	28	4	11	10	13	38
Average	8.6	8.9	9.6	10.5	9.6	13.0	12.2	13.2	14.9	13.5
Median	6.9	8.9	8.7	11.0	9.2	11.4	11.9	14.2	14.8	13.0
Minimum	6.6	5.2	6.3	6.5	5.2	10.5	0.5	6.0	4.1	0.5
Maximum	12.4	11.9	14.1	13.6	14.1	18.6	18.9	17.5	25.1	25.1
Geometric Mean	8.3	8.6	9.3	10.2	9.2	12.6	9.3	12.7	13.6	11.8
No. samples > 25.6 C^0	0	0	0	0	0	0	0	0	0	0
% of samples > 25.6 C^0	0	0	0	0	0	0	0	0	0	0

TABLE 8-36. Summary Statistics for pH (Standard Units) Measured at Columbus Creek Upper and Lower Stations During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	**Columbus Creek - Upper**					**Columbus Creek - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	5	7	6	10	28	4	11	10	13	38
Average	8.2	8.4	8.0	8.2	8.2	8.0	8.1	7.9	7.8	7.9
Median	8.3	8.5	8.1	8.2	8.3	7.9	8.1	8.0	8.0	8.0
Minimum	7.9	8.1	7.1	7.5	7.1	7.8	7.8	6.8	7.3	6.8
Maximum	8.5	8.6	8.4	8.5	8.6	8.3	8.5	8.4	8.1	8.5
Geometric Mean	8.2	8.4	8.0	8.1	8.2	8.0	8.1	7.9	7.8	7.9
No. samples <6.5 or >9.0	0	0	0	0	0	0	0	0	0	0
% of samples <6.5 or >9.0	0	0	0	0	0	0	0	0	0	0

TABLE 8-37. Summary Statistics for Conductivity (Micromhos per Centimeter) Measured at Columbus Creek Upper and Lower Stations During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	**Columbus Creek - Upper**					**Columbus Creek - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	5	7	6	10	28	4	11	10	13	38
Average	442	401	374	404	404	546	639	428	498	525
Median	439	401	370	409	406	545	590	346	397	454
Minimum	370	319	330	323	319	300	386	274	260	260
Maximum	493	496	419	476	496	794	931	842	977	977
Geometric Mean	440	398	372	403	401	502	610	395	446	479
No. Samples >7500	0	0	0	0	0	0	0	0	0	0
% Samples >7500	0	0	0	0	0	0	0	0	0	0

TABLE 8-38. Summary Statistics for Dissolved Oxygen (Mg/l) Analyses for Samples Collected at Columbus Creek Upper and Lower Stations During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	**Columbus Creek - Upper**					**Columbus Creek - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	1	NC*	NC	8	9	1	1	1	9	12
Average	11.0	NC	NC	10.0	10.1	8.0	11.2	9.7	8.8	9.0
Median	11.0	NC	NC	10.0	10.1	8.0	11.2	9.7	8.4	8.8
Minimum	11.0	NC	NC	8.1	8.1	8.0	11.2	9.7	7.9	7.9
Maximum	11.0	NC	NC	10.9	11.0	8.0	11.2	9.7	9.9	11.2
Geometric Mean	11.0	NC	NC	10.0	10.1	8.0	11.2	9.7	8.8	9.0
No. Samples < 5 mg/l	0	NC	NC	0	0	0	0	0	0	0
No. Samples < 4 mg/l	0	NC	NC	0	0	0	0	0	0	0

NC* = No samples collected.

TABLE 8-39. Summary Statistics for Turbidity (NTU) Analyses for Samples Collected at Columbus Creek Upper and Lower Stations During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	**Columbus Creek - Upper**					**Columbus Creek - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	5	7	6	10	28	4	11	10	12	37
Average	0.7	6.2	12.0	1.5	4.8	21.4	48.4	41.9	73.0	51.7
Median	1.0	6.0	11.5	1.4	1.6	17.2	36.0	30.5	80.0	36.0
Minimum	0.04	0.6	9.0	0.5	0.04	15.0	10.0	105	6.5	3.4
Maximum	1.2	14.0	15.0	3.5	15.0	36.0	120	105	185	185
Geometric Mean	0.4	4.3	11.8	1.3	2.3	20.0	38.1	30.0	49.2	36.2

TABLE 8-40. Summary Statistics for Fecal Coliform Bacteria (Number per 100 Milliliters) Analyses for Samples Collected at Columbus Creek Upper and Lower Stations During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	**Columbus Creek - Upper**					**Columbus Creek - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	3	7	6	11	27	3	7	7	9	27
Average	1	76	558	45	162	115	414	95	395	284
Median	1	19	12	47	19	13	200	64	480	190
Minimum	1	1	1	1	1	1	8	15	5	1
Maximum	1	390	3300	110	3300	330	1800	290	750	1800
Geometric Mean	1	11	15	23	12	16	153	59	227	107
Geometric Mean (Recreation Season)	NC[A]	NC	NC	49	NC	NC	NC	NC	**405**[WQV]	NC
No. samples > 400/100ml	0	0	1	0	1	0	2	0	5	7
% of samples > 400/100ml	0	0	**17**[WQV]	0	4	0	**29**[WQV]	0	**56**[WQV]	**26**[WQV]

NC[A] = Not calculated; less than 5 samples were collected during separate 24 periods within a 30 day period.

WQV = Violation of Wyoming Surface Water Quality Standard.

TABLE 8-41. Summary Statistics for Total Nitrate Nitrogen (Mg/l) Analyses for Samples Collected at Columbus Creek Upper and Lower Stations During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	**Columbus Creek - Upper**					**Columbus Creek - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	4	7	6	8	25	4	8	7	8	27
Average	.380	.138	.064	.146	.161	.019	.133	.029	.024	.057
Median	.095	.140	.065	.055	.090	.008	.030	.020	.014	.010
Minimum	.008	.070	.004	.004	.004	.001	.002	.001	.001	.001
Maximum	1.32	.190	.120	.720	1.32	.060	.800	.080	.090	.800
Geometric Mean	.099	.130	.044	.064	.076	.007	.025	.015	.012	.015
No. Samples >10 mg/l	0	0	0	0	0	0	0	0	0	0

TABLE 8-42. Summary Statistics for Total Phosphorus (Mg/l) Analyses for Samples Collected at Columbus Creek Upper and Lower Stations During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	**Columbus Creek - Upper**					**Columbus Creek - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	2	NC*	NC	1	3	2	1	1	2	6
Average	.055	NC	NC	.006	.039	.060	.060	.020	.094	.065
Median	.055	NC	NC	.006	.040	.060	.060	.020	.094	.045
Minimum	.040	NC	NC	.006	.006	.030	.060	.020	.008	.008
Maximum	.070	NC	NC	.006	.070	.090	.060	.020	.180	.180
Geometric Mean	.053	NC	NC	.006	.026	.051	.060	.020	.038	.041
No. Samples >0.10 mg/l	0	NC	NC	0	0	0	0	0	1	1
% Samples >0.10 mg/l	0	NC	NC	0	0	0	0	0	50	17

NC* = No samples collected.

TABLE 8-43. Summary Statistics for Alkalinity, Total Chloride, Total Hardness, Total Sulfate, and Total Suspended Solids Analyses for Samples Collected by WDEQ at Columbus Creek River Upper (1993) and Lower (1996-1999) During Tongue River 205j Project, Sheridan County, Wyoming

Summary Statistic	**Columbus Creek - Upper**					**Columbus Creek - Lower**				
	ALK	CL	HARD	SUL F	TSS	ALK	CL	HARD	SULF	TSS
Number Samples	1	1	1	1	1	4	4	4	4	4
Average	170	<5	320	68	<2	326	10	392	162	18
Median	170	<5	320	68	<2	352	10	410	180	20
Minimum	170	<5	320	68	<2	210	2.5	239	65	6
Maximum	170	<5	320	68	<2	390	17.3	510	223	23
Geometric Mean	170	<5	320	68	<2	317	8	378	147	15

TABLE 8-44. Summary Statistics for Water Temperature (C^0) Measured at Wolf Creek Upper and Lower and Five Mile Creek Lower Stations During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	**Wolf Creek - Upper**					**Wolf Creek - Lower**					**Five Mile Creek - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	4	6	7	10	27	4	11	10	13	38	5	11	10	12	38
Average	9.3	9.1	10.5	11.3	10.3	12.8	12.2	13.5	14.4	13.4	12.6	13.5	13.8	15.4	14.1
Median	8.2	9.2	10.3	12.1	9.6	11.8	12.0	12.8	13.1	12.1	10.9	13.1	12.7	17.5	13.0
Minimum	5.6	4.4	5.1	4.1	4.1	9.6	0.9	6.7	6.3	0.9	10.0	0.7	6.6	5.5	0.7
Maximum	15.0	13.2	14.8	16.3	16.3	18.2	19.7	21.0	22.0	22.0	20.8	21.1	22.6	21.7	22.6
Geometric Mean	8.6	8.4	9.7	10.4	9.5	12.5	10.2	12.8	13.3	12.1	12.0	10.8	13.2	14.3	12.6
No. samples > 25.6 C^0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
% of samples > 25.6 C^0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 8-45. Summary Statistics for pH (Standard Units) Measured at Wolf Creek Upper and Lower and Five Mile Lower Stations During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	**Wolf Creek - Upper**					**Wolf Creek - Lower**					**Five Mile Creek - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	4	6	7	10	27	4	11	10	13	38	5	11	10	12	38
Average	8.2	7.8	7.6	7.8	7.8	8.1	8.1	7.9	7.9	8.0	7.9	8.1	8.0	8.0	8.0
Median	8.2	7.8	7.5	7.8	7.8	8.1	8.0	8.0	8.0	8.0	7.8	8.1	8.0	8.0	8.0
Minimum	8.0	7.5	6.9	7.3	6.9	7.9	7.8	7.3	7.5	7.3	7.7	7.7	7.6	7.6	7.6
Maximum	8.4	8.3	8.1	8.4	8.4	8.2	8.5	8.4	8.3	8.5	8.3	8.5	8.2	8.4	8.5
Geometric Mean	8.2	7.8	7.6	7.8	7.8	8.0	8.1	7.9	7.9	8.0	7.9	8.1	7.9	8.0	8.0
No. samples <6.5 or >9.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
% of samples <6.5 or >9.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 8-46. Summary Statistics for Conductivity (Micromhos per Centimeter) Measured at Wolf Creek Upper and Lower and Five Mile Creek Lower Stations During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	**Wolf Creek - Upper**					**Wolf Creek - Lower**					**Five Mile Creek - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	4	6	7	10	27	4	11	10	13	38	5	11	10	12	38
Average	376	171	147	180	198	638	416	386	381	429	919	971	751	696	819
Median	294	173	170	181	180	654	440	386	389	430	690	854	686	644	717
Minimum	280	86	78	84	78	530	156	198	144	144	157	608	468	381	157
Maximum	635	230	181	276	635	713	608	964	576	964	1568	1824	1145	1599	1824
Geometric Mean	352	162	139	172	179	633	382	368	352	388	704	914	715	646	742
No. Samples >7500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
% Samples >7500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 8-47. Summary Statistics for Dissolved Oxygen (Mg/l) Analyses for Samples Collected at Wolf Creek Upper and Lower and Five Mile Creek Lower Stations During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	**Wolf Creek - Upper**					**Wolf Creek - Lower**					**Five Mile Creek - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	1	NC*	NC	8	9	1	1	1	9	12	1	1	1	7	10
Average	11.2	NC	NC	9.8	10.0	8.4	9.8	10.1	9.5	9.5	8.5	10.8	7.9	9.5	9.4
Median	11.2	NC	NC	9.8	10.0	8.4	9.8	10.1	9.3	9.4	8.5	10.8	7.9	9.4	9.0
Minimum	11.2	NC	NC	8.4	8.4	8.4	9.8	10.1	8.1	8.1	8.5	10.8	7.9	8.3	7.9
Maximum	11.2	NC	NC	11.6	11.6	8.4	9.8	10.1	13.0	13.0	8.5	10.8	7.9	11.2	11.2
Geometric Mean	11.2	NC	NC	9.8	9.9	8.4	9.8	10.1	9.4	9.4	8.5	10.8	7.9	9.4	9.3
No. Samples < 5 mg/l	0	NC	NC	0	0	0	0	0	0	0	0	0	0	0	0
No. Samples < 4 mg/l	0	NC	NC	0	0	0	0	0	0	0	0	0	0	0	0

NC* = No samples collected.

TABLE 8-48. Summary Statistics for Turbidity (NTU) Analyses for Samples Collected at Wolf Creek Upper and Lower and Five Mile Creek Lower Stations During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	**Wolf Creek - Upper**					**Wolf Creek - Lower**					**Five Mile Creek - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	4	6	7	10	27	4	11	10	13	38	5	11	10	11	37
Average	1.4	8.2	8.1	1.5	4.7	5.9	22.2	21.0	24.6	21.0	6.6	30.9	36.7	65.2	39.4
Median	1.2	8.0	7.0	0.6	2.1	7.0	19.0	17.5	6.5	15.5	6.5	27.0	36.0	50.0	34.0
Minimum	0.6	0.9	5.0	0.5	0.5	1.9	3.4	3.6	4.2	1.9	6.0	4.5	3.8	30.0	3.8
Maximum	2.6	17.0	15.0	7.5	17.0	7.9	48.0	41.0	125	125	7.6	100	90	155	155
Geometric Mean	1.2	5.0	7.6	0.9	2.4	5.2	15.1	17.6	12.6	13.2	6.6	21.5	28.1	58.0	26.5

TABLE 8-49. Summary Statistics for Fecal Coliform Bacteria (Number per 100 Milliliters) Analyses for Samples Collected at Wolf Creek Upper and Lower and Five Mile Creek Lower Stations During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	**Wolf Creek - Upper**					**Wolf Creek - Lower**					**Five Mile Creek - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	2	6	9	10	25	3	7	7	10	27	3	7	7	10	27
Average	3	18	5	14	11	5	194	118	176	148	34	359	396	1620	799
Median	3	16	5	8	6	3	163	64	120	109	50	150	250	305	190
Minimum	1	1	1	1	1	1	4	3	16	1	1	45	27	9	1
Maximum	5	37	9	41	41	12	570	460	700	700	52	910	1170	9100	9100
Geometric Mean	2	11	3	7	5	3	102	42	111	57	14	207	196	359	185
Geometric Mean (Recreation Season)	NC[A]	NC	NC	17	NC	NC	NC	NC	147	NC	NC	NC	NC	**565**[WQV]	NC
No. samples > 400/100ml	0	0	0	0	0	0	1	1	1	3	0	3	2	3	8
% of samples > 400/100ml	0	0	0	0	0	0	**14**[WQV]	**14**[WQV]	**10**[WQV]	**11**[WQV]	0	**26**[WQV]	**26**[WQV]	**30**[WQV]	**30**[WQV]

NC[A] = Not calculated; less than 5 samples were collected during separate 24 periods within a 30 day period.

WQV = Violation of Wyoming Surface Water Quality Standard.

TABLE 8-50. Summary Statistics for Total Nitrate Nitrogen (Mg/l) Analyses for Samples Collected at Wolf Creek Upper and Lower and Five Mile Creek Lower Stations During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	**Wolf Creek - Upper**					**Wolf Creek - Lower**					**Five Mile Creek - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	2	NC*	NC	1	3	4	8	7	8	27	5	8	7	8	28
Average	.065	NC	NC	.020	.050	.019	.018	.012	.006	.013	.266	.965	.498	.276	.526
Median	.065	NC	NC	.020	.050	.010	.018	.006	.006	.007	.150	.380	.190	.195	.260
Minimum	.050	NC	NC	.020	.020	.002	.002	.050	.002	.002	.100	.009	.100	.005	.005
Maximum	.080	NC	NC	.020	.080	.050	.050	.080	.010	.050	.600	5.32	1.32	.870	5.32
Geometric Mean	.063	NC	NC	.020	.043	.013	.007	.063	.006	.008	.214	.303	.312	.122	.222
No. Samples >10 mg/l	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

NC* = No samples collected.

TABLE 8-51. Summary Statistics for Total Phosphorus (Mg/l) Analyses for Samples Collected at Wolf Creek Upper and Lower and Five Mile Creek Lower Stations During Tongue River 205j Project, 1996 - 1999, Sheridan County, Wyoming

Summary Statistic	**Wolf Creek - Upper**					**Wolf Creek - Lower**					**Fivemile Creek - Lower**				
	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total	1996	1997	1998	1999	Total
Number Samples	2	NC*	NC	1	3	2	1	1	2	6	2	2	1	2	7
Average	.026	NC	NC	.004	.018	.008	.080	.060	.003	.027	.055	.070	.002	.065	.055
Median	.026	NC	NC	.004	.004	.008	.080	.060	.003	.008	.055	.070	.002	.065	.050
Minimum	.001	NC	NC	.004	.001	.006	.080	.060	.003	.003	.050	.050	.002	.050	.002
Maximum	.050	NC	NC	.004	.050	.010	.080	.060	.003	.080	.060	.090	.002	.080	.090
Geometric Mean	.007	NC	NC	.004	.006	.008	.080	.060	.003	.012	.054	.067	.002	.063	.038
No. Samples >0.10 mg/l	0	NC	NC	0	0	0	0	0	0	0	0	0	0	0	0
% Samples >0.10 mg/l	0	NC	NC	0	0	0	0	0	0	0	0	0	0	0	0

NC* = No samples collected.

TABLE 8-52. Summary Statistics for Alkalinity, Total Chloride, Total Hardness, Total Sulfate, and Total Suspended Solids Analyses for Samples Collected by WDEQ at Wolf Creek River - Berry's (1995) and Lower (1996-1999) and Five Mile Creek Lower Stations (1996-1999) During Tongue River 205j Project, Sheridan County, Wyoming

Summary Statistic	**Wolf Creek - Upper (Berry's)**					**Wolf Creek - Lower**					**Fivemile Creek - Lower**				
	ALK	CL	HARD	SULF	TSS	ALK	CL	HARD	SULF	TSS	ALK	CL	HARD	SULF	TSS
Number Samples	1	1	1	1	1	4	4	4	4	4	3	4	4	4	4
Average	190	<5	264	779	<2	244	<5	293	83	7	420	10	556	392	11
Median	190	<5	264	779	<2	235	<5	294	81	6	490	10	633	472	10
Minimum	190	<5	264	779	<2	230	<5	251	67	5	240	2.5	296	131	5
Maximum	190	<5	264	779	<2	275	<5	334	101	10	530	17	663	495	17
Geometric Mean	190	<5	264	779	<2	243	<5	291	81	7	396	8	529	346	10

TABLE 8-53. Habitat Assessment Scores for Five Mile Creek, Wolf Creek and Smith Creek 205j Project Stations, 1995 Through1999

Habit Descriptor	**Five Mile Cr. Lower**				**Wolf Cr. Upper**	**Wolf Creek Lower**					**Smith Creek Lower**				
	1996	1997	1999	Mean	1995	1996	1997	1998	1999	Mean	1996	1997	1998	1999	Mean
Substrate / Percent Fines	1	12	11	8	19	19	17	19	20	19	18	15	19	19	18
Instream Cover	2	7	5	5	18	6	12	12	14	11	7	10	10	13	10
Embeddedness	1	1	0	1	18	1	2	2	5	2	10	11	5	4	8
Velocity / Depth	1	8	1	3	16	13	15	18	16	16	5	10	10	14	10
Channel Flow Status	19	18	19	19	15	15	17	19	17	17	19	19	18	16	18
Channel Shape	11	11	11	11	12	8	11	11	12	10	11	10	9	8	10
Pool Riffle Ratio	4	9	3	5	14	7	12	10	6	9	4	4	14	13	9
Channelization	9	10	13	11	11	10	11	11	11	11	10	9	10	6	9
Width Depth Ratio	4	12	11	9	10	1	8	9	9	7	9	6	14	13	10
Bank Vegetation Protection	9	9	9	9	9	9	8	10	8	9	9	7	9	9	8
Bank Stability	9	9	9	9	7	7	8	10	8	8	8	7	9	9	8
Disruptive Pressures	9	9	8	9	10	9	9	9	9	9	9	7	9	8	8
Riparian Zone Width	4	7	1	4	10	5	8	2	2	4	4	2	0	0	2
TOTAL SCORE	83	122	101	102	169	110	138	142	137	132	123	117	136	132	128

TABLE 8-54. Mean Percent Stream Substrate Composition, Percent Embeddedness and Current Velocity for Five Mile Creek, Wolf Creek and Smith Creek 205j Project Stations,1995 Through 1999

SUBSTRATE TYPE	Five Mile Cr. Lower				Wolf Cr. Upper	Wolf Creek Lower					Smith Creek Lower				
	1996	1997	1999	Mean	1995	1996	1997	1998	1999	Mean	1996	1997	1998	1999	Mean
Cobble	6	26	38	23	67	79	82	76	85	80	51	62	77	68	64
Coarse Gravel	2	29	18	16	18	11	9	12	6	10	23	12	11	17	16
Fine Gravel	2	28	16	15	12	8	3	8	9	7	22	15	9	12	14
Silt	90	6	8	35	0	1	4	0	0	1	0	7	0	0	2
Sand	0	10	0	3	3	1	2	3	0	2	4	4	3	3	4
Clay	0	0	19	6	0	0	0	0	0	0	0	0	0	0	0
EMBEDDEDNESS RATING Weighted Value	21.6	22.6	20.0	21.4	90	21.2	26.8	24.6	39.0	27.9	58.6	64.0	36.6	33.2	48.1
CURRENT VELOCITY (Feet Per Second)	0.7	1.5	1.9	1.4	2.3	1.7	1.6	1.2	1.1	1.4	2.2	0.9	1.2	1.6	1.5

TABLE 8-55. Summary statistics from fecal coliform sample stations in the Goose Creek and Tongue River watersheds exceeding Wyoming fecal coliform bacteria standards during the Recreation Season and Non-Recreation Season based on five (5) samples collected within a 30 day period, 1998-1999, Sheridan County, Wyoming

Water body / Station	Year (Season)	No. Samples	Mean (#/100ml)	Geometric Mean (#/100ml)	# Samples > 400/100ml	# Samples < 400/100ml	% Samples < 400 /100ml
Little Goose Creek / #1	1998 (Rec.)	5	692	489	2	3	60
Little Goose Creek / #2	1998 (Rec.)	5	962	573	3	2	40
Little Goose Creek / #3	1998 (Rec.)	5	956	611	3	2	40
Little Goose Creek / #4	1998 (Rec.)	5	710	624	5	0	0
Little Goose Creek / #5	1998 (Rec.)	5	318	314	1	4	80
Little Goose Creek / #6	1998 (Rec.)	5	273	218	1	4	80
Little Goose Creek / #1	1999 (Rec.)	5	302	275	2	3	60
Little Goose Creek / #2	1999 (Rec.)	5	308	296	1	4	80
Little Goose Creek / #3	1999 (Rec.)	5	672	642	5	0	0
Little Goose Cr. / Woodland	1999 (Rec.)	5	466	457	4	1	20
Little Goose Creek / #4	1999 (Rec.)	5	306	294	1	4	80
Little Goose Creek / #5	1999 (Rec.)	5	321	279	2	3	60
Sacket Creek	1999 (Rec.)	5	710	587	3	2	40
Jackson Creek	1999 (Rec.)	5	506	469	2	3	60
Kruse Creek	1999 (Rec.)	5	528	514	4	1	20

TABLE 8-55. Con't

Water body / Station	Year (Season)	No. Samples	Mean (#/100ml)	Geometric Mean (#/100ml)	# Samples > 400/100ml	# Samples < 400/100ml	% Samples < 400 /100ml
Big Goose Creek / #1	1998 (Rec.)	5	529	513	4	1	20
Big Goose Creek / #2	1998 (Rec.)	5	514	482	3	2	40
Big Goose Creek / #2	1998 (Rec.)	5	592	457	2	3	60
Big Goose Creek / #4	1998 (Rec.)	5	356	283	1	4	80
Goose Creek / #2	1998 (Non-Rec.)	5	390	317	2	3	60
Goose Creek / #3	1998 (Non-Rec.)	5	501	330	2	3	60
Goose Creek / #4	1998 (Non-Rec.)	5	395	318	2	3	60
Big Goose Creek / #1	1999 (Rec.)	5	275	258	1	4	80
Big Goose Creek / #2	1999 (Rec.)	5	324	307	1	4	80
Big Goose Creek / #3	1999 (Rec.)	5	313	287	2	3	60
Big Goose Creek / #4	1999 (Rec.)	5	607	458	3	2	40
B. Goose Cr. bel. Beaver Cr.	1998 (Rec.)	5	66	619	4	1	20
Big Goose Cr. / High. 81	1998 (Rec.)	5	452	411	3	2	40
Beaver Creek	1998 (Rec.)	5	1012	1003	5	0	0

TABLE 8-55. Con't

Water body / Station	Year (Season)	No. Samples	Mean (#/100ml)	Geometric Mean (#/100ml)	# Samples > 400/100ml	# Samples < 400/100ml	% Samples < 400 /100ml
Rapid Creek	1998 (Rec.)	5	430	389	2	3	60
Fivemile Creek / Lower	1999 (Rec.)	5	2056	565	3	2	40
Little Tongue River / Lower	1999 (Rec.)	5	377	290	2	3	60
Columbus Creek / Lower	1999 (Rec.)	5	448	405	5	0	0
Smith Creek / Lower	1999 (Rec.)	5	740	534	3	2	40
GRAND TOTAL	-----	**170**	-----	-----	**89**	**81**	**48**

9 CUMULATIVE EFFECTS AND PRIORITIZATION

The Tongue River watershed assessment 205j Project identified pollutants affecting the mainstem Tongue River and primary tributaries. There were no significant pollutants identified from point source discharge, thus the majority of pollutants affecting water bodies were from non-point sources. The assessment provided potential sources for pollutants and discussed land use associations with fecal coliform bacteria concentration and certain water quality parameters. Sampling provided baseline chemical, physical, biological and habitat data for several of the primary tributaries to the Tongue River, all of which had never been sampled at this intensity. Section 8 presented results and discussion for each sampling station and each sampling parameter. Section 9 provides a cumulative overview of monitoring and assessment results. Evaluation of cumulative water quality effects at the Project watershed scale will assist planning future watershed restoration activity described in the Tongue River Watershed Management Plan.

9.1 Tongue River

The water quality assessment conducted by SCCD using historic and current data from WDEQ, USGS, RPWD and WGFD found water quality in the Tongue River from the BHNF boundary to the Town of Ranchester good to excellent with few exceptions. Land use activities in the BHNF produced no significant effects for water quality and stream biological condition in the Tongue River and its primary tributaries. Nutrient concentrations (nitrate, phosphorus and ammonia) were either low or not detected, herbicides and pesticides sampled by SCCD and USGS were not detected. USGS sampling at the Upper station found non-detectable or low stream bed sediment metal concentrations; brown trout fish tissue and liver samples indicated no accumulation of organic compounds. Water column metals sampling found non-detectable or low concentrations. The metals and organic sampling suggested low potential for contamination of the aquatic food chain and no fish consumption advisory. Water quality sampling by USGS in 1999 at the Tongue River Upper station confirmed findings from SCCD and WDEQ water quality sampling. Comparison of historic fecal coliform bacteria data with current Project fecal coliform bacteria data indicated a decline in bacteria level at the Middle station and Lower station since the 1970's and 1980's. The decline in bacteria levels at the Middle station appeared to be related to upgrade and effective operation and maintenance of the Dayton WTP. Intensive monitoring conducted by WDEQ in 1998 in the vicinity of the Dayton WTP confirmed this finding. No significant amount of pollutants were entering the Tongue River from the Dayton WTP discharge.

Water temperature at the Tongue River Lower station appeared to regularly exceed the Wyoming water quality standard for Class 2 cold water streams during the summer when air temperatures were highest and stream discharge was reduced for irrigation demand. Concurrent reduced discharge from primary tributaries during the summer irrigation season compounded the effects of high water temperature and low discharge at the Tongue River Lower station. Other than high water temperature and a single high fecal coliform sample at Tongue River Lower, there were no exceedences of Wyoming water quality standards during the four year Project (Table 9-1). The Tongue River will remain on the Wyoming 303d list identifying water quality limited stream segments due to exceedence of the water temperature and fecal coliform bacteria standards. However, the size of the current water quality limited segment should be reduced. The current water quality limited segment was from near the Tongue River Upper station and BHNF boundary to the Tongue River Lower station at Ranchester. The revised water quality limited segment should be listed as from the Halfway Lane County Road near the Tongue River Middle station located about midway between the Town of Dayton and the Town of Ranchester, to the Town of Ranchester. Reduction in size of the water quality limited segment was justified because no water quality problems were identified at or upstream of the Tongue River Middle station. Impairments will be listed as water temperature and fecal coliform bacteria. Placement on the 303d list will require remedial action probably in the form of BMP implementation and voluntary conservation land treatments in concert with water management modification to restore water quality. SCCD prepared the Tongue River Watershed Management Plan (SCCD, 2000) under the auspices of the Tongue River Watershed Steering Committee (TRWSC) and Tongue River watershed landowners with assistance from NRCS. The management plan and TRWSC will guide future prioritization of voluntary land treatment, land management changes and monitoring activity within the Project area to bring affected water bodies back into compliance with Wyoming water quality standards. The Watershed Plan will delay implementation of Total Maximum Daily Loads (TMDL's) for both water temperature and fecal coliform.

Long term monitoring data sets provided by RPWD for daily turbidity, water temperature and pH measurements at the Ranchester WTP raw water intake indicated a gradual, but significant decline for these parameters over the years. Decline in alkalinity was also indicated. Decline in pH and alkalinity could be related to anthropogenic (man caused) effects affecting other water bodies nationwide (i.e. acid rain), change in water management in Wolf Creek or other unknown factors. Continued monitoring by RPWD will be important to track trends because further decline in these parameters will potentially affect the aquatic biological community, fishery and the ability of the Tongue River to meet Wyoming water quality standards.

Biological condition based on sampling and analysis of benthic macroinvertebrate communities was rated good at each Tongue River station. Benthic macroinvertebrate sampling conducted by USGS in 1999 at the Upper station compared favorably with SCCD and WDEQ benthic macroinvertebrate sampling despite differences in sampling method, sampling date and sampling location. The transition from a cool water benthic community at the Upper station to a warmer water benthic macroinvertebrate community at the Lower station reflected the natural increase in water temperature along the longitudinal gradient from the Upper station to the Lower station. Increase in summer water temperature appeared to be accelerated by dewatering for irrigation demand.

Review of historic and current WGFD fish population data found game fish populations dominated by trout species in the Upper canyon. Whitefish dominate and replace trout species downstream of the canyon. Extensive historic channelization appeared to further reduce trout habitat and trout populations allowing non-game fish populations to increase in abundance downstream to the Town of Ranchester. Loss of habitat due to channelization and elevated summer water temperature accelerated by dewatering appeared to be the primary reasons for the decline in game fish populations observed in the Tongue River over the years. Effects of channelization continue to this day requiring stream bank stabilization projects.

In-stream and riparian habitat quality was reduced from the Tongue River Upper to Lower stations based on qualitative habitat scoring criteria. The reduction in habitat scores was due to lower scores for embeddedness (silt cover on cobble and gravel stream substrate), channel flow status, channel shape, channelization, width depth ratio and bank stability. Reduced scores for some of the habitat parameters were related not only to current land use practices and water management, but to lingering effects from the period of extensive channelization that apparently occurred in the late 1950's to early 1960's. The semi-quantitative stream substrate particle size distribution varied little between stations. The general decrease in substrate particle size observed from the Upper station to the Lower station was normal because particle size generally decreases as stream size and stream order increase (Rosgen, 1996). Stream substrate composition at Tongue River stations in order of importance was cobble, coarse gravel and fine gravel. Sand and silt deposition was minimal. Sand comprised from 1 percent to 5 percent of stream substrate at Tongue River stations. Only the Upper and Lower stations had detectable silt deposition. Silt comprised about one (1) percent of total substrate at those stations.

Stream substrate embeddedness increased from the Tongue River Upper to Lower stations. Increase in embeddedness from the Upper to Lower stations was considered normal for the size (drainage area was 347 square miles at Tongue River Lower station) and stream order of the Tongue River. Stream substrate and embeddedness had no apparent detrimental effect on the benthic macroinvertebrate population because biological condition was rated very good and full support of aquatic life use was indicated. Despite the reduction in habitat scores and increase in embeddedness values from Tongue River Upper to Lower stations, these stations ranked high when compared to habitat scores and embeddedness values observed at other plains streams in the Northwestern Great Plains ecoregion of Wyoming. The small percent of sand and silt comprising the Tongue River stream substrate further indicated no large scale disruption in the Tongue River watershed.

Water temperature naturally increases along the longitudinal gradient in the Tongue River during the warmer summer months. Dewatering accelerated the increase in water temperature and resulted in loss of habitat by restricting trout to reaches further upstream. However, after accounting for these factors and evaluation of credible historic and current chemical, physical and biological data, SCCD determined that the Tongue Rive Lower station was sited in the transition zone between a cold water system (WDEQ Class 2 cold water) and a warm water system (WDEQ Class 2 warm water). The entire length of the Tongue River to the Montana border is currently a Class 2 cold water, water body. SCCD proposed that reclassification of the Tongue River from

Class 2 cold water to Class 2 warm water was warranted. The Interstate 90 Bridge was proposed as a possible point of division between cold water and warm water stream classes. SCCD will formally petition WDEQ to initiate the reclassification process. Data and findings contained in this Final Report should provide adequate justification for initiation of the proposed reclassification. The proposed reclassification will not change the current status for placement of the Tongue River Lower segment on the Wyoming 303d list, but will provide more appropriate water quality goals for the downstream segments.

9.2 Tributaries to the Tongue River

Each primary tributary to the Tongue River within the Project area exceeded one or more Wyoming water quality standards. Each tributary will be placed on the Wyoming 303d list for water quality limited stream segments. Smith Creek and Little Tongue River were previously on the 303d list and will remain. Columbus Creek, Wolf Creek and Five Mile Creek will be new additions to the 303d list.

Smith Creek will be listed for exceedence of the fecal coliform bacteria standard, the turbidity standard and water temperature standard (Table 9-1). The water quality limited length of stream was identified as the segment from the Smith Creek Upper station to the Smith Creek Lower station because the impairments were occurring somewhere between the two stations.

Little Tongue River was listed for exceedence of the fecal coliform bacteria standard, the water temperature standard and narrative biological criteria standard. The water quality limited length of stream was identified as the segment from the Little Tongue River Upper station to the Little Tongue River Lower station because the impairments were occurring somewhere between the two stations. The Little Tongue River Upper station exceeded the narrative biological criteria standard based on WDEQ benthic macroinvertebrate sampling in 1993. SCCD analysis confirmed the WDEQ finding. SCCD recommended the WDEQ station be relocated downstream to the current SCCD Little Tongue River Upper station and site of USGS gage station No. 06298500 for better comparison with the water quality sampling station.

Columbus Creek will be listed for exceedence of the fecal coliform bacteria standard, water temperature standard, turbidity standard and narrative biological criteria standard (Table 9-1). The water quality limited length of stream was identified as the segment from the Columbus Creek Upper station to the Columbus Creek Lower station because the impairments were occurring somewhere between the two stations. Water quality upstream of the Upper station was good with the exception of a single high fecal coliform bacteria sample. SCCD proposed that the Columbus Creek segment upstream of this station not be placed on the 303d list due to the single sample exceedence. Rather, SCCD proposed to continue monitoring to determine if significant bacterial contamination persisted.

Wolf Creek will be listed for exceedence of the fecal coliform bacteria standard, water temperature standard and turbidity standard (Table 9-1). The water quality limited length of stream was identified as the segment from the Wolf Creek Upper station to the Wolf Creek Lower station because the impairments were occurring somewhere between the two stations. The EPA secondary drinking water standard for total sulfate was exceeded based on a single WDEQ sample collected in 1995 at the Wolf Creek - Berry station. The EPA secondary drinking water standard was not enforceable and as such, will not require a potential TMDL.

Five Mile Creek will be placed on the 303d list for exceedence of the fecal coliform bacteria standard, water temperature standard, turbidity standard and narrative standard for biological criteria (Table 9-1). The water quality limited length of stream was identified as the entire Five Mile Creek drainage including the Five Mile Ditch and both irrigation storage reservoirs because the impairments were occurring somewhere upstream of the Five Mile Creek Lower station. Five Mile Creek exhibited the poorest water quality of any stream assessed during this Project.

Five Mile Creek was currently not classified by WDEQ, but assumed the classification of the Tongue River (Class 2 cold water) due to the "tributary rule" (WDEQ, 1998). Five Mile Creek functions as an irrigation water supply conduit. Because of it's dependence upon Columbus Creek for discharge, and the evaluation of chemical, physical and biological data collected during this Project, SCCD proposed that Five Mile Creek be classified as a Class 3 water body. Data and findings contained in this Final Report should provide adequate justification for the proposed classification. Because Five Mile Creek was currently not classified, SCCD believes notification and reference to this Final Report should provide sufficient documentation to justify the proposed classification. The Class 3 determination will not change the status for placement of Five Mile Creek on the Wyoming 303d list. However, the exceedence of the water temperature standard when classified as a Class 2 cold water, water body (25.6^0C) would not be an exceedence of the water temperature standard for a Class 3 water body (32.2^0C). The exceedences for fecal coliform, turbidity and narrative biological criteria standards remain applicable.

9.3 Effect of Tributary Water Quality on Tongue River

Water quality in the Tongue River was good to excellent and water quality in tributary streams draining to the Tongue River was of lessor quality. Each tributary stream had one or more violations of Wyoming water quality standards. An important assumption made at the beginning of this Project was that water quality in tributaries caused deterioration of water quality in the Tongue River. This Project demonstrated that tributaries to the Tongue River had no significant effect on water quality in the Tongue River. The primary reason was that each tributary was significantly dewatered thereby reducing discharge and introduction of potential water pollutants into the Tongue River. It should be noted that discharge measurements during this Project did not reflect the annual discharge regime in the tributaries because measurements were taken primarily from April through September.

During this Project, the Little Tongue River contributed an estimated 6.2 percent of the Tongue River discharge. Smith Creek comprised an estimated 1.3 percent, Columbus Creek 1.3 percent, Wolf Creek 8.9 percent and Five Mile Creek an estimated 1.6 percent of the total Tongue River discharge. The small, but proportionally high percentage attributed to Five Mile Creek was due to diversion of Columbus Creek water into the Five Mile Creek watershed. Accordingly, diversion reduced the amount of discharge from Columbus Creek to the Tongue River.

Although each tributary had specific water quality problems, cumulative total discharge from tributaries comprised a relatively small proportion of total discharge in the Tongue River. With the exception of Smith Creek and Five Mile Creek, each tributary exhibited a reduction in stream discharge from Upper to Lower stations. Reductions in discharge were most apparent during the summer irrigation months. The water chemistry data further suggested that discharge in each tributary, especially Smith Creek, Columbus Creek and Wolf Creek was primarily comprised of irrigation return water. This suggested that potential pollutants entering the Tongue River from tributaries were significantly diluted and produced no significant water quality effect. Irrigation return did not appear to have a significant impact on Tongue River water quality because primary points for return water were located downstream of the Project area.

The change in many water quality parameters from most Upper to Lower tributary stations was greater than the change in water quality parameters from the Tongue River Upper to Lower stations. The larger change in water quality parameters in tributaries appeared to be related to water management practices that affected discharge and the amount of irrigation return comprising total tributary discharge.

9.4 Water Body Ranking and Prioritization for Restoration

Chemical, physical, biological and habitat attributes were ranked by station to assist prioritization of voluntary land treatments and management activity to improve water quality. Mean values for each water quality parameter were compared among Tongue River stations and Lower tributary stations (Table 9-2). The same ranking process was conducted for benthic macroinvertebrate communities by ranking select metrics (Table 9-3) and for habitat parameters (Table 9-4). Parameters and metrics were ranked individually and then summed to provide a ranking value for comparison among stations (Table 9-5).

Based on the ranking system, water quality was highest at the Tongue River Middle station followed by the Tongue River Upper and Tongue River Lower stations. The Tongue River Middle station ranked higher than the Upper station due to additional intensive sampling by WDEQ at the Dayton WWTF near the Middle station during low flow in the fall, 1998. Wolf Creek Lower ranked 4th for water quality followed by Little Tongue River Lower and Smith Creek Lower. The poorest water quality was at Columbus Creek Lower and Five Mile Creek Lower. Columbus Creek Lower had a total of 4 Wyoming water quality numeric and narrative standard exceedences and Five Mile Creek had a total of 5 standard exceedences. Wolf Creek Lower and Little Tongue Lower had 3 exceedences of standards and Tongue River Lower had 2 exceedences. Results for the water quality ranking agreed favorably with results for the benthic macroinvertebrate community ranking (Table 9-5). Comparability between results for habitat assessment rankings and both water quality and benthic macroinvertebrate rankings was not good. The subjective nature of the habitat assessment and variability in flow dependent habitat parameters may be related to the lack of comparability to water quality and benthic macroinvertebrate rankings. Close agreement between water quality and benthic macroinvertebrate rankings suggested that macroinvertebrate sampling alone could provide a good estimate for overall water quality at a fraction of the cost. The percent contribution of benthic oligochaetes (worms) to the total benthic macroinvertebrate community was a statistically significant and reliable predictor for identification of significant fecal coliform bacteria contamination in the Tongue River watershed Project area. Certain worm taxa including *Ophidonais serpentina*, *Eiseniella tetraedra*, *Nais variabilis* and Lumbricina may present additional predictive power because these organisms occurred most frequently at stations exceeding the Wyoming water quality standard for fecal coliform bacteria. No *Tubifex tubifex* worms were identified from samples. *T. tubifex* is very common in polluted waters (Goodnight, 1959) and is significantly involved in the whirling disease life cycle caused by a parasite (*Myxobolus cerebralis*) that penetrates the head and spinal cartilage of fingerling trout. Whirling disease may eventually cause death in trout and the absence of this worm indicated low probability for the occurrence of whirling disease in the Tongue River watershed within the Project area.. These associations further indicated the importance of benthic macroinvertebrates as cost-effective water quality indicators.

The TRWSC will prioritize voluntary water quality improvement activity after consultation with SCCD, landowners, WDEQ and EPA. Water bodies with confirmed fecal coliform bacteria standard violations may receive the highest priority because they represent immediate public health and safety concerns. Water bodies with turbidity, water temperature, sulfate and narrative biological criteria exceedences may receive secondary priority. Other important watershed resource concerns (i.e. roads) and willingness of landowners to apply voluntary land treatments should be closely factored into the prioritization process. Potential stream habitat improvement projects should be reviewed by WGFD before implementation. Improvement in water quality will play a major role in improvement of aquatic resources and fisheries.

Restoration strategy must involve the entire watershed because water management practices affecting each tributary and the Lower Tongue River station appeared to be indirectly responsible for some water temperature, turbidity and narrative biological criteria standard exceedences. The role that water management practice had on fecal coliform bacteria standard exceedences was less clear. Water management in the upper watershed affects water users in the lower watershed. The Tongue River Watershed Management Plan listed this topic as a watershed concern.

TABLE 9-1. Summary of Wyoming Water Quality Standard Numeric, Narrative and Drinking Water Standard Violations During Tongue River Watershed Assessment 205j Project, Sheridan County, Wyoming

Sampling Station	**Fecal Coliform**[A]	**Temperature**[A]	**Turbidity**[A]	**Total Sulfate**[B]	**Biological Criteria**[C]
Tongue - Upper					
Tongue - Middle					
Tongue - Lower		X			
Little Tongue - Upper					X
Little Tongue - Lower	X	X[A]			X
Smith Creek - Upper					
Smith Creek - Lower	X	X[A]	X		
Columbus Creek - Upper					
Columbus Creek - Lower	X	X[A]	X		X
Wolf Creek - Upper				X [B]	
Wolf Creek - Lower	X	X[A]	X		
Five Mile Creek - Lower	X	X[A]	X [C]	X	X

A = Wyoming surface water quality numeric standard.
B= EPA secondary drinking water standard (not enforceable); Wyoming groundwater standard.
C = Wyoming surface water quality narrative standard.
X[A] = Based on projected maximum water temperature.
X[B] = Based on single sample in 1995 collected downstream of SCCD Wolf Creek Upper station.
X [C] = Based on comparison to Columbus Creek - Upper which is the primary source of water for this station.

TABLE 9-2. Final Project Average Water Quality Values and Ranking (1 equals highest rank decreasing to 8 for lowest rank) by Station Within the Tongue River Watershed Project Area, 1996 Through 1999

	Tongue Upper		**Tongue Middle**		**Tongue Lower**		**Little Tongue Lower**		**Smith Lower**		**Columbus Lower**		**Wolf Creek Lower**		**Five Mile Lower**	
Chemical Parameter	**Mean**	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**
Temperature	9.6	1	9.8	2	11.7	3.5	11.7	3.5	12.6	5	13.5	7	13.4	6	14.1	8
pH	8.2	7.5	8.0	3.5	8.0	3.5	8.1	6	8.2	7.5	7.9	1	8.0	3.5	8.0	3.5
Conductivity	209	1	277	2	300	3	436	5	574	7	525	6	429	4	819	8
DO	10.2	2	11.0	1	9.9	3	9.5	4.5	9.2	7	9.0	8	9.5	4.5	9.4	6
Turbidity	7.3	1	9.0	3	13.5	4	8.5	2	19.0	5	51.7	8	21.0	6	39.4	7
TSS	3	3.5	2	1.5	3	3.5	2	1.5	10	6	18	8	7	5	11	7
Alkalinity	122	1	145	2	174	3	220	4	271	6	326	7	244	5	420	8
Sulfate	<10	1	23	2	33	3	201	7	151	5	162	6	83	4	392	8
Chloride	<5	3.5	<5	3.5	<5	3.5	<5	3.5	<5	3.5	10	7.5	<5	3.5	10	7.5
Nitrate	.028	4	.030	5	.019	2	.022	3	.036	6	.057	7	.013	1	.526	8
Phosphorus	.044	5	.041	3	.028	2	.042	4	.067	8	.065	7	.027	1	.055	6
Hardness	209	3	176	1	202	2	380	6	361	5	392	7	293	4	556	8
F. Coliform	5	1	15	2	25	3	32	4	176	7	107	6	57	5	185	8
SUM RANKINGS		34.5		31.5		39.0		54.0		78.0		85.5		52.5		93.0
WATER CHEMISTRY RANK	**2**		**1**		**3**		**5**		**6**		**7**		**4**		**8**	

TABLE 9-3. Final Project Average Macroinvertebrate Metric Values and Ranking (1 equals highest rank decreasing to 8 for lowest rank) by Station Within the Tongue River Watershed Project Area, 1996 Through 1999

	Tongue Upper		**Tongue Middle**		**Tongue Lower**		**Little Tongue Lower**		**Smith Lower**		**Columbus Lower**		**Wolf Creek Lower**		**Five Mile Lower**	
Macroinvertebrate Metric	**Mean**	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**
Number Taxa	27.2	7	39.5	3	37.5	4	34.8	5	27.0	8	39.8	2	42.0	1	31.3	6
Number EPT Taxa	18.5	3	19.8	1.5	19.8	1.5	16.2	5	10.5	7	10.8	6	17.0	4	6.3	8
% Plecoptera	10.0	1	6.2	3	1.4	5	3.40	4	7.38	2	0.10	7	0.54	6	0.06	8
% Chironomidae	1.0	2	7.1	4.5	7.1	4.5	1.7	3	0.7	1	12.58	7	7.5	6	14.3	8
% Oligochaeta	0.0	1	1.7	4	1.3	2	3.3	5	1.6	3	14.2	7	6.3	6	22.9	8
No. Predator Taxa	6.5	1	6.0	2	5.0	4.5	2.5	7	2.0	8	4.8	6	5.0	4.5	5.3	3
% Scrapers	33.8	2	14.3	5	8.3	6	15.9	4	25.3	3	2.9	7	35.1	1	0.7	8
% Collect.Filterers	12.1	2	25.9	4	45.7	8	4.1	1	44.6	7	33.8	5	17.0	3	35.8	6
Modified HBI	2.31	1	2.93	2	3.81	3	3.85	4	4.55	5	5.65	6	5.66	7	6.12	8
BCI CTQa	48.0	1	69.4	2	73.8	4	70.8	3	79.5	5	91.9	7	85.2	6	98.2	8
Shannon H (Log 2)	3.50	4	3.82	1	3.24	7	3.34	5	2.78	8	3.65	3	3.81	2	3.29	6
% Multivoltine	16.9	3	13.9	2	23.2	6	8.4	1	19.1	4	39.4	8	22.7	5	27.6	7
% Univoltine	70.3	1	64.2	5	69.3	2	31.7	8	68.9	3	56.4	6	45.6	7	66.4	4
SUM RANKINGS		29		39		57.5		55		64		77		58.5		88
METRIC RANK	1		2		5		3		6		7		4		8	

TABLE 9-4. Final Project Average Habitat Assessment Parameter Values and Ranking (1 equals highest rank decreasing to 8 for lowest rank) by Station Within the Tongue River Watershed Project Area, 1996 Through 1999

	Tongue Upper		Tongue Middle		Tongue Lower		Little Tongue Lower		Smith Lower		Columbus Lower		Wolf Creek Lower		Five Mile Lower	
Habitat Parameter	**Mean**	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**
Substrate / Percent Fines	18	5.3	19	2.5	20	1	18	5.3	18	5.3	8	7.5	19	2.5	8	7.5
Instream Cover	18	1	16	2	15	3	8	6	10	5	3	8	11	4	5	7
Embeddedness	19	1	15	2	4	5	11	3	8	4	1	7.5	2	6	1	7.5
Velocity / Depth	18	1	16	3	16	3	9	6	10	5	8	7	16	3	3	8
Channel Flow Status	18	2.5	13	7.5	15	5	13	7.5	18	2.5	14	6	17	4	19	1
Channel Shape	10	3	6	8	9	5	8	6	10	3	7	7	10	3	11	1
Pool Riffle Ratio	13	2	13	2	13	2	6	6	9	4.5	4	8	9	4.5	5	7
Channelization	15	1	10	4.5	10	4.5	9	7	9	7	9	7	11	2.5	11	2.5
Width Depth Ratio	10	1.5	7	5.5	3	8	4	7	10	1.5	9	3.5	7	5.5	9	3.5
Bank Vegetation Protection	9	2	8	5.5	8	5.5	8	5.5	8	5.5	3	8	9	2	9	2
Bank Stability	9	1.5	5	7	7	6	8	4	8	4	3	8	8	4	9	1.5
Disruptive Pressures	10	1	7	7	8	5	8	5	8	5	6	8	9	2.5	9	2.5
Riparian Zone Width	7	1	5	3	6	2	2	7	2	7	2	7	4	4.5	4	4.5
TOTAL SCORE	174		140		134		112		128		77		132		102	7
SUM RANKINGS		21.3		59.5		55.0		75.3		59.3		92.5		48.0		55.5
HABITAT RANK	1		6		3		7		5		8		2		4	

TABLE 9-5. Comparison of Final Project Water Quality, Macroinvertebrate, and Habitat Assessment Ranking (1 equals highest rank decreasing to 8 for lowest rank) by Station Within the Tongue River Watershed Project Area, 1996 Through 1999

	Tongue Upper	**Tongue Middle**	**Tongue Lower**	**Little Tongue Lower**	**Smith Lower**	**Columbus Lower**	**Wolf Lower**	**Five Mile Lower**
Water Quality Rank	2	1	3	5	6	7	4	8
Macroinvertebrate / Biological Condition Rank	1	2	5	3	6	7	4	8
Habitat Assessment Rank	1	6	3	7	5	8	2	4

10 RECOMMENDATIONS

Numerous recommendations were proposed throughout this Final Report. This Section summarizes those recommendations. Additional water quality and benthic macroinvertebrate monitoring will be required at some time because the Tongue River Lower station and each tributary within the Project area will be placed on the Wyoming 303d list identifying water quality limited stream segments. The role that SCCD may play in future monitoring efforts is uncertain due to staffing limitations, limited operating budget dependent upon "soft money", unknown future funding and public support for voluntary BMP implementations and land treatments. SCCD has a commitment not only the Tongue River watershed, but to all Sheridan County residents to promote and implement wise conservation practices county-wide.

Monitoring will be required to determine when water quality in these water bodies is improved to meet Wyoming water quality standards. This Project identified water quality pollutants of concern and the water bodies in which they occurred. Because each tributary had only Upper and Lower stations, with the exception of Five Mile Creek (single Lower station), the entire reach between stations will be placed on the 303d list. However, it was unlikely that the entire reach was water quality limited. Future monitoring may be directed toward the identification of those specific segments within each impaired tributary to better identify potential sources of significant pollution and effectively target resources to improve water quality. Monitoring to identify segments with significant pollutants and the potential sources of pollutants will require a more complex and intensive sampling design than the basic upstream and downstream design used during this Project. A project of this scope would require significant additional resources currently beyond those available to SCCD in order for the District to fulfill it's other conservation commitments to Sheridan County residents.

It is possible that future monitoring will be funded through Section 319 of the Clean Water Act administered by WDEQ through EPA funding. Section 319 projects include a combination of voluntary BMP implementations, land treatments and appropriate land management changes in concert with an emphasis on intensive "implementation monitoring" to determine if BMP's and on the ground changes are effective by reducing water pollutants. Intensive implementation monitoring will require more resources, QA/QC oversight, time and coordination between the Project Sponsors, land owners and funding agencies. The following recommendations may be considered during design of future monitoring projects within the Tongue River Project area.

1. The Project Manager and Field Coordinator must ensure that all new equipment is calibrated and maintained according to manufacturer instructions. New equipment should undergo adequate field testing and training by sampling personnel before use.

2. The Pre-project planning phase should include better communication with the contract analytical laboratory for specific analytical method and costs.

3. Future monitoring efforts should allow for adequate time (a minimum of six (6) months) to conduct planning prior to collection of the first sample. This will allow sampling to begin as scheduled.

4. For future sampling, an adequate number of full-time sampling technicians should be employed and firm commitments from volunteers for monitoring should be secured at least two weeks in advance of scheduled sampling. Field logistics should be improved to account for the short holding time for fecal coliform samples by increasing the number of vehicles for use to deliver samples to the analytical laboratory.

5. Adequate salaries, benefits, flexibility and support should be provided to personnel involved in monitoring activities to reduce employee turnover and ensure monitoring consistency.

6. Ensure that duplicate samples are included in budget planning at the start. Provide field samplers with a "tracking sheet" to record the number of duplicate samples required and the total number of duplicate samples collected. Training should stress the importance of duplicate samples in the QA process.

7. Establish all monitoring stations upstream of road crossings. Better land owner familiarity and involvement with projects should enhance the ability to gain broader access for sampling.

8. Ensure that enough funds are available for identical sampling frequency between all monitoring stations on a water body if required.

9. SCCD and WDEQ instantaneous water temperature sampling was not sufficient to detect maximum daily temperature needed to evaluate attainment of the Wyoming water quality standard for water temperature. Continuous water temperature recorders or thermistors should be purchased for monitoring at stations suspected of approaching the Wyoming water temperature standard.

10. The benthic macroinvertebrate sampling station established by WDEQ at the Little Tongue River Upper station should be relocated to the SCCD Little Tongue River Lower water quality sampling station to allow better comparison of the benthic macroinvertebrate data with water quality data.

11. The stream reach upstream of the Columbus Creek Upper stations should not be placed on the WDEQ (303d) list for Wyoming water quality limited segments based on the single high fecal coliform bacteria sample. Sampling for fecal coliform should continue to determine if frequent, significant bacteria levels are

present to ensure that public health and safety are protected.

12. Biological condition ratings that border between two ratings (i.e. fair and good) should always be re-sampled the next year to confirm findings from the previous year especially when the determination may result in listing the stream segment for non-support for aquatic life use. Should additional sampling indicate impairment of the biological community, another sample should be collected and if impairment is reconfirmed, restoration measures should be considered.

13. Future sampling for fecal coliform bacteria in the Tongue River watershed (and other water bodies) should consist of five (5) samples each collected on separate days during a 30 day period within the Recreation Season (May 1 through September 30) to ensure detection of significant bacterial levels for protection of public health and safety. Sampling may be conducted outside the Recreation Season to identify pollution sources that may be related to seasonal factors such as discharge, turbidity, wildlife use and irrigation demand. Monthly fecal coliform sampling, although less time consuming and costly, should be abandoned because sampling at this frequency runs the risk of missing significant fecal coliform bacteria contamination about 50 percent of the time.

14. Future monitoring should include placement of continuous discharge recorders at the lower end of each primary tributary and at the Tongue River near the Ranchester Water Treatment Plant.

15. The Ranchester Public Works Department should be encouraged to continue daily water temperature, pH, turbidity and alkalinity measurements at the Tongue River raw water intake to track long term water quality change in the Tongue River.

16. Objectives and goals in the Tongue River Watershed Management Plan should be implemented as scheduled. Date, location and type of voluntary BMP implementations, land treatments or land management changes should be tracked by SCCD and the Tongue River Watershed Steering Committee to relate to potential water quality and water resource improvement possibly precluding the need for future TMDL's.

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