Total Maximum Daily Load (TMDL) Water Quality Analysis of Soldier Creek Watershed, Utah

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- Cindy Burton: Natural Resource Conservation Service (formerly Timp-Nebo Soil Conservation District)

- Timp-Nebo Soil Conservation District

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  Jeffrey Ostermiller and Mark Stanger: Utah Division of Water Quality

  Larry Gray: Utah Valley State College

- Spanish Fork Watershed Committee

1.0 INTRODUCTION

1.1 Purpose

Soldier Creek is listed on Utah's 303(d) of impaired waterbodies for excessive sediment and phosphorous. As a tributary to the Spanish Fork River, the flows from Soldier Creek ultimately reach Utah Lake which is also on the 303 (d) list due to excessive nutrients and high total dissolved solids (TDS).

Soldier Creek's cold water fisheries are negatively impacted by excessive sediment and nutrients. The sources of impairment originate from natural features, agricultural activities, storm runoff, and roads. There are no permitted point source discharges in the watershed.

This document addresses the water quality impairment of Soldier Creek through the establishment of total maximum daily loads (TMDLs) for sediment and phosphorus, the pollutants of concern. The purpose of this TMDL is to improve water quality by restoring and protecting its designated fisheries beneficial use.

In 1997 under the leadership of the Timp-Nebo Soil Conservation District (SCD) a locally led work group systematically began working to improve water quality in the Spanish Fork River Watershed. In the spring of 2003, a draft coordinated resource management plan (CRMP) for Soldier Creek was completed. Upon its approval by EPA, this TMDL will be included in the plan to guide the implementation of resource improvements and ensure that beneficial uses are attained through a voluntary incentive based program.

1.2 Location

Soldier Creek Watershed is located 21 miles southeast of Provo, in eastern Utah County (Figure 1-1). Soldier Creek flows west through Spanish Fork Canyon, sharing the narrow valley floor with Highway 6 and the tracks of the Union Pacific Railroad and Utah Railway Company. The watershed lies within the Wasatch Mountains, comprising the eastern headwaters of the Spanish Fork River watershed.

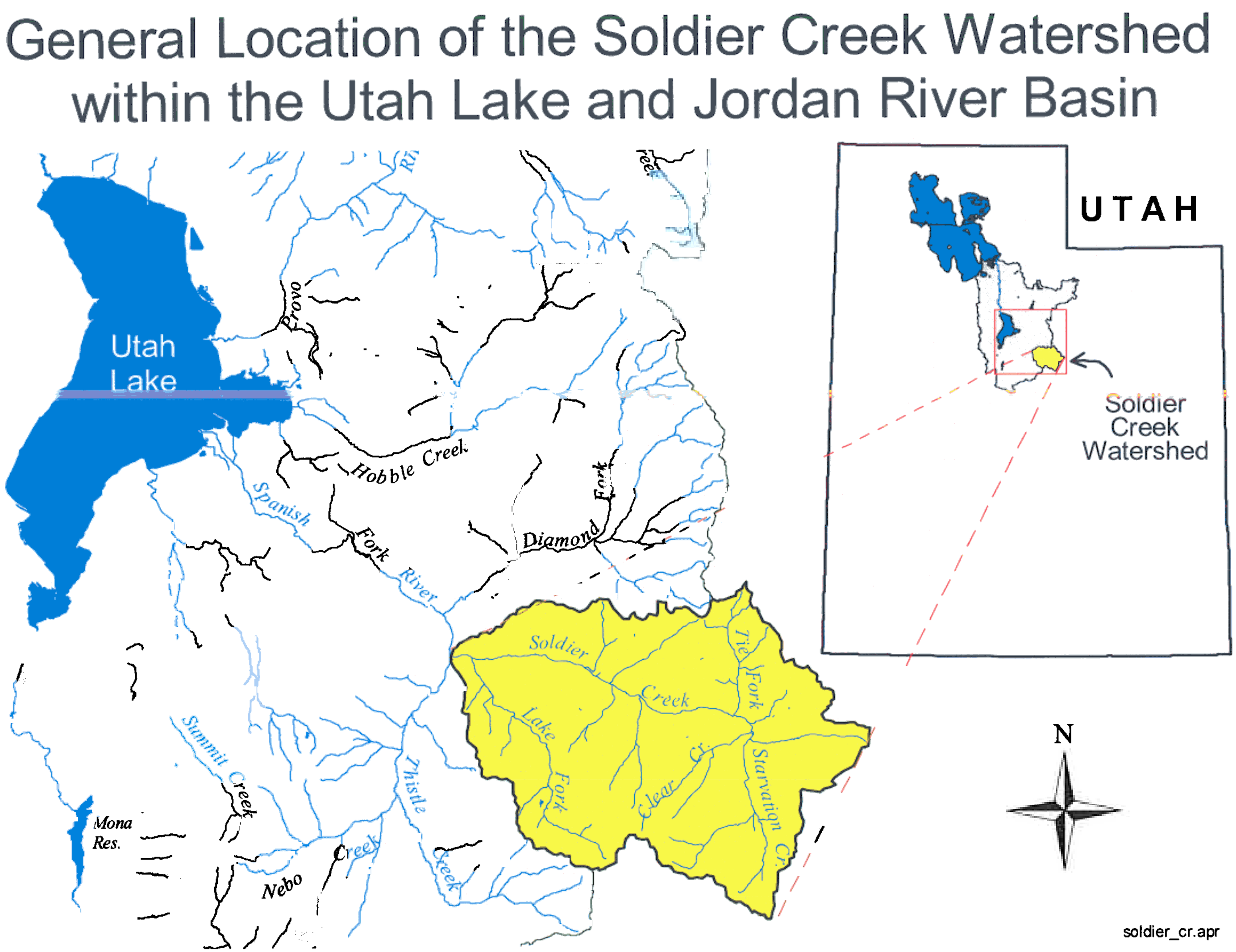
1.3 Physiography

Soldier Creek's watershed spans from Soldier Summit at 7,440 feet in elevation to its confluence with Thistle Creek at 5,100 feet. The watershed is 24 miles long and 17 miles wide, encompassing 150,751 acres of mixed ownership lands. Within the Spanish Fork River watershed Soldier Creek's sub-watershed boasts the steepest terrain. Only 6% of the sub-watershed has slopes of 10% or less. Slopes of 20% or greater are found in 74% of the area. Rock outcrops are common along the main canyon and tributary channels. See Table 1-1 below for a summary of slopes within Soldier Creek's watershed.

TABLE 1-1. Solder Creek Watershed by percent slope and acres.

% Slope	Acres	% of Sub-watershed
0-10	9,325	6
10-20		20
20-40	66,190	44
40+	44,865	30

FIGURE 1-1. Soldier Creek Watershed Location

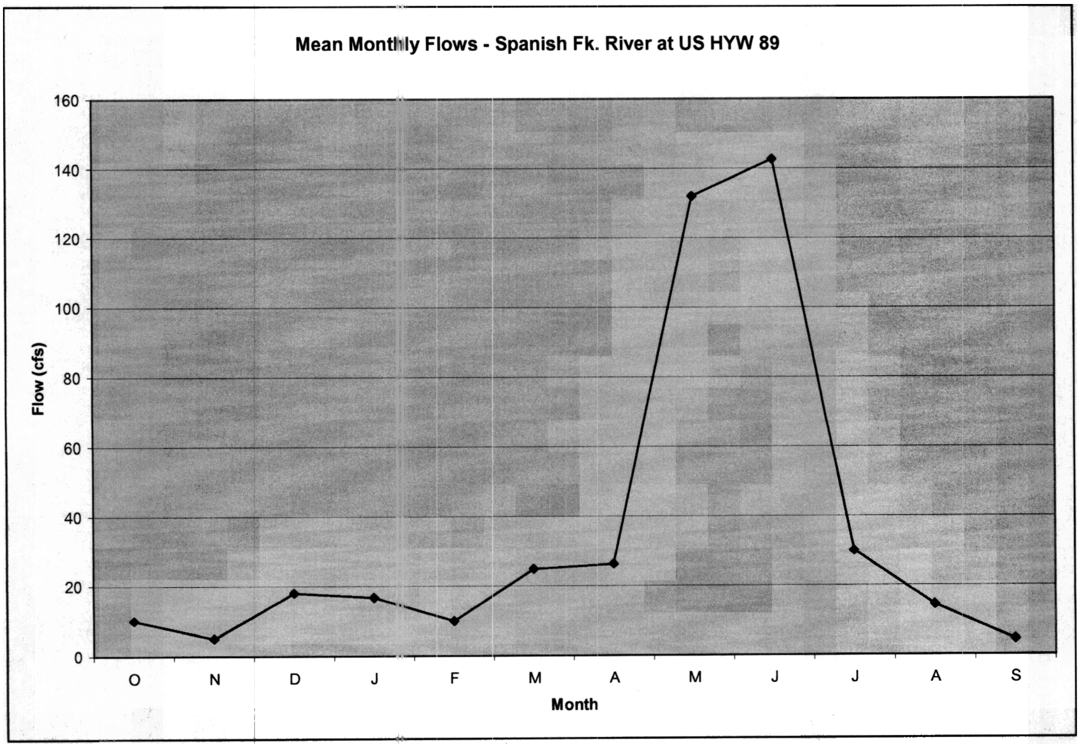


1.4 Hydrology

The hydrology of the Soldier Creek Watershed is typical of semi-arid regions dependent upon precipitation. The climate is characterized by cold, moist winters and warm, dry summers. Temperatures range from -40 degrees to 90 degrees Fahrenheit. The frost free period is approximately 50 to 60 days. Average annual precipitation ranges from 12 inches at 6000 feet elevation to 22 inches at 8800 feet. About 65% of the precipitation occurs as snow from October through April and 35% occurs as rain from May through September. December through April is the wettest period. July and September are the driest months. High intensity convection storms are common, especially during August. These localized "cloud bursts" may produce 2 to 3 inches of rainfall in less than an hour. The steep topography of the watershed funnels the rainfall into the stream channels with high velocities and thus the potential for erosion is great during these events. This is evident by high total suspended solid (TSS) measurements and turbid water appearance during and after rain events.

Figure 1-2 shows a monthly mean flow hydrograph from the Spanish Fork River, a typical snowmelt-dominated flow pattern common with most Utah streams where flows peak in the months of May and June. After the snowmelt, flows drop and become more consistent and fluctuate only during storm events. This same flow pattern is seen throughout the watershed. It is assumed the average annual flow increases from the top of the watershed to the outlet.

FIGURE 1-2. Spanish Fork River Mean Monthly Flows



1.5 Geology and Soils

Soil Survey information is available for the Uinta and Manti-LaSal National Forests, which encompass the upper elevations of the watershed. These surveys indicate that highly erosive soils are common because of the pervasive occurrence of the Green River Formation. As parent material, the Green River Formation produces excessively erosive, saline soils making establishment difficult for most plants. As a result, these soils tend to be sparsely vegetated. The combination of steep slopes, poor vegetative cover and highly erosive soils makes soil erosion a serious concern for theses sites.

1.6 Land Ownership and Use

1.6.1 Land Ownership

The predominant landowner in the watershed is the federal government. Almost 70% is under the management of the Manti-LaSal and Uinta National Forests. These lands are managed for multiple uses including water quality, aesthetic values, recreation, livestock grazing and wildlife habitat.

Figure 1-2 shows the distribution of land ownership in the watershed. Utah Division of Wildlife Resources (DWR) manages 10% of the lands in the watershed. These lands consist of three wildlife management units; Starvation Creek, Dairy Fork, and Lake Fork. The management goals for these lands are to improve or maintain big game habitat for the appropriate number of animals. The remaining 20% of the land is privately owned. The majority of these lands are found within a mile or two of Soldier Creek, with a large tract of private lands in the Starvation Creek area. Table 1-2 summarizes land ownership in the watershed.

TABLE 1-2. Land ownership by acres and percent watershed

Land Owner or Manager	Total Acres	% of Watershed
Private land	30,749	20
Division of Wildlife Resources	Starvation WMA = 8,137 Dairy Fk WMA = 5,319 Lake Fk WMA = 1,280 TOTAL = 14,736	10
State Lands – other	1,280	1
Bureau of Land Management	1,833	1
Forest Service	Manti-LaSal = 58,757 Uinta = 43,396 TOTAL = 102,153	68
TOTAL	150,751	100

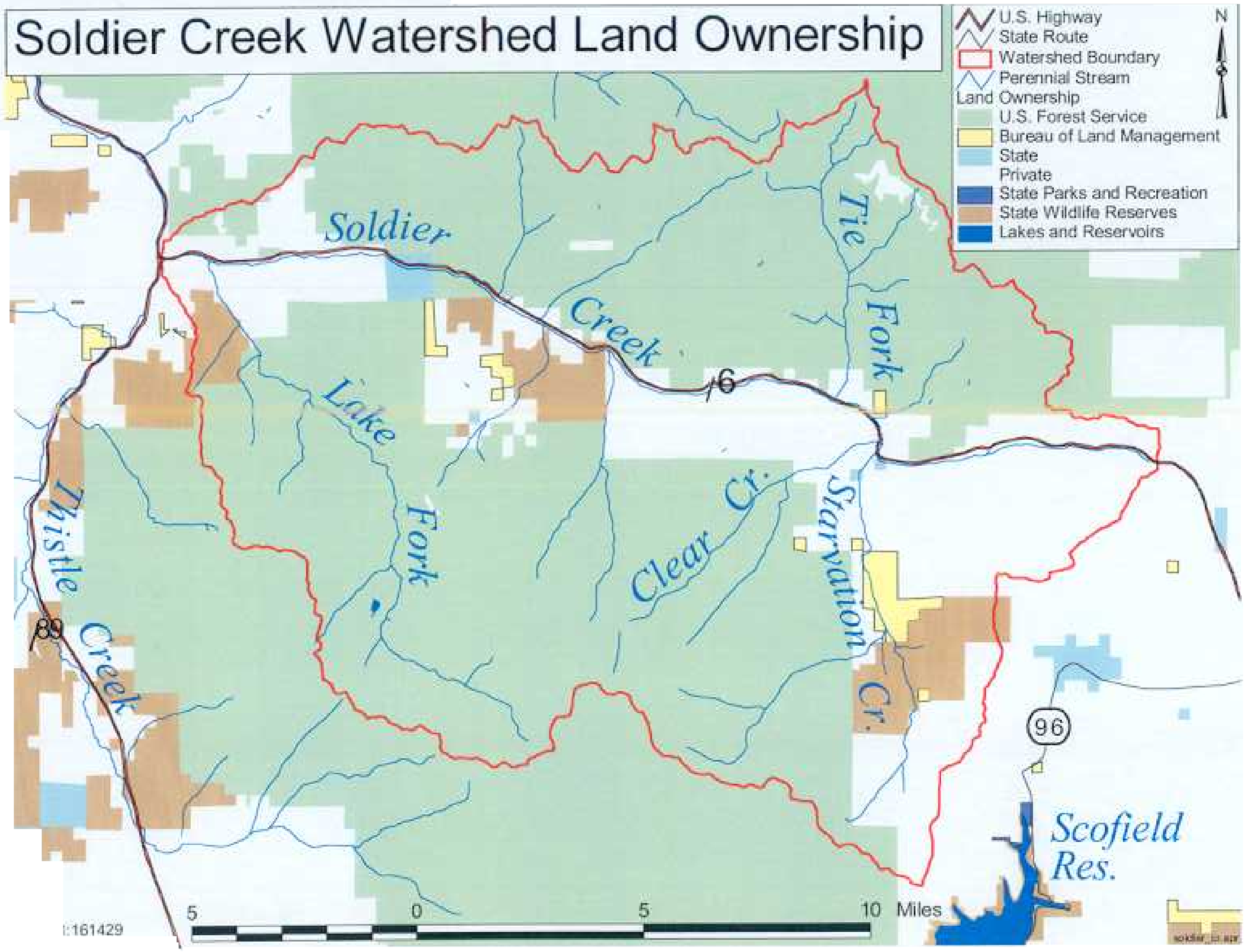
1.6.2 Land Use

Recreation, transportation, development, livestock grazing and wildlife habitat are the primary land uses in the area. There is also an area of approximately 1,000 acres of irrigated agricultural land near the mouth of the Lake Fork tributary.

With nearly 80% of the watershed under state or federal land management, recreation is a widespread land use. Common recreational activities in the area include hunting, camping, fishing, ATV riding, horseback riding and sightseeing. Several privately owned campgrounds are scattered along the length of the watershed.

Transportation is another important land use in the watershed. Spanish Fork Canyon has served as a major east to west artery through the state since pre-European settlement.

FIGURE 1-2. Soldier Creek Watershed Land Ownership



Today there are 568 miles of roads in the Soldier Creek Watershed, including Highway 6, Ray's Valley Road and Skyline Drive. The Utah Department of Transportation is working to improve safety on Highway 6 and to widen the road where practicable. The vast majority of roads within the area are unpaved. Utah Railway Company and Union Pacific Railroad continue to be an important presence in the canyon. Hauling materials along Soldier Creek since before 1912, Utah Railway Company now works with Union Pacific Railroad to transport goods through the canyon (Utah Railway Company, 2002). Today they move coal from Carbon County to the Delta Power Plant and Salt Lake City.

Residential development is not a major land use within the canyon at this time. A few summer homes are scattered along the stream corridor, the area's remoteness suppresses accelerated interest in development. Elected officials have expressed concern about the effects of development on natural resources, including water quality. To attempt to reduce these impacts, Utah County Zoning Ordinances require residential lots to be at least 20 acres in size (Utah County, 2000).

Livestock grazing also occurs throughout most of the watershed, primarily on a seasonal basis within the Uinta and Manti-LaSal National Forests.

1.7 Biology

1.7.1 Aquatic Life

The Division of Wildlife Resources (DWR) manages Soldier Creek and its tributaries for self-sustaining wild fish populations (Slater, 2003). Lower Soldier Creek is also managed for intensive yields, which includes stocked catchable fish. The native fish found in these waters include Bonneville cutthroat trout (Oncorhynchus clarki utah), mottled sculpin (Cottus bairdi), mountain sucker (Catostomus platyrhynchus), leatherside chub (Gila copei), and long nosed dace (Rhinichtys cataractae). Non-natives found and managed for in Soldier Creek and its tributaries include an occasional rainbow trout (Oncorhynchus mykiss) and brown trout (Salmo trutta).

Class III waters are the highest stream class found within the watershed and comprise 35 stream miles. Tie Fork, Clear Creek, Bennion Creek and lower Soldier Creek are Class III waters, providing important fisheries that can withstand most fishing pressure. Non-native fish are found in all of these waters, except Bennion Creek.

Class IV waters have limited fishery value, but may support native fish. In the watershed, 41 miles of Class IV waters exist. These waters include upper Soldier Creek, upper Lake Fork, Mill Fork, Mine Hollow and Indian Creek.

One mile of Class VI stream is located within the Soldier Creek watershed on lower Lake Fork. This segment of stream is dewatered for a significant part of the year.

Two State-listed sensitive fish species are known to inhabit the watershed; Bonneville cutthroat trout and leatherside chub. In addition, the lower Spanish Fork River is believed to have once supported June sucker (Chasmistes liorus), a federally listed endangered species.

1.7.2 Wildlife

Within the watershed, DWR manages over 14,000 acres, in three wildlife management units; Lake Fork, Dairy Fork and Starvation Canyon. Management objectives for these units are to provide big game winter range in adequate quantity and quality for manageable wildlife demands (Ogborn & Sakaguchi, 2001).

The watershed provides important habitat for several managed wildlife species. Nearly 75% of the watershed is considered critical elk winter range, and 43% is critical mule deer winter range. At this time, populations of elk and mule deer are considered stable (Ogborn & Sakaguchi, 2001).

Moose, black bear and mountain lion habitats are found throughout the watershed, with ranges extending beyond its boundaries. Bald eagle and osprey seasonally frequent habitat near the stream channels. Northern goshawk occupy habitat in the upper elevation expanses of coniferous forests. Turkeys have been introduced in the lower elevations and are successfully expanding their range. The loss or modification of habitat is the most significant problem facing wildlife within the watershed. Another significant problem is human safety and wildlife casualties attributed to Highway 6 and the railroads, which create barriers for migrating animals.

1.7.3 Vegetation

Vegetation data from Utah State's Automated Geographic Reference Center (AGRC) indicates that the dominant plant communities within the watershed are 59% maple, 17% aspen, 23% juniper, and 1% mountain mahogany.

Maple communities are found between the elevations of 5,100 to 9000 feet above sea level. With a shrub component of 40% and perennial grass of 30%, the potential natural community provides good to fair habitat for big game. The tree component is primarily juniper and maple, and average 8 feet in height (NRCS Technical Guide, 1993).

The community dominated by aspen is located between 7,000 and 9,000 feet in elevation. Trees comprise 10% of the potential natural community and their average tree height is 30 feet. Perennial grasses make up 45% of this community (NRCS Technical Guide, 1993).

Utah juniper community is found between 5,500 to 7,000 feet in elevation. The potential natural community is comprised of 50% perennial grasses, 25% shrubs and 15% juniper. However, on these sites juniper is generally far denser and the grass component far sparser (NRCS Technical Guide, 1993).

Mountain mahogany community comprises only 1% of the sub-watershed. This community is found between 5,200 to 8700 feet in elevation. The potential natural community has a shrub component of 60% and a perennial grass component of 35%. There are no trees within this community, but the average shrub height 9 feet (NRCS Technical Guide, 1993).

The riparian communities along Soldier Creek and its tributaries are generally lined with willows or cottonwoods. Although these comprise a very small portion of the total plant community in the watershed, they are important for the universal habitat they provide wildlife.
There are 3 protected plant species found with the watershed; clay phacelia, Ute's ladies tresses, and fireleaf beardtongue. Clay phacelia is federally listed as endangered, Ute's ladies tresses is federally listed as threatened, and fireleaf beardtongue is state listed as sensitive.

TABLE 1 3. Threatened, endangered and sensitive species in the sub-watershed

Common Name	Special Status	Aquatic/Riparian Dependent	Reason for protection
-Wildlife-			
Bald eagle	Threatened	Yes	Likely to become de-listed
Bonneville cutthroat trout	Sensitive	Yes	Declining populations & limited distribution
June sucker[1]	Endangered	Yes	Declining populations
Leatherside chub	Sensitive	Yes	Declining populations
Northern goshawk	Sensitive	Yes	Declining populations
Osprey	Sensitive	Yes	Limited distribution
Western boreal toad	Sensitive	Yes	Declining populations
-Plants-			
Clay phacelia	Endangered	No	Extremely rare, vulnerable to extinction
Fireleaf beardtongue	Sensitive	No	Rare, restricted range
Ute's Ladies Tresses	Threatened	Yes	Extremely rare, vulnerable to extinction

[1] June sucker is believed to have historically occupied habitat in the lower Spanish Fork River. The extent of its natural habitat is not known, and may not have extended up into Soldier Creek. Existing barriers currently prohibit June sucker expansion into Soldier Creek.

2.0 WATER QUALITY STANDARDS

2.1 Water Quality Impairments

Under the Federal Clean Water Act, states are required to protect, maintain, and improve the conditions of the nation's waters by adopting water quality standards. Utah's water quality standards consist of three different components: beneficial uses, numeric criteria, and the anti-degradation policy.

Beneficial uses are the desired uses that water quality should support. Utah's beneficial uses include drinking water supply, recreation, fishery and aquatic life support, and agriculture (irrigation and stock watering). Each beneficial use has specific water quality requirements or numeric criteria that must be met for the use to be supported. A water body is considered impaired when it does not meet the water quality standards needed to support its beneficial uses.

The anti-degradation policy specifies the conditions under which water quality may be lowered in surface waters. Existing beneficial uses must always be maintained and protected. Water quality better than that needed to protect existing beneficial uses must be maintained unless lower quality is deemed necessary to allow important economic or social development.

The Utah Water Quality standards (R317-2, Utah Administrative Code) designate the following beneficial use classifications for Soldier Creek from its confluence with Thistle Creek to the headwaters (Table 2-1):

TABLE 2-1. Soldier Creek Water Quality Classification/Beneficial Uses

Class 2B - Protected for secondary contact recreation such as boating, wading, or similar uses.

2.2 **Class 3A** - Protected for cold water species of game fish and other aquatic life, including the necessary aquatic organisms in their food chain.

Class 4 - Protected for agricultural uses including irrigation of crops and stockwatering.

Soldier Creek is listed as impaired on Utah's 2004 303(d) list for excess sediment and total phosphorous (Table 2-2). Utah does not have numeric standards for either of these pollutants. Soldier Creek was listed as impaired based on narrative criteria stating that waters should be free of suspended or deposited sediments at levels detrimental to designated uses. The 303(d) listing was based on a weight of evidence approach based on watershed observations, water quality data, stream and watershed assessment tools and macroinvertebrate data.

TABLE 2-2: Information for the 2004 Section 303(d) listed Soldier Creek

Name	Beneficial Use Class	Cause of Impairment	Priority	DEQ Stream Assessment Unit Code
Soldier Creek from confluence with Thistle Creek to confluence with Starvation Creek	3A	Sediment	High	1602020202-012
Soldier Creek from confluence with Thistle Creek to confluence with Starvation Creek	3A	Total Phosphorous	High	1602020202-012

2.2.1 Sediment

Sediment in surface waters is generally measured by turbidity and total suspended solids (TSS) concentrations, with higher concentrations indicating greater sediment content. Excess sediment in a waterbody can impair many beneficial uses. Sediment in streams negatively impacts aquatic life by burying aquatic habitat, spawning areas, fish eggs, and bottom dwelling macroinvertebrates, a primary food source for fish. Nutrients, metals and bacteria are often bound to sediment particles and are washed into surface waters resulting in considerable negative water quality impacts. These degraded water quality conditions threaten important municipal, industrial and recreational uses associated with streams. Increased sediment in surface waters also causes the water to be cloudy which reduces light penetration and beneficial plant growth, as well as impairs fish visibility making it more difficult for them to locate and capture prey.

Erosion and overland flow contribute some amount of TSS into most streams. In highly erodible watersheds, such as Soldier Creek, natural TSS concentrations can be very high. Spring runoff and rain storm events are followed by spikes in TSS concentrations and turbidity values.

2.2.2 Phosphorous

Phosphorous is listed as an indicator value in Utah's Water Quality Standards for the aquatic life beneficial use classifications. Lakes have an indicator value of 0.025 mg/l and streams 0.05 mg/l of total phosphorous.

As a pollutant, phosphorous does not directly impact the beneficial uses of a waterbody. In combination with other factors, high levels of nutrients such as phosphorous can cause rapid growth of algal populations and shifts in the composition of the population to undesirable species of blue-green algae. Too much phosphorus in water can also cause excessive aquatic plant growth.

In standing water, most oxygen comes from photosynthesis of plants, both rooted aquatic plants (macrophytes) and algae. Algae include readily visible growths on substrates such as rocks and wood, as well as suspended microscopic phytoplankton. Flowing and turbulent water contains higher levels of oxygen because the water is constantly mixing with the oxygen in the atmosphere.

Respiration of fish and other aquatic plants and animals depletes the oxygen in water. Decomposing organisms and aquatic plants, whether macrophytes or phytoplankton, also deplete oxygen levels. During the day, photosynthesis exceeds respiration and oxygen levels increase; however at night, or when light cannot penetrate the water, oxygen levels decline as photosynthesis cannot occur and respiration and decomposition continues.

3.0 SOURCE ASSESSMENT

3.1 Water Quality Data

Raw water quality data were acquired from the Utah DWQ/EPA STORET database for the period 1994 – 2000. DWQ's water quality monitoring program rotates intensive monitoring through the state on a five-year rotation. The data set analyzed for this study encompassed two full intensive monitoring rotations. Table 3-1 lists the STORET monitoring stations used in this analysis.

TABLE 3-1. Water Quality Sample Locations

STORET #	Description
499595	Soldier Creek above Starvation Creek
499594	Starvation Creek above Soldier Creek
499593	Clear Creek above Soldier Creek
499592	Tie Fork above Soldier Creek
499591	Dairy Fork above confluence with Soldier Creek
499590	Sheep Creek above confluence with Soldier Creek
499587	Lake Fork above Soldier Creek
499588	Soldier Creek at highway US 89 crossing

Although historic data are available in the Soldier Creek Watershed, a number of data limitations occur which control the ability to fully characterize Soldier Creek, its tributaries, and potential sources of pollution without making various assumptions. The primary limitations or inconsistencies in the data include:

- Limited continuous flow data throughout the watershed;
- Limited spatial coverage throughout the watershed
- Lack of water quality and flow data for storm/runoff events (high flow);

3.2 Water Quality Assessment

Table 3-2 provides a summary of the flow, total suspended solids (TSS), turbidity, total phosphorous and dissolved phosphorous data collected and used for the analyses. Table 3-3 shows mean flows as well as mean concentrations and loads of selected water quality parameters.

Table 3-2. Summary of Selected Water Quality Data from DWQ's STORET 1995-2000

STORET #	499595	499594	499593	499592	499591	499590	499587	499588
Site Description	**Soldier Creek above Starvation Creek**	**Starvation Creek above Soldier Creek**	**Clear Creek above Soldier Creek**	**Tie Fork above Soldier Creek**	**Dairy Fork above confluence with Soldier Creek**	**Sheep Creek above confluence with Soldier Creek**	**Lake Fork above Soldier Creek**	**Soldier Creek at highway US 89 crossing**
Flow (cfs)								
N	34	34	34	34	30	34	30	34
Min	2.3	1.4	0.5	1.5	0	0	0	4
Max	41.2	75	36	15	12	21.1	52	290
Mean	8.59	8.74	6.11	4.67	1.06	2.45	11.92	56.03
Total Suspended Solids (mg/l)								
N	34	34	34	34	7	12	29	34
Min	1.5	1.5	1.5	1.5	39	2	1.5	4
Max	2880	446	4156	539	4960	3996	126	4740
Mean	182	52	194	44	785	631	22	250
Turbidity (NTU)								
N	34	34	34	34	7	12	28	34
Min	1.3	1.3	0.65	0.87	5.2	0.545	0.3	2.2
Max	315	207	160	85	150	490	759	386
Mean	47.4	16.4	32.5	10.9	53.3	129.2	34.1	57.3
Total Phosphorous (mg/l)								
N	34	34	34	34	7	9	29	34
Min	0.005	0.005	0.005	0.005	0.03	0.01	0.005	0.005
Max	2.455	0.454	4.38	1.54	3.355	2.414	0.082	3.519
Mean	0.139	0.044	0.180	0.077	0.534	0.434	0.019	0.19
Dissolved Phosphorous (mg/l)								
N	34	34	34	34	6	10	29	34
Min	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Max	0.063	0.026	0.034	1.54	0.078	0.091	0.058	0.116
Mean	0.012	0.008	0.008	0.053	0.023	0.028	0.009	0.013

N=number of samples

For mean calculations, if a value was reported as"<", half the detection level was used to represent the value.

Table 3-3. Mean flows, concentrations and loads, Soldier Creek

Mean Flows, Concentrations and Loads - Soldier Creek Drainage - 1994-2000

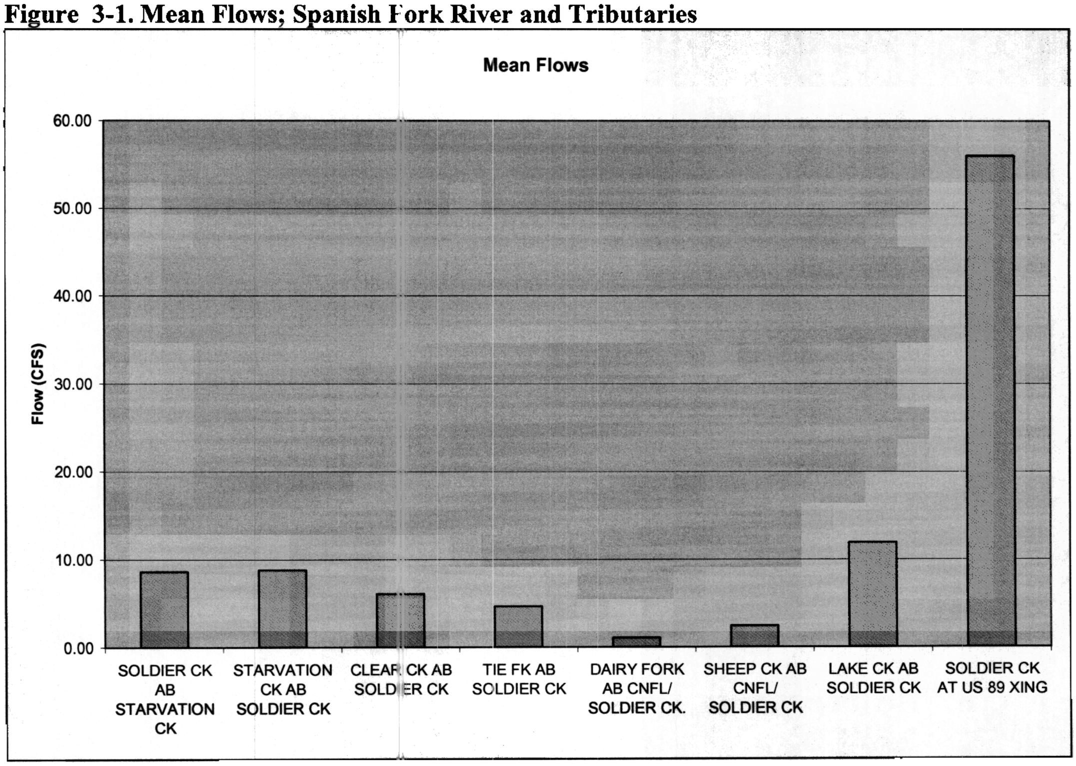
Monitoring Site	STORET	Flow (cfs)	TSS (mg/l)	TSS Load (lbs/d)	D-P (mg/l)	D-P Load (lbs/d)	T-P (mg/l)	T-P Load (lbs/d)	Turbidity (NTU)
SOLDIER CK AB STARVATION CK	499595	8.59	182.39	13,292	0.012	0.52	0.139	10.13	47.38
STARVATION CK AB SOLDIER CK	499594	8.74	51.81	4,853	0.008	0.49	0.044	4.38	16.43
CLEAR CK AB SOLDIER CK	499593	6.11	194.27	13,904	0.008	0.25	0.180	13.12	32.45
TIE FK AB SOLDIER CK	499592	4.67	44.04	2,341	0.053	0.87	0.077	2.16	10.90
DAIRY FORK AB CNFL/ SOLDIER CK.	499591	1.06	785.00	13,874	0.023	0.25	0.534	9.37	53.33
SHEEP CK AB CNFL/ SOLDIER CK	499590	2.45	630.87	4,751	0.028	0.36	0.434	2.94	129.17
LAKE CK AB SOLDIER CK	499587	11.92	21.86	3,735	0.009	0.49	0.019	2.45	34.12
SOLDIER CK AT US 89 XING	499588	56.03	249.91	254,709	0.013	3.92	0.186	190.90	57.28

3.2.1 Flow

The mean monthly flows depicted in Figure 1-2 show the snowmelt driven nature of the annual hydrograph in the Soldier Creek drainage. In addition to spring runoff, high intensity convection storms are common, especially during August. These localized “cloud bursts” may produce 2 to 3 inches of rainfall in less than an hour. The steep topography of the watershed funnels the rainfall into the stream channels with high velocities and thus the potential for erosion is great during these events.

Figure 3-1 shows the mean flows at each of the mainstem and tributary sites. Flows vary widely throughout the year at all stations. Sheep Creek and Dairy Fork showed extended periods of no flow at their monitoring stations.

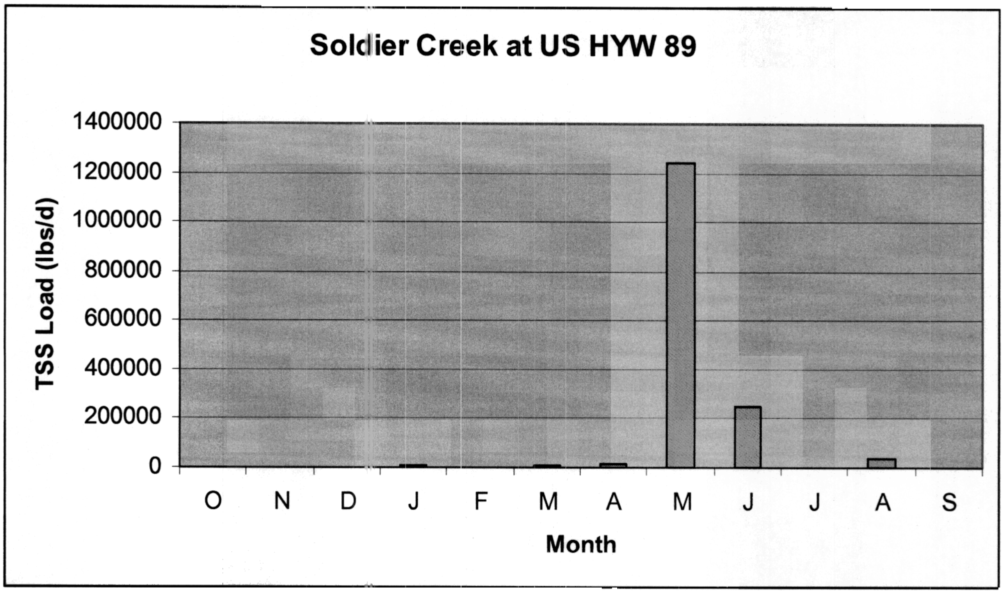
Figure 3-1. Mean Flows; Spanish Fork River and Tributaries



3.2.2 Total Suspended Solids

Total suspended solids (TSS) values for each of the tributaries as well as the main stem of Soldier Creek vary considerably throughout the course of the year (Table 3.2). Highest TDS values were associated with spring runoff. A single event captured during runoff in early May of 1995 resulted in TSS values in the in the 3,000 – 5,000 mg/l range across many of the stations in the watershed. The data showed corresponding high flow values resulting in very high loading rates during these periods. Figure 3-2 shows the typical sediment loading pattern in the watershed which is characterized by high loading during spring runoff. Annual TDS loading calculated at each of the main tributaries and Soldier Creek is presented in Table 3-3.

Figure 3-2. Mean Monthly TSS loading



TSS load percentage by tributary is presented in Figure 3-3. When all of the measured tributary mean loads are summed (including Soldier Creek above Clear Creek) and compared to the total mean load observed at Soldier Creek at US 89 crossing, there is a percent of the total load that is not accounted for by measured tributaries (Figure 3-4). The additional load can be attributed to in-stream loading along the length of Soldier Creek and from any unmeasured inflows. Because the majority of significant known inflows are accounted for, the majority of the additional load must be attributed to the Soldier Creek channel. Dairy Fork and Sheep Creek show the highest mean TSS concentrations, with Dairy Fork, Clear Creek and Soldier Creek above Clear Creek showing the highest mean TSS loads among the tributary sources.

Figure 3-3. Percent TSS loading by tributary source.

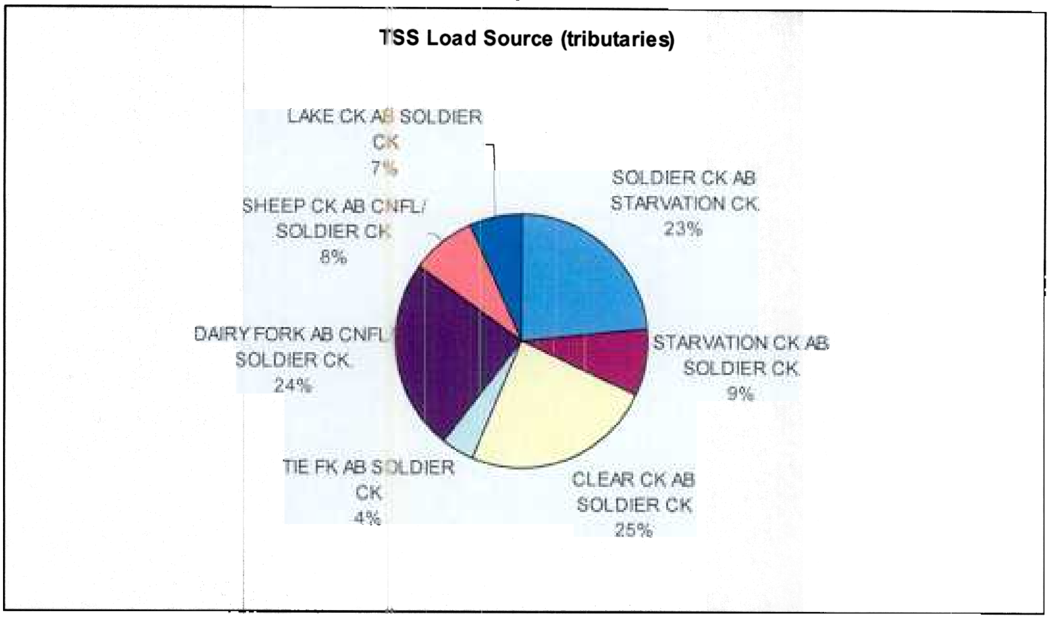
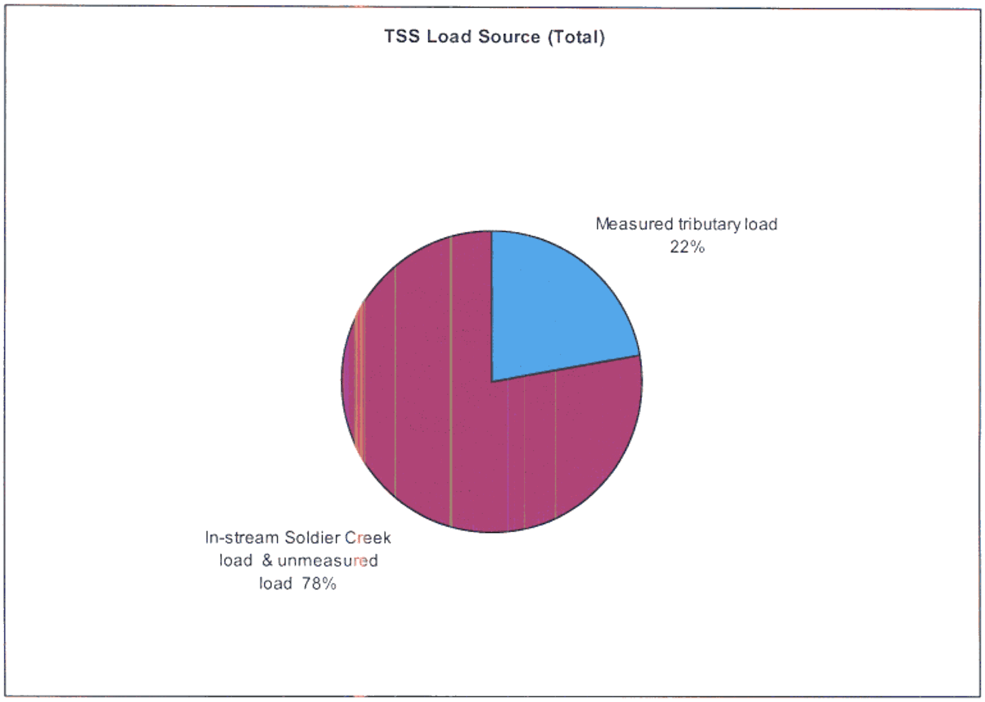


Figure 3-4. Percent TSS total load by source



3.2.3 Phosphorous

Total and dissolved phosphorous values for Soldier Creek and tributaries are summarized in Table 3-2. Mean concentrations and loads are presented in Table 3-3. Total phosphorous (TP) loads and concentration values for Soldier Creek and its tributaries vary considerably throughout the course of the year (Table 3.2). Like TSS, the highest TP values were associated with high flows and periods of active erosion. Figure 3-5 shows the typical phosphorous loading pattern in the watershed. The majority of the loading occurs during snowmelt runoff in May and June. A small load increase is also observed in August, during the convective storm season. Annual dissolved and total phosphorous loading calculated at each of the main tributaries and Soldier Creek is presented in Table 3-3. Mean monthly TP concentrations are compared to the state's 0.05 mg/l TP indicator criteria in Figure 3-6. Large exceedances of the indicator value were observed during the peak of spring runoff in May and June, and again in August.

Review of dissolved phosphorous (DP) versus total phosphorous (TP) data indicates that the dissolved fraction constitutes a small percentage of the total phosphorous (Figure 3-7). As depicted on Figures 4-1 and 4-2, strong relationships were observed between TP and TSS on both the main stem of the Spanish Fork River and in Clear Creek, a representative tributary stream. This relationship coupled with the low percentage of dissolved phosphorous as a fraction of total phosphorous confirms that phosphorous in the Spanish Fork system is bound to suspended soil particles in the water column.

Figure 3-5. Mean monthly TP loading

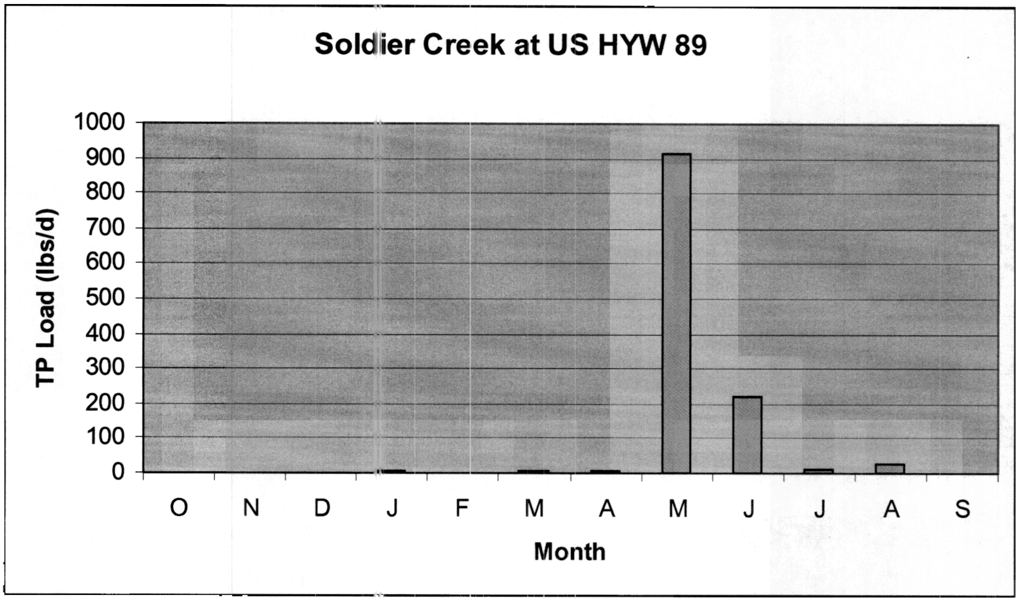


Figure 3-6. Mean monthly total phosphorous concentration on Soldier Creek.

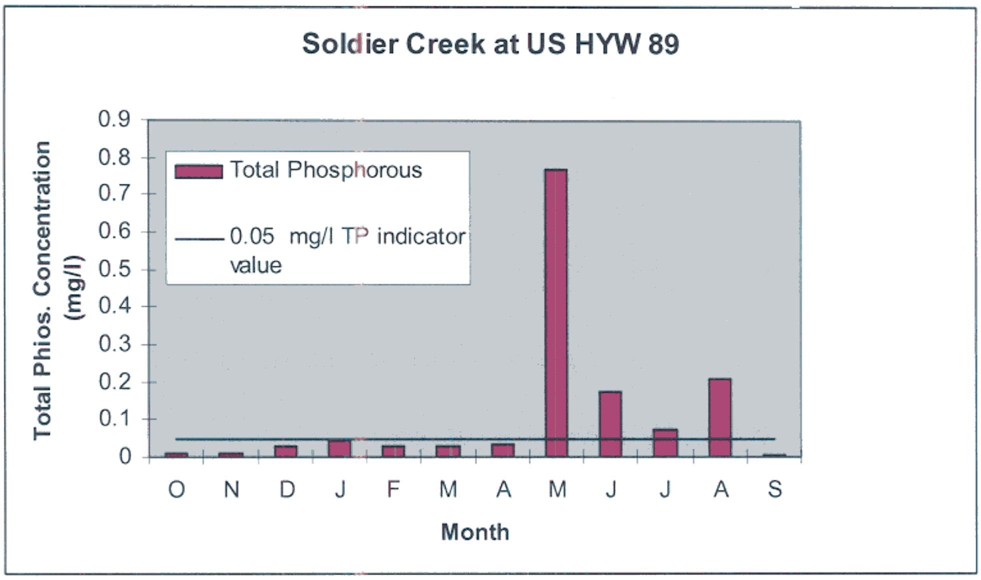
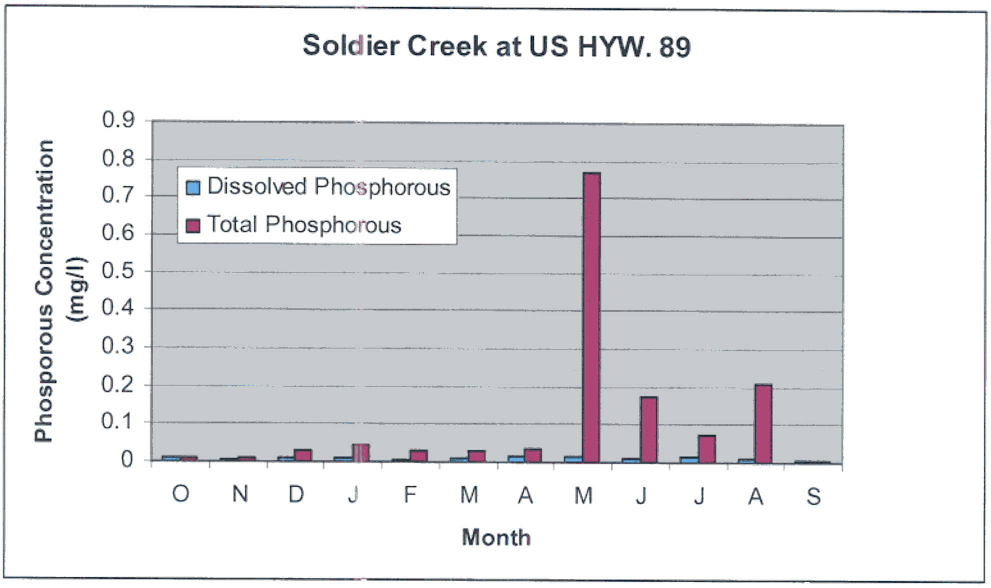


Figure 3-7. Total and dissolved phosphorous on Soldier Creek.



3.2.4 Dissolved Oxygen

Dissolved oxygen is required to support the aquatic biology. For the 3A cold water fishery beneficial use the 30-day average (chronic) standard for dissolved **oxygen** is 6.5 mg/l. Dissolved oxygen values compared against this standard resulted in no exceedances from the data from both Soldier Creek monitoring stations.

3.3 PSIAC Erosion Estimates

In the summer of 2001 an interdisciplinary team inventoried Soldier Creek watershed's uplands for soil erosion potential. The Pacific Southwest Inter-Agency Committee methodology or PSIAC was used to estimate general erosion rates of specific sites (Pacific Southwest Inter-Agency Committee, 1968). This information was then tailored to existing Uinta and Manti-La Sal National Forest soil surveys and extrapolated across the entire watershed. Using this strategy, upland soil loss was estimated to be 142,300 tons of sediment annually, with erosion rates ranging from 161 tons per acre to 0.24 tons per acre.

Sheet and gully erosion are by far the largest sources of sediment loading to Soldier Creek. About one third of the watershed soils have moderately high to very high erosion rates. The highest potential for soil erosion occurs during snowmelt and isolated summer thunderstorms. Table 3-3 shows a summary of erosion rates and the affected acres for the watershed.

Table 3-3. Erosion Rates by acre and percent of watershed.

Erosion Rate (tons/acre)	Acres	% of Sub-watershed
Low (.6 and Below)	7,144	5
Moderate (.7-1.5)	92,806	62
Moderately high (1.6-2.97)	16,635	11
High (2.98-8.7)	29,165	19
Very high (8.8+)	5,001	3

The Utah Division of Wildlife Resources (DWR) also has 8 permanent vegetation monitoring sites where soil data are collected in the Soldier Creek area . While soil erosion at some sites has been identified as a problem, the overall data indicates stable to slightly improving erosion trends. In 1997, bare soil sampled at these sites ranged from 44 to 9 percent (DWR, 1997).

Most of the watershed is considered upland range and wildlife habitat. Improper grazing has been attributed as a potential cause in the decline in upland vegetation condition. This decline is demonstrated by a loss of understory perennial grasses and broad-leafed plants, as overstory shrubs and trees increase in size and number. Because understory plants perform an important role of holding soil in place, as they decline in the plant community, soil loss accelerates. Soil erosion potential increases with the characteristic steep slopes and highly erosive soils of the watershed.

3.4 Stream Channel Erosion Estimates

In 2001, an inter-agency team completed an inventory of stream bank erosion using the Ventura method (NRCS, 1983) for Soldier Creek and its tributaries. The inventory identified unstable stream channel reaches, estimated the amount of sediment coming from those reaches and provided an estimate of total soil loss from the entire stream system. The estimated total loss of soil in the Soldier Creek Watershed was estimated at 60,800 tons per year. Soil loss varied along the 133 miles of perennial stream channel sampled. Each sampled site had a unique erosion rate and potential for sediment reduction. These rates were averaged by stream or stream segment as shown in Table 3-4.

Table 3-4. Estimated Stream Channel Erosion Rates

Stream or Segment Name	Number of Miles Applied	Erosion Rate (tons/mile)	Total Sediment Load (tons/year)
Clear Creek	14.7	156	2,293
Dairy Fork (lower)	2	97	194
Dairy Fork (upper)	3.2	375	1,200
	2.5	108	270
Lake Fork (lower)	2.7	42	113
	29	225	6,525
	10.3	375	3,862
Sheep Creek (main channel)	5.2	268	1,394
Sheep Creek (tributaries)	.5	2,079	1,040
Soldier Creek (upper w/culvert gullies)	7	4,400	30,800
Soldier Creek (upper)	1.6	298	477
Soldier Creek (middle)	6.4	18	115
Soldier Creek (lower)	11.6	369	4,280
Starvation Creek (upper)	15.8	309	4,882
Starvation Creek (lower)	3.4	`475	1,615
Tie Fork	17.1	108	1,747
TOTAL	133		60,807

1 Indian Creek was not surveyed. Erosion rates from nearby Tie Fork were applied for this estimate.

2 Mill Creek was not surveyed. Erosion rates from nearby Dairy Fork were applied for this estimate.

Upper Soldier Creek, from Tucker Rest Stop east to Soldier Summit, showed the highest erosion rate, with over 4,400 tons per mile per year. This 7-mile stretch contributes over ½ of the estimated total annual stream sediment load per year for the creek. In these reaches, high sediment yield is largely due to gullies 20 to 30 feet deep associated with culverts. The culverts were installed to divert runoff away from the railroad tracks and Highway 6. However, when storm water collects in these culverts, the force of the water actively erodes at the outlet, forming gullies. The sediment contribution of these gullies is sporadic, but extreme.

A ½ mile reach of an ephemeral tributary to Sheep Creek is another area with an extremely high erosion rate. This short reach was estimated to contribute sediment exceeding 2,000 tons per mile per year to Sheep Creek. Characteristics of this short reach are 30-foot high, highly erosive slopes that lack any vegetative cover. While the sediment contribution of this gully is sporadic, it is extreme when it is active.

Most of the remaining streams inventoried had erosion rates ranging from 100 to 475 tons per mile per year. Streambank loss is greatest in the early spring during peak snowmelt runoff. Episodic severe thunderstorms can also overwhelm a stream system and increase the risk of bank loss.

The lowest stream bank erosion rates were also found along Soldier Creek. Approximately 6 ½ miles of the channel were extremely well armored with dense stands of coyote willows and appeared to be functioning well. Erosion rates for these stream reaches were estimated at 18 tons per mile per year.

4.0 TECHNICAL ANALYSIS

4.1 Water Quality Analysis

To evaluate the potential effectiveness of proposed control strategies and to potentially assess water quality conditions that may occur under different flow conditions, water quality relationships were evaluated between total suspended solids (TSS), total phosphorous (TP), and flow.

As depicted on Figures 4-1 and 4-2, strong relationships were observed between TP and TSS on both the main stem of Soldier Creek and in Clear Creek, a representative tributary stream. This relationship coupled with the low percentage of dissolved phosphorus as a fraction of total phosphorus (Figure 3-7, Table 3-2) confirm that phosphorus in the Soldier Creek system is bound to suspended soil particles in the water column. As a result, reductions in sediment loads to the system will result in corresponding phosphorus reductions.

Figure 4-1. Relationship between total suspended solids and total phosphorous on Soldier Creek

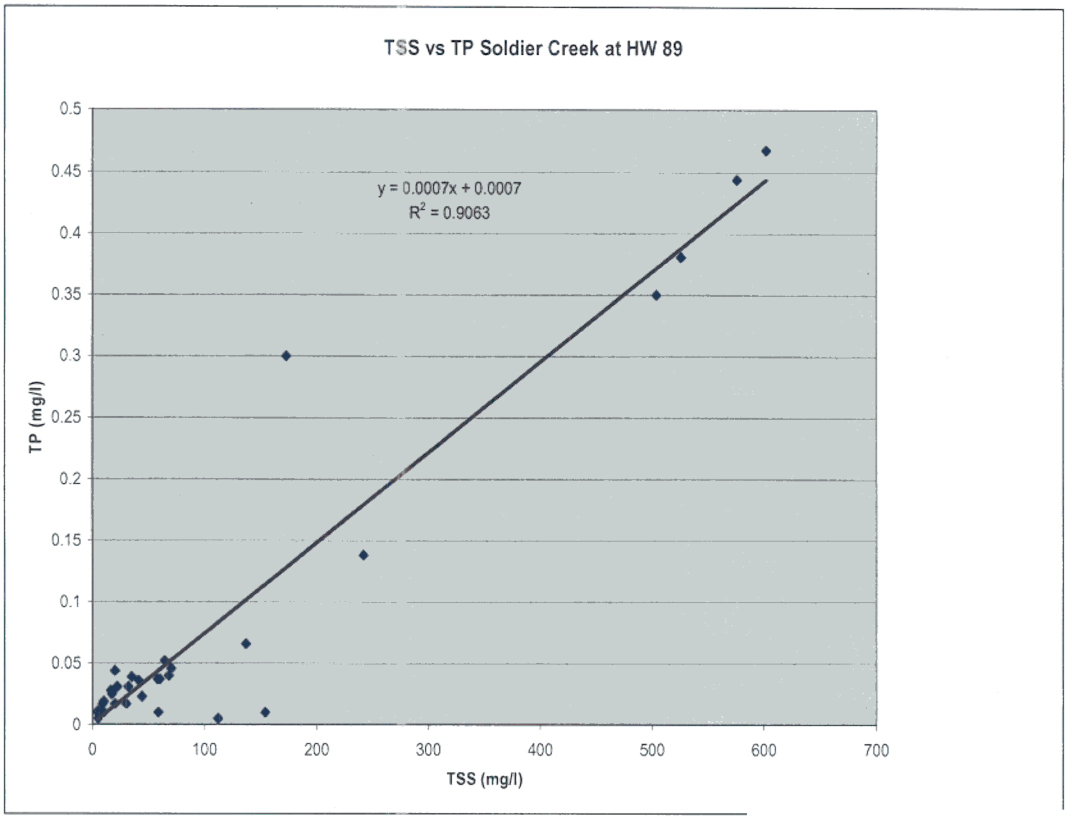
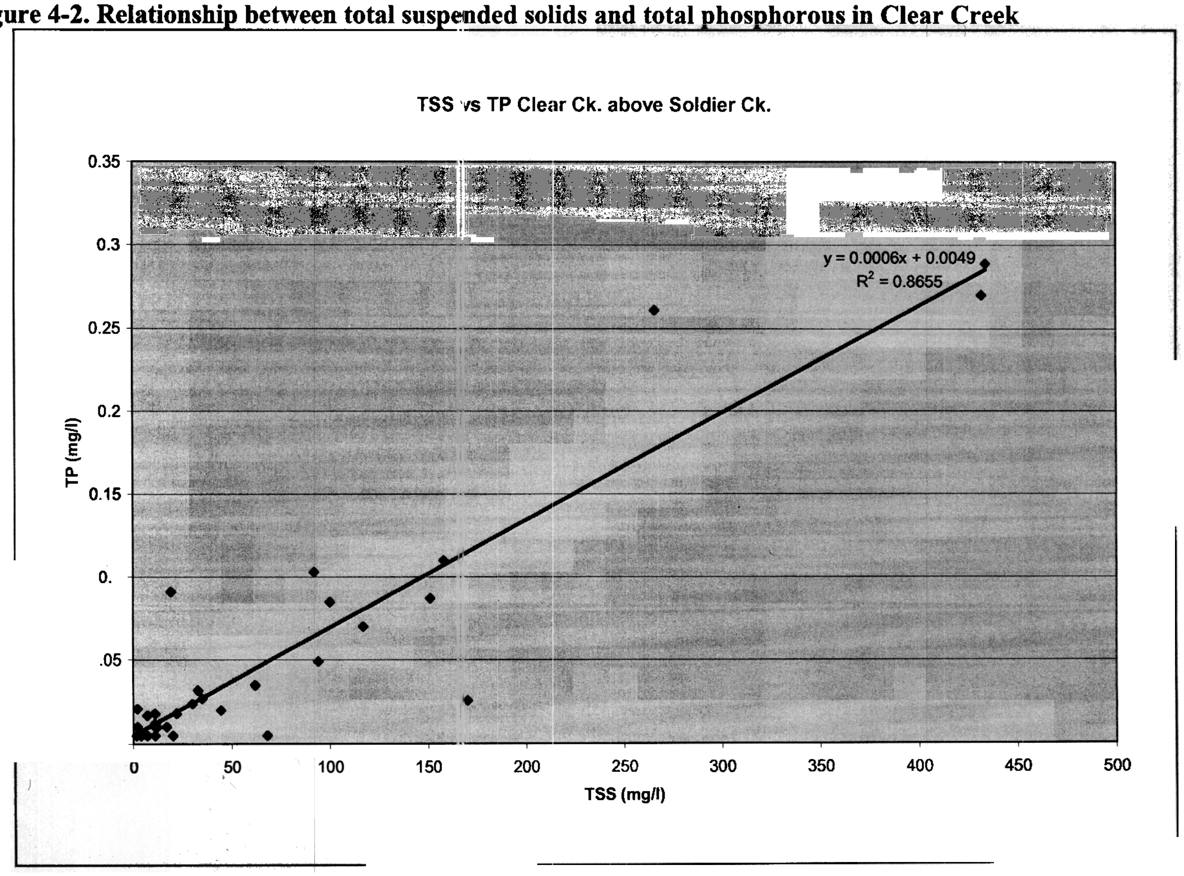


Figure 4-2. Relationship between total suspended solids and total phosphorous in Clear Creek



4.2 Macroinvertebrates

4.2.1 Introduction

This Section presents excerpts from a report summarizing the physical/chemical and benthic macroinvertebrate data collected from various reaches of Soldier Creek and its tributaries, from July 2000 to October 2002 by Dr. Lawrence Gray, Utah Valley State College (Gray 2003). The full report is found in Appendix A.

4.2.2 Methods

Study Sites

The locations of the study sites, site designations, and STORET site equivalents are given in the table summarizing the physical/chemical parameters. The primary emphasis was placed on the mainstem reaches and upper tributaries of Soldier Creek. All sites except for Tie Fork Creek have primarily cobble riffles of varying degrees of embeddedness overlying finer sediments of sand, silt and clay (Tie Fork Creek has unconsolidated gravel and finer substrates). Riparian vegetation consists of sagebrush, willow, and occasional cottonwoods. Organic debris dams are uncommon, except in Starvation and Clear Creeks where beavers have constructed dams. The stream reaches at Site SCB (Soldier Creek at Dale Barney's) have been undergoing rehabilitation for the past several years, including reduction in cutbanks, modifying meanders, and replanting of willows.

Table 4-1. Macroinvertebrate sample stations and site codes

STORET #	Description	Site Code
499595	Soldier Creek above Starvation Creek	SCC
499594	Starvation Creek above Soldier Creek	SSC
499593	Clear Creek above Soldier Creek	
499592	Tie Fork above Soldier Creek	TFC
499591	Dairy Fork above confluence with Soldier Creek	SCM
499590	Sheep Creek above confluence with Soldier Creek	
499587	Lake Fork above Soldier Creek	LFC
499588	Soldier Creek at highway US 89 crossing	SCB

Physical/Chemical Parameters

Measurements of total suspended solids, conductivity, pH, dissolved oxygen, temperature, sediment samples and soil compaction measurements were taken during normal (non-storm) flows at the time of the macroinvertebrate sampling at all sites.

Macroinvertebrates

Macroinvertebrates were collected with a Surber sampler (0.25-mm mesh) that enclosed an area of 1 ft^2. Three to four samples were taken in riffle/run portions of the creek at each sampling site on each date. Macroinvertebrates were preserved in 5% formalin in the field and transferred to 70% ethanol for identification and counting. All specimens were hand-picked from debris. Dry mass for each species was determined after drying the specimens at 80°C for 24 h and weighing to the nearest 0.1 mg. Density and biomass values per square meter were based on simple (not transformed) averages of values from all samples taken at a site on a particular date.

Two tolerance indices are presented. The "EPA Tolerance Index" is based on the tolerance values for individual taxa given in Appendix B of Barbour et al. (1999) using the Northwest column (Idaho). This index was calculated as a simple average of all tolerance values for individual taxa in a collection and is not density weighted. It is similar to the Hilsenhoff Biotic Index in that taxa are rated on a 0 to 10 scale of tolerance with higher numbers indicating greater tolerance. CTQa and CTQd metrics were calculated from Mangum's (1989) tolerance values for individual taxa.

4.2.3 Results

Physical/Chemical Parameters

Water chemistry parameters (TDS, pH, dissolved oxygen) were similar at all sites and typical of streams in the region. Dissolved oxygen was at or near saturation at all sites, and there was no indication of organic pollutants. TSS was highest in Starvation Creek and the mainstem sites of Soldier Creek with the highest average value at Site SCB. Consistently high TSS concentrations are atypical of streams in the region and reflect significant erosion from cutbanks and upland soils. Clear Creek, Tie Fork Creek, and Lake Fork Creek had relatively low TSS, although these may reflect the limited sampling during low flow periods.

Substrates at all sites show relatively high amounts of finer sediments. Compaction of sediments generally increased downstream, although additional data is needed to determine if these differences are statistically significant.

Macroinvertebrates

Macroinvertebrate communities showed distinct and consistent differences between the 3 sites in the upper watershed (SSC, SCC, and TFC) compared to the 3 sites in the lower watershed (SCM, SCB, and LFC) in terms of abundance measures, species composition, species diversity metrics, and pollution-tolerance metrics. Two tables are attached with data; the first with data from all sampling dates at all sites, the second with summaries of site data.

Upper watershed sites typically had greater abundance of macroinvertebrates than lower watershed sites. Tie Fork Creek and Starvation Creek had the highest average densities of all sites, and all 3 upper-watershed sites had higher average total biomass values than lower-watershed sites. Compared to other streams in the region, only Starvation Creek and Tie Fork Creek had typical total density and biomass values. All other sites had total density and biomass values well below regional averages.

Common taxa throughout the watershed included the mayfly *Baetis tricaudatus*, the blackfly *Simulium* sp., the stonefly *Isoperla fulva*, the caddisflies *Hydropsyche occidentalis* and *Brachycentrus occidentalis*, the elmid beetle *Optioservus quadrimaculatus*, the cranefly *Tipula* sp., orthoclad and pentaneurid chironomids, and small oligochaetes. Several common species generally associated with low TSS and sedimentation were either restricted to or most abundant at the upper-watershed sites, including the mayflies *Drunella grandis*, *Rhithrogena* sp., *Epeorus* sp. and *Paraleptophlebia* sp.; the stoneflies *Isogenoides colubinus* and *Zapada* sp., the caddisfly *Arctopsyche grandis*, and the tipulid *Hexatoma* sp.. The mayfly *Tricorythodes minutus* was present in highest numbers at Site SCB and increased in abundance through the study period. This mayfly is a good indicator of stream reaches with high TSS and substrate sedimentation.

Summary metrics reflected the changes in species composition. Starvation Creek and Clear Creek had higher total species, EPT (Ephemeroptera + Plecoptera + Trichoptera) species, number of intolerant species, and values for diversity indices (Shannon and Simpson) than the mainstem sites.

particularly Soldier Creek at Mill Creek (SCM). These 2 sites also showed greater balance among trophic groups, particularly the greater relative abundance of scrapers, shredders, and predators. Among the community tolerance indices, the macroinvertebrate community in Clear Creek had the lowest values for the EPA Tolerance Index, CTQa, and CTQd, and these values are typical for other regional streams. Community values were lower at Starvation Creek and the mainstem sites. At Starvation Creek, low community indices were primarily due to the presence of several snail species, whereas the lack of many intolerant species contributed to the low values at Sites SCM and SCB.

Summary metrics for Tie Fork Creek were lower than the other two upper-watershed sites, which may reflect its lack of larger substrates (e.g., cobble) and greater influence of flows from springs (as indicated by the high abundance of elmids and *Dugesia* sp.). The community metrics for Lake Fork Creek indicate this site is the most impacted site of all sites studied. Like Site SCM, the macroinvertebrate community was dominated by small, surface-dwelling species (*Baetis tricaudatus* and *Simulium* sp.). Consequently, the trophic structure is dominated by gatherer-collectors and filterer-collectors.

4.2.4 Conclusion

High sediment loads have impacted most of the Soldier Creek watershed. The relatively high amounts of fine sediments in stream substrates, high TSS values, and high compaction of sediments at the mainstem Soldier Creek sites and Lake Fork Creek contribute to low macroinvertebrate abundance and diversity relative to Starvation and Clear Creeks, although community metrics show that only Clear Creek has a community composition consistent with other regional streams not affected by high rates of sedimentation.

Although additional sampling is needed, the general trend at Site SCB (the most studied site) over the past two years has been towards decreases in abundance and diversity (e.g., total density, total biomass, total species, EPT species, and number of intolerant taxa) and an increase in sediment-tolerant mayfly *Tricorythodes minutus* concurrent with increased amounts of fine sediments in substrates and greater substrate compaction.

4.3 TMDL Endpoints

One of the goals of a TMDL is to establish water quality endpoints that can be used to determine when water quality has improved sufficiently to support beneficial uses. The primary beneficial use of concern in Soldier Creek is the protection of cold-water fish and the organisms upon which they depend. Aquatic biota have been shown to be negatively impacted by excessive sediment inputs in numerous studies (see Cordone and Kelley 1961, Berry et al. 2003 for reviews). The primary objective of the indicators and targets in this TMDL is to ensure that sediment inputs are sufficiently controlled to maintain a healthy stream ecosystem.

TMDL endpoints are often based on numeric criteria defined in water quality standards for the pollutant of concern. However, there is no water quality standard for TSS.

Biological indicators are the primary water quality targets for this TMDL. Biological indicators are appropriate for measuring water quality improvement for several reasons. First, measures of biological integrity directly quantify the extent to which aquatic life beneficial uses are met. Second, biological organisms integrate the effects of stressors through time, which will better capture the effects of the episodic sediment loads into Soldier Creek.

4.3.1 Benthic Mactroinvertebrates

As noted by Zweig and Rabeni (2001) benthic macroinvertebrates are ideal candidates for monitoring the effects of human-caused sediment inputs, because substrate is one of the primary factors regulating their distribution and abundance. Macroinvertebrate populations are altered by sediment deposition because habitat is reduced by a loss of interstitial spaces (Cummins and Lauff 1969). In addition, pulses of sediment such as those observed at Soldier Creek have been shown to alter the composition of benthic invertebrate assemblages (Shaw and Richardson 2001). These alterations in the composition of benthic macroinvertebrate assemblages are likely to be detectable by both general measures of biotic integrity and measures of biota specifically designed to detect the effects of sediment deposition (i.e., Relyea et al. 2000, Zweig and Rabeni 2001).

Macroinvertebrate samples have been collected from a number of stream reaches throughout the watershed (see Technical Analysis section). The taxonomic composition of these samples can be used to calculate numerous measures of general biotic condition. However, this TMDL recommends, at a minimum, the following:

Percent EPT

An index that is frequently used to assess the overall condition of streams is the percent of individuals in a sample that are in the orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). In general, species within these Orders are more sensitive to anthropogenic stressors than species from other Orders of macroinvertebrates.

Modified Hilsenhoff Biotic Index (HBI)

HBI is an index that summarizes the relative tolerance of an assemblage to human-caused nutrient enrichment. HBI calculations for this TMDL are based on the tolerance values for individual taxa given in Appendix B (Northwest Idaho data) of Barbour et al. (1999). This index was calculated as a density-weighted average of the tolerance values for individual taxa such that lower HBI values are indicative of higher quality waters.

Taxa Richness

Taxa richness is a metric that describes the total number of individuals in a sample. Taxa richness decreases in concert with the magnitude or frequency of human-caused stressors.

Multi-Metric Index (MMI)

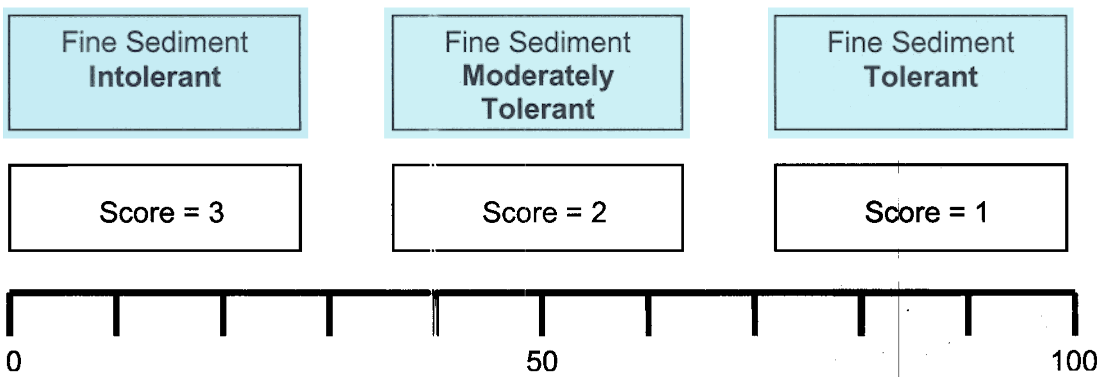
A MMI is a combination of indices that together quantify important compositional and functional traits of the macroinvertebrate assemblage (Karr and Chu 1999). Expected MMI values are estimated from measures obtained from a number of physically and geographically similar reference sites. These expected conditions can then be compared against values obtained from a new site to quantify the magnitude of biological impairment. A MMI is currently under development for Utah's streams and, once complete, will be used to evaluate Soldier Creek samples.

O/E

O/E is another measure of biological integrity that is derived from RIVPACS-type empirical models (Wright et al. 1984). These models use geographical and physical watershed characteristics from reference sites to predict the number of taxa that are expected to occur in the absence of human-caused disturbance (E). These predictions are then compared with those taxa observed at a site that the model predicted to occur (O). The ratio O/E describes the percent of taxa lost as a result of anthropogenic stressors. RIVPACS-type models are currently under development and O/E scores will be used to evaluate Soldier Creek samples.

In addition to the more general measures of biological condition, indices that are generated from sediment-specific relations to alterations of macroinvertebrate assemblages will be explored. Sediment-specific measures of biological condition have been found to be more sensitive to the sediment inputs than more general measures of biological condition (Zweig and Rabeni 2001, Rinella et al. 2002). Relyea et al. (2000) used macroinvertebrate and fine sediment data compiled from 562 stream segments throughout western states to develop sediment tolerance scores for 83 widely-occurring macroinvertebrate taxa (see Appendix B). These tolerance scores were then used to create 3 tolerance categories and associated scores (Figure 3-1). Taxa found to occur in streams with 0-40% fines were placed in the intolerant category and scored 3. Those taxa found in streams with 41-70% fines were placed in the moderately tolerant category and scored a 2. Those taxa found in streams with 71-100% fines were placed into the tolerant category and scored a 1.

Figure 3-1: Benthic macroinvertebrate classification into 3 tolerance classes.



These fine sediment tolerance scores were then used to generate the following sediment-specific measures of biotic condition:

<u>Sediment-weighted EPT</u>
Sediment-weighted EPT is a modification of EPT that uses empirically-derived sediment tolerance values to give higher weight to those EPT taxa that are sensitive to fine sediment. This metric was calculated as:

Sediment-weighted EPT = $\sum(N_i a_i)/N_{EPT}$

where N_i is the total number of individuals in an EPT taxon, a_i is the tolerance value for taxon i, and N is the total number of EPT taxa.

<u>Sediment-weighted diversity</u>
Measures of diversity combine estimates of richness with the relative abundance of each taxon. Empirically-derived measures of sediment tolerance were used to calculate a measure of diversity that gives a higher weight to sediment-sensitive tolerance as follows:

Sediment-weighted diversity = $\sum(N_i a_i)$

where N_i is the total number of individuals in a taxon, and a_i is the tolerance value for taxon i. A tolerance of 1 was assigned to taxa where the tolerance values are not assigned.

The tolerance values used to generate these metrics will be refined with collections made throughout Utah as the data are made available.

4.3.2 Defining Endpoints

Effective use of biological indicators as endpoints, or targets, for the implementation of this TMDL will require that naturally-occurring spatial and temporal variability in the composition of macroinvertebrate assemblages is accounted for. Spatial variability will be accounted for in a couple of ways. First, 2 to 3 sites will be selected on Soldier Creek to help tease out differences in macroinvertebrate assemblages associated with local characteristics (i.e., in-stream habitat and riparian conditions) instead of human-caused stressors. Second, data collected at Soldier Creek will be compared against other physically and geographically similar reference streams to better understand the range of biological conditions encountered in unimpaired stream ecosystems. Temporal variability will be estimated by comparing measures of biological condition obtained from samples collected within the same season for more than 3 years.

Once quantified, measures of spatial and temporal variability will be used to help determine whether TMDL implementation has resulted in improved biological conditions. Remediation efforts will continue at Soldier Creek until measures of biological condition for 3 consecutive samples falls within 80% of values observed at comparable reference sites. These conditions will continually be reevaluated with the most robust indicators of biological condition available, so that the biological assessment tools under development can be utilized.

Aquatic biota have been shown to be negatively impacted by excessive sediment inputs in numerous studies (see Cordone and Kelley 1961, Berry et al. 2003 for reviews). The primary objective of the indicators and targets in this TMDL is to ensure that sediment inputs are sufficiently controlled to maintain a healthy stream ecosystem.

4.4 Margin of Safety

TMDLs require a margin of safety (MOS) component that accounts for the uncertainty about the relationship between the pollutant loads and the receiving waterbody. The MOS can be implicit or explicit. An explicit MOS is often accounted for in the allocation section as a percentage of the overall allocation, but we are not setting a percentage reduction in turbidity or TSS values. For this TMDL, the MOS will be addressed implicitly by using conservative methods of measuring macroinvertebrate response.

4.5 Seasonality

The Clean Water Act requires that TMDLs consider seasonal variations. In the context of sediment TMDLs, it is apparent that sediment, like most nonpoint source loads, enters the stream during high flow periods associated with snowmelt runoff or rainfall events. In the Soldier Creek watershed, the majority of sediment (and associated phosphorus) load occurs during spring runoff. Unlike other pollutants which may cause an immediate effect on beneficial uses, sediment impacts may occur some time after and at some distance downstream from their initial point of discharge. Because the impairment caused by sediment is caused by long-term deposition and the impact of fine particles on the biological condition of the stream, it is appropriate that the TMDL focus on long-term sediment load and biological response time frames.

4.6 Load Analysis

4.6.1 Current Load

The primary water quality monitoring station at the bottom of the watershed (Station 499588, Soldier Creek at US Highway 89) was used to establish current sediment loading. The current mean annual load for Soldier Creek based on TSS data was calculated as:

Current mean annual load = 46,485 tons/year

As outlined in Sections 3.3 and 3.4, sediment yields from in-stream, upland and road sources were estimated using field assessment techniques. These estimates produced the following sediment yields:

Stream channel erosion	60,807 tons/year
Roads	40,000 tons/year
Upland erosion	142,300 tons/year
Total estimated load	243,107 tons/year

In order to compare the field erosion estimates on a relative basis with the observed in-stream annual TSS loads observed in Soldier Creek, the field erosion estimates were normalized to the observed 46,485 tons/year value calculated for Soldier Creek yielding:

Stream channel erosion	11,627 tons/year
Roads	7,649 tons/year
Upland erosion	27,209 tons/year
Total estimated load	46,485 tons/year expressed as TSS

4.6.2 Load Capacity, Reduction and Allocation

Load Capacity 40,558 tons per year

Load Reduction expressed as TSS	
Culvert gullies, upper Soldier Creek	2,868 tons/year
Stream channel erosion	2,103 tons/year
Upland erosion	956 tons/year
Total estimated load	5,927 tons/year expressed as TSS

In order to compare the TSS-based reduction estimates to the original erosion field estimates, load reductions were converted back to their original un-normalized values yielding the following reductions:

Culvert gullies, upper Soldier Creek	15,000 tons/year
Stream channel erosion	11,000 tons/year
Upland erosion	5,000 tons/year
Required load reduction	31,000 tons/year

4.7 Linkage Analysis

4.7.1 Linkage between controls and biological endpoints.

An all-inclusive theory of deposited or suspended sediments on benthic macroinvertebrate assemblages is difficult to formulate due to differences in study objectives, methods, and evaluations of biological responses (Zweig and Rabeni 2001). Nonetheless, a few generalizations are possible. Sediment pulses such as those that occur at Soldier Creek have been shown to increase the drift of macroinvertebrates which in turn reduces total density and diversity (Shaw and Richardson 2001). As sediment settles, interstitial spaces are filled and the quality of macroinvertebrate habitat is diminished (Cummins and Lauff 1969). In addition, sediment input alters distributions of substrate size classes, which are an important determinant of macroinvertebrate distributions (Minshall 1984). All of these effects of sediment should lead to alterations of the composition and function of macroinvertebrates in Soldier Creek. Indeed, preliminary analyses suggest that Soldier Creek is biologically impaired relative to a physically comparable reference sites. Measures of biological condition obtained from continued monitoring of macroinvertebrates at Soldier Creek should allow us to evaluate the success of the remediation projects described in this TMDL.

4.7.2 Linkage between sediment and total phosphorous.

Total phosphorous values are closely related to total suspended solids concentrations in Soldier Creek and its tributaries (Figure 4-1, 4-2). Analysis of representative data shows total suspended solids is a measure of the amount of sediment being transported by the stream system. Based on this relationship, we expect that a reduction in sediment loads to the watershed will result in lower TSS concentrations, resulting in a corresponding reduction in total phosphorus concentrations. The net effect will be that controlling sediment loads in the watershed will reduce phosphorus concentrations.

5.0 IMPLEMENTATION

5.1 Spanish Fork Coordinated Resource Management Plan

In 1997 the Timp-Nebo SCD, with help from the Natural Resources Conservation Service (NRCS), agreed to establish a local working group for the Spanish Fork River Watershed. The committee was formed to address watershed and water quality issues in the Spanish Fork River Drainage. As part of that process, the committee agreed to develop coordinated resource management plans (CRMP) for six sub-watersheds in the drainage. A draft CRMP for the Soldier Creek drainage was prepared in 2003. The CRMP is the source of much of the watershed information, source analysis and implementation information contained in this TMDL.

5.2 Recommended Best Management Practices

As outlined in the Draft 2003 Soldier Creek Watershed Coordinated Resource Management Plan, the Spanish Fork River Watershed Steering Committee recommended implementation of the following best management practices (BMPs) to control sedimentation and erosion, and improve the quality of the Spanish Fork River:

1. To protect and stabilize at least 21 miles of eroding streambanks by applying best management practices that will result in at least a 11,000 ton/year reduction of soil loss within ten years of CRMP plan implementation.
2. To restore the natural function (dimension, pattern and profile) to 14 miles of stream corridor within ten years of the CRMP plan implementation
3. To improve fish habitat by increasing protective habitat cover by 15% and reducing eroding banks by at least 10%, resulting in 118 pounds/acre of trout biomass, within ten years of the CRMP plan implementation.
4. To reduce sediment coming from the uplands by 5,000 tons/year by applying BMPs on 16,000 acres of rangelands within five years of complete plan implementation.
5. To reduce the influence of noxious weeds infestations within ten years of complete plan implementation.

6. To increase coordination with the various land owners and land management agencies to minimize potential conflicts and resource damage as transportation and recreation demands increase over the next 10 years.
7. To actively promote coordination between CRMP partners, including seeking team review of proposed actions that could affect Soldier Creek watershed resources.
8. Provide recommendations regarding natural resources and development to the Utah and Wasatch County planning commissions, as needed, throughout the planning and implementation phases of the CRM plan.

5.3 Monitoring

This section has intentionally been left blank pending the collection of additional information

6.0 PUBLIC PARTICIPATION

Due to recognition of water quality and other resource concerns, the Timp-Nebo Soil Conservation District, with help from the Natural Resources Conservation Service (NRCS), agreed to establish a local working group for the Spanish Fork River Watershed. In 1997, the Spanish Fork Watershed Committee was formed to address watershed and water quality issues in the Spanish Fork River Drainage. Many meeting have been held since that time and have been attended by local, state and federal cooperators. As part of that process, the committee agreed to develop coordinated resource management plans (CRMP) for six sub-watersheds in the drainage. A draft CRMP for the Soldier Creek drainage was prepared and reviewed by the committee in 2003. This TMDL is based largely on the findings of that report.

Public comment period for the draft TMDL will be from March 10 through March 24, 2006. Notices of availability of the Draft TMDL were published in the Salt Lake Tribune, the Deseret News, and the Division of Water Quality's internet web site.

7.0 REFERENCES

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Appendix B. Sediment tolerance values (FSBI) and modifications obtained from Relyea et al. 2000.

Order	Taxon	FSBI	Modified FSBI
Coleoptera	*Cleptelmis ornata*	2	1
Coleoptera	*Cleptelmis spp.*	2	1
Coleoptera	*Lara avara*	2	1
Coleoptera	*Optioservus spp.*	3	1
Diptera	*Chelifera spp.*	2	1
Diptera	*Dicranota spp.*	2	1
Diptera	*Dixa spp.*	1	1
Diptera	*Hexatoma spp.*	3	1
Diptera	*Limnophila spp.*	2	1
Diptera	*Simulium spp.*	3	1
Diptera	*Tipula spp.*	3	1
Ephemeroptera	*Cinygma spp.*	2	1
Ephemeroptera	*Heptagenia/Nixe spp.*	2	1
Ephemeroptera	*Paraleptophlebia spp*	2	1
Megaloptera	*Sialis spp.*	1	1
Plecoptera	*Isoperla spp.*	2	1
Plecoptera	*Malenka spp.*	2	1
Plecoptera	*Zapada cinctipes*	3	1
Plecoptera	*Zapada columbiana*	3	1
Trichoptera	*Cheumatopsyche spp.*	2	1
Trichoptera	*Lepidostoma* - panel case larvae	2	1
Trichoptera	*Lepidostoma spp.*	2	1
Trichoptera	*Psychoglypha spp.*	3	1
Trichoptera	*Rhyacophila Sibirica grp.*	3	1
Trichoptera	*Wormaldia spp.*	2	1
Coleoptera	*Heterlimnius corpulentus*	5	2
Coleoptera	*Heterlimnius spp.*	5	2
Coleoptera	*Narpus concolor*	5	2
Coleoptera	*Narpus spp.*	5	2
Coleoptera	*Zaitzevia spp.*	5	2
Diptera	*Antocha spp.*	6	2
Diptera	*Atherix spp.*	6	2
Diptera	*Clinocera spp.*	5	2
Diptera	*Glutops spp.*	5	2
Diptera	*Hemerodromia spp.*	5	2
Diptera	*Pericoma spp.*	5	2
Ephemeroptera	*Acentrella spp.*	6	2
Ephemeroptera	*Ameletus spp.*	4	2
Ephemeroptera	*Baetis bicaudatus*	5	2

Ephemeroptera	*Baetis bicaudatus/tricaudatus*	5	2
Ephemeroptera	*Baetis spp.*	4	2
Ephemeroptera	*Baetis tricaudatus*	5	2
Ephemeroptera	*Cinygmula spp.*	6	2
Ephemeroptera	*Diphetor hageni*	4	2
Ephemeroptera	*Epeorus albertae*	6	2
Ephemeroptera	*Epeorus longimanus*	6	2
Ephemeroptera	*Epeorus spp.*	6	2
Ephemeroptera	*Ephemerella inermis/infrequens*	4	2
Ephemeroptera	*Ephemerella spp.*	4	2
Ephemeroptera	*Paraleptophlebia bicornuta*	5	2
Ephemeroptera	*Rhithrogena spp.*	6	2
Ephemeroptera	*Serratella spp.*	5	2
Ephemeroptera	*Serratella tibialis*	5	2
Ephemeroptera	*Tricorythodes minutus*	4	2
Ephemeroptera	*Tricorythodes spp.*	4	2
Plecoptera	*Calineuria californica*	5	2
Plecoptera	*Pteronarcys spp*	6	2
Plecoptera	*Skwala spp.*	5	2
Plecoptera	*Sweltsa spp.*	4	2
Plecoptera	*Visoka cataractae*	5	2
Plecoptera	*Yoraperla spp.*	5	2
Plecoptera	*Zapada oregonensis*	6	2
Plecoptera	*Zapada spp.*	4	2
Trichoptera	*Brachycentrus occidentalis*	6	2
Trichoptera	*Brachycentrus spp.*	6	2
Trichoptera	*Dicosmoecus spp.*	6	2
Trichoptera	*Glossosoma spp.*	6	2
Trichoptera	*Hydropsyche spp.*	5	2
Trichoptera	*Hydroptila spp.*	5	2
Trichoptera	*Lepidostoma* - sand case larvae	5	2
Trichoptera	*Micrasema spp.*	4	2
Trichoptera	*Neophylax spp.*	6	2
Trichoptera	*Parapsyche elsis*	4	2
Trichoptera	*Parapsyche spp.*	4	2
Trichoptera	*Rhyacophila Betteni grp.*	6	2
Trichoptera	*Rhyacophila Brunnea grp.*	5	2
Trichoptera	*Rhyacophila Coloradensis grp.*	4	2
Trichoptera	*Rhyacophila spp.*	5	2
Ephemeroptera	*Attenella spp.*	7	3
Ephemeroptera	*Caudatella spp*	8	3
Ephemeroptera	*Drunella coloradensis/flavilinea*	7	3
Ephemeroptera	*Drunella doddsi*	7	3

Ephemeroptera	*Drunella grandis*	7	3
Ephemeroptera	*Drunella grandis/spinifera*	7	3
Ephemeroptera	*Drunella spinifera*	7	3
Ephemeroptera	*Drunella spp.*	7	3
Ephemeroptera	*Epeorus grandis*	8	3
Plecoptera	*Cultus spp*	7	3
Plecoptera	*Doroneuria spp*	7	3
Plecoptera	*Hesperoperla pacifica*	7	3
Plecoptera	*Megarcys spp*	8	3
Trichoptera	*Apatania spp*	7	3
Trichoptera	*Arctopsyche grandis*	8	3
Trichoptera	*Arctopsyche spp*	8	3
Trichoptera	*Brachycentrus americanus*	7	3
Trichoptera	*Ecclisomyia spp*	8	3
Trichoptera	*Oligophlebodes spp*	8	3
Trichoptera	*Rhyacophila Hyalinata grp.*	7	3