Utah Department of Environmental Quality
Division of Water Quality
TMDL Section

Thistle Creek TMDL

EPA Approval: July 9, 2007

Waterbody ID	**Thistle Creek**
Hydrologic Unit	16020202
Location	Utah, Sanpete, Juab Counties, north central Utah
Pollutants of concern	Sediment
Impaired beneficial uses	2B – protected for secondary contact recreation such as boating, wading or similar uses 3A – protected for cold water species of game fish and other cold water aquatic life, including the necessary aquatic organisms in their food chain 4 – protected for agricultural uses including irrigation of crops and stock watering
LOADING ASSESSMENT **Current load** **TMDL target load** **Load reduction**	SEDIMENT 72,000 tons/year 58,000 tons/year 14,000 tons/year
Defined targets/endpoints	- Restore natural stream function along 8 miles of Thistle Creek to reduce sediment load by 5,000 tons/year - Increase the effectiveness of riparian vegetation along 35 miles of stream by the application of BMPs to reduce sediment load by 2,400 tons/year - Reduce upland soil erosion by 7,200 tons/year - Improve fish habitat resulting in 30 lbs/acre of trout biomass - Shift from sediment and organic enrichment tolerant macro-invertebrates in Thistle Creek - Improve irrigation systems to at least 50% efficiency
Implementation Strategy	- Install structures to improve streambank stability - Implement stream restoration to improve aquatic and riparian habitat - Establish buffers along riparian areas to filter runoff - Improve irrigation efficiency - Improve upland vegetation production, diversity & vigor - Implement noxious weed treatment plan - Implement best management practices for grazing

EXECUTIVE SUMMARY

THISTLE CREEK TMDL

The Thistle Creek TMDL is submitted to the U.S. Environmental Protection Agency under section 303 (d) of the Clean Water Act for review and approval.

Purpose

This document addresses Thistle Creek sub-watershed water quality impairments through the establishment of total maximum daily loads (TMDLs) for sediment, the pollutant of concern. The purpose of this TMDL is to improve water quality by restoring and protecting designated beneficial uses.

Although not currently on the State's 303(d) of impaired waterbodies, in 1996 Thistle Creek was listed due to excessive sediment and nutrients. It was subsequently removed from the 303(d) list due to a lack of information. As a tributary to the Spanish Fork River, the flows from Thistle Creek ultimately reach Utah Lake which is on the 303 (d) list due to excessive total dissolved solids and total phosphorus.

Considered an important stream for game fish and State-listed sensitive non-game fish, Thistle Creek's cold water fisheries are being negatively impacted by excessive sediment. The sources of impairment originate from natural features, agricultural activities, storm runoff, and roads. There are no permitted point source discharges in the watershed.

Background

Located in north-central Utah, Thistle Creek sub-watershed encompasses 138,400 acres while crossing 3 county lines; Utah, Sanpete and Juab. Elevations range from over 10,000 feet at Loafer Peak to 5,100 feet at the confluence of Thistle and Soldier Creek. Vegetation is characteristPrush-grass or agricultural lands in the bottomlands.

The 1980 Census identified less than 200 residents of the Thistle Creek sub-watershed. Agriculture is the primary land use in the valley, spanning irrigated croplands in the privately owned valley bottom, to rangeland on state and federally managed lands.

Water Quality

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. They began by focusing on the Thistle Creek sub-watershed, one of six sub-watersheds in the Spanish Fork River system.

In 2001 a draft coordinated resource management plan (CRMP) for Thistle Creek was completed. 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 approach.

The flow of Thistle Creek varies dramatically due to spring snow melt, periodic drought, irrigation diversions, and occasional summer thunderstorms. Ten years of water quality data indicate spring flows can range from 15 cubic feet per second (cfs) to 350 cfs. Flows drop as low as 5 cfs during the summer, but more commonly range between 20–30 cfs.

Sediment from upland and in-channel sources collectively contribute 72,000 tons of sediment to the stream annually. The CRMP established an aggressive plan of action to reduce sediment by 11,000 tons per year from private lands.

Implementation strategies to reduce sediment will be implemented in phases to permit the monitoring and evaluation of their effectiveness. The implementation strategy adopted by the Spanish Fork River Watershed CRM Steering Committee includes the following:

- Improve bank stability,
- Establish buffers along 35 miles of stream
- Improve irrigation efficiency

- Improve upland plant production
- Implement noxious weed plan, and
- Implement BMPs for livestock grazing.

There is not a direct correlation between sediment and its effects on Thistle Creek's beneficial uses. To establish suitable endpoints that cumulatively address sediment, a variety of measurements will be employed, including macro-invertebrate composition, biological productivity, stream morphology, and the biological integrity of the stream and its riparian corridor.

The specific endpoints for Thistle Creek are:

- Increased effectiveness of riparian vegetation along 35 miles of stream and reduce streambank erosion by approximately 2,400 tons/year
- Restoration of 8 miles of stream to reduce streambank erosion by approximately 5,000 tons/year
- Reduce upland soil erosion by approximately 7,200 tons/year
- Improve game fish habitat resulting in 30 pounds/acres of trout biomass
- Shift away from organic enrichment and sediment tolerant macro-invertebrates
- Improve irrigation systems to at least 50% efficiency, and

In February 2002 the draft Thistle Creek TMDL was made available for public comment, in preparation for subsequent EPA review and approval.

PROBLEM STATEMENT

Watershed Location & Description

Thistle Creek is a tributary of the Spanish Fork River, which ultimately flows into Utah Lake. The Thistle Creek sub-watershed is located 21 miles southeast of Provo in the Wasatch Mountains, spanning 3 counties; Utah, Sanpete and Juab (Figure 1). It is approximately 19 miles wide and 21 miles long, while elevation ranges from 10,500 to 5,100 feet above sea level. There are 106 miles of perennial stream channels and 313 miles of intermittent stream channels in the sub-watershed.

Climate & Streamflow

Annual average precipitation for the sub-watershed is 16 inches, measured at the weather station in Birdseye. The majority of the precipitation is received between October and April.

Peak stream flows occur with snowmelt, between March and May. During this time of year flows have ranged from 360 cubic feet per second (cfs) to 10 cfs. Stream flows during the summer range from 260 to 5 cfs, with average flows of 20 to 30 cfs.

January tends to be the coldest month of the year and July the hottest month. At the sub-watershed community of Birdseye, one inch or more of snow will be on the ground for 69 days in an average year. The growing season spans from the end of May through mid-September.

Soils & Geology

Photo 1. About 8% of the sub-watershed has severe to highly erosive soils.

Soils range from sandy and very sandy loams in the bottomlands to stony clay loams in the uplands. About 8% of the sub-watershed has soils identified as highly to severely erosive. Many of these soils are associated with steep slopes.

A combination of steep slopes, shallow soils and clay substrate make landslides a common phenomenon in this area. In the spring of 1983 a slow-moving landslide dammed Thistle Creek and the Spanish Fork River, blocked Highway 6 and shutdown railroad access through the canyon. Water backed up behind the dam created by the landslide, flooding the community of Thistle creating what was referred to as Thistle Lake. Thistle Lake was drained some months later, but lake sediments and subsequent channel down-cutting still impact the sediment load of Thistle Creek.

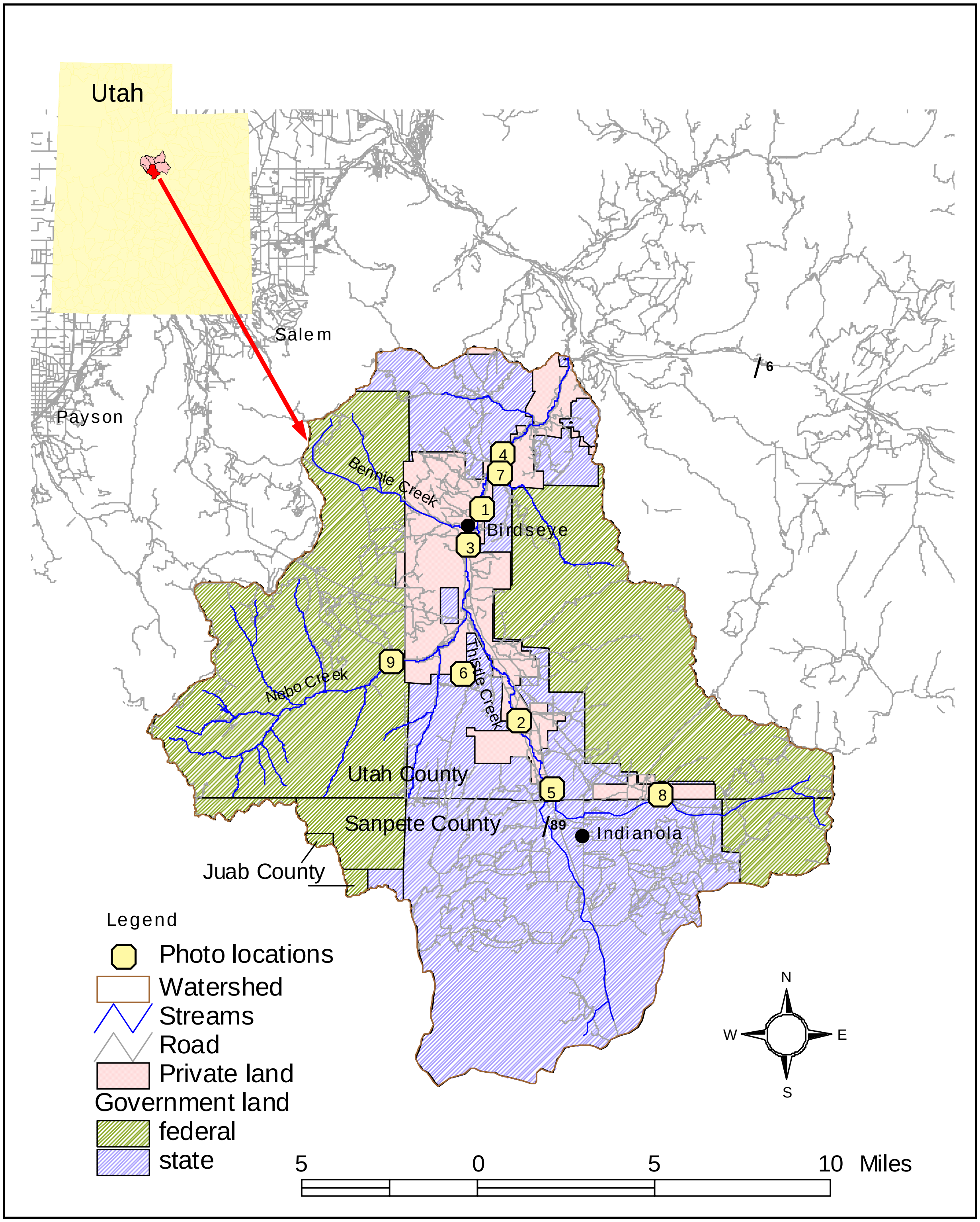
Landscape & Land Use

The Thistle Creek sub-watershed is a narrow river valley bounded by steep mountains. Slopes of more than 20% predominate, occupying more than 60% of the terrain. These uplands are mostly under the management of the U.S. Forest Service or the State's Division of Wildlife Resources and are grazed by domestic livestock and big game. Mid-elevation rangelands are critical winter range for big game including mule deer, elk, and moose. Juniper, mountain mahogany and oak brush dominate mid-elevation plant communities, with mixed conifer dominating the higher elevations.

The lower elevation valley bottom consists of a patchwork of privately owned lands. Agriculture is the primary land use, although less than 3% of the land is actually under cultivation. Livestock grazing occurs throughout the sub-watershed on cultivated lands as well as rangelands.

The 1980 census identified less than 200 residents in the valley. Recent interest in selling residential lots along Highway 89 may increase the number of valley residents in the near future.

Figure 1. Location of Thistle Creek Sub-watershed



Aquatic Resources

The Division of Wildlife Resources (DWR) manages Thistle Creek for cold water game and native non-game fish. While trout is the primary game fish under management, two State sensitive fish species, leatherside chub and Bonneville cutthroat trout (Utah DWR, 1998) also inhabit the main channel or its tributaries.

DWR conducted leatherside chub surveys in Thistle Creek in 1987, 1993, and 2000. Survey results show considerable variation in fish density from the head waters to the confluence with Soldier Creek. Overall, the population in Thistle Creek is the most robust of any stream in the Central Region. In higher reaches, leatherside chub is still present and considered common, while in the lower reaches of the stream few individuals persist.

Population densities of leatherside chub throughout Thistle Creek is influenced by predation and habitat suitability. Brown trout, the primary game fish in Thistle Creek, is also a major predator of the chub. Shallower waters in the upper reaches are favored by the leatherside chub, in part because they provide good escape habitat from brown trout. DWR manages these upper reaches for the conservation and enhancement of genetically unique fish within their historic ranges, including the leatherside chub.

In contrast, brown trout is less common in the upper reaches of Thistle Creek, but is found in higher densities in the lower reaches. Lower Thistle Creek and its fish-bearing tributaries are important sport fishing waters. Previously these reaches were stocked to meet fishing demand, but now DWR allows the condition of the stream to establish the natural level of fish reproduction and sustenance.

The Bonneville cutthroat trout, another sensitive species, primarily inhabits the upper tributaries of Nebo Creek and is not common in Thistle Creek. Sediment in Nebo Creek and its tributaries are generally lower than Thistle Creek and are not considered a limiting factor for Bonneville cutthroat trout.

Water Quality Impairments & Effects on Beneficial Uses

In 1996 Thistle Creek was identified on the state's 303(d) list of impaired waterbodies due to excess sediment and nutrients. It was subsequently removed from the list in 1998 due to the need for additional information. However the State of Utah committed to local stakeholders to complete a TMDL to assist them in addressing their resource concerns and as part of the State's effort to improve water quality within Utah Lake that is currently on the State's 303(d) list for impairments associated with excess sediment and nutrients. Although Thistle Creek was not been identified as a high priority for TMDL development in the 2004 303(d) list this effort has not interfered with the State's ability to meet established deadlines for other high priority TMDLs.

Recent surveys have identified an annual load of 72,000 tons of sediment entering Thistle Creek from upland and streambank sources. Upland soil erosion contributes over 54,000 tons of sediment, while unstable streambanks contribute nearly 18,000 tons of sediment annually. These estimates are based on the Pacific Southwest Interagency Committee upland monitoring strategy and the Ventura Channel Evaluation method (USDA, NRCS).

Macro-invertebrate sampling can provide a more holistic indication of changes in water quality due to stream restoration projects. Macro-invertebrate samples were randomly collected at two locations on Thistle Creek in July 2001. The first sampling site was in a degraded condition (pre-treatment) while the second had been the site of a stream restoration project. Surber samples were used for collection and organisms were identified to species.

In Table 1 below, data from the July 2001 sampling on Thistle Creek are shown. *Class 1* organisms exhibit a rapid response to aquatic environmental changes and are reduced in number when their environment is degraded. *Class 2* organisms have the capability to live under varying conditions including where organic pollution is present. *Class 3* organisms are capable of withstanding the most degraded conditions. The number of species within each class and the overall diversity of organisms represented provide clues to water quality.

Table 1. Comparison of macro-invertebrate samples pre and post treatment

Pre-treatment reach		Post-treatment reach	
Class	No./m^2	Class	No./m^2
Class 1	1,438	Class 1	2,166
Class 2	540	Class 2	92
Class 3	4,330	Class 3	1,551

Although the total of all organisms were higher at the pre-treatment site, the ratio of pollution intolerant *Class 1* organisms to pollution tolerant *Class 3* organisms is higher at the post-treatment site. From this data it is apparent that *Class 1* macro-invertebrates responded quickly to the stream restoration project.

Photo 2. Excess sediment impairing the cold water fish habitat in Thistle Creek.

Excess sediment also negatively impacts Thistle Creek's recreational and agricultural beneficial uses. The quality and quantity of recreation opportunities are diminished when trout populations are suppressed due to inadequate habitat, food sources and spawning sites. Agricultural beneficial uses are impacted when sediment-laden water is diverted into irrigation systems and onto a field. Irrigation systems may clog, interfering with water delivery and plants or seeds can become buried.

WATER QUALITY STANDARDS & IMPAIRMENTS

Water Quality Standards

The Utah Division of Water Quality (DWQ) has designated the beneficial uses of Thistle Creek as below:

2B protected for secondary contact recreation such as boating, wading, or similar uses
3A protected for cold water species of game fish and other cold water aquatic life, including the necessary aquatic organisms in their food chain
4 protected for agricultural uses including irrigation of crops and stock watering

Existing Water Quality Impairments

Excess sediment is impairing Thistle Creek's cold water fisheries beneficial use. Excess sediment can impair spawning success, egg survival to emergence, rearing habitat, and food availability.

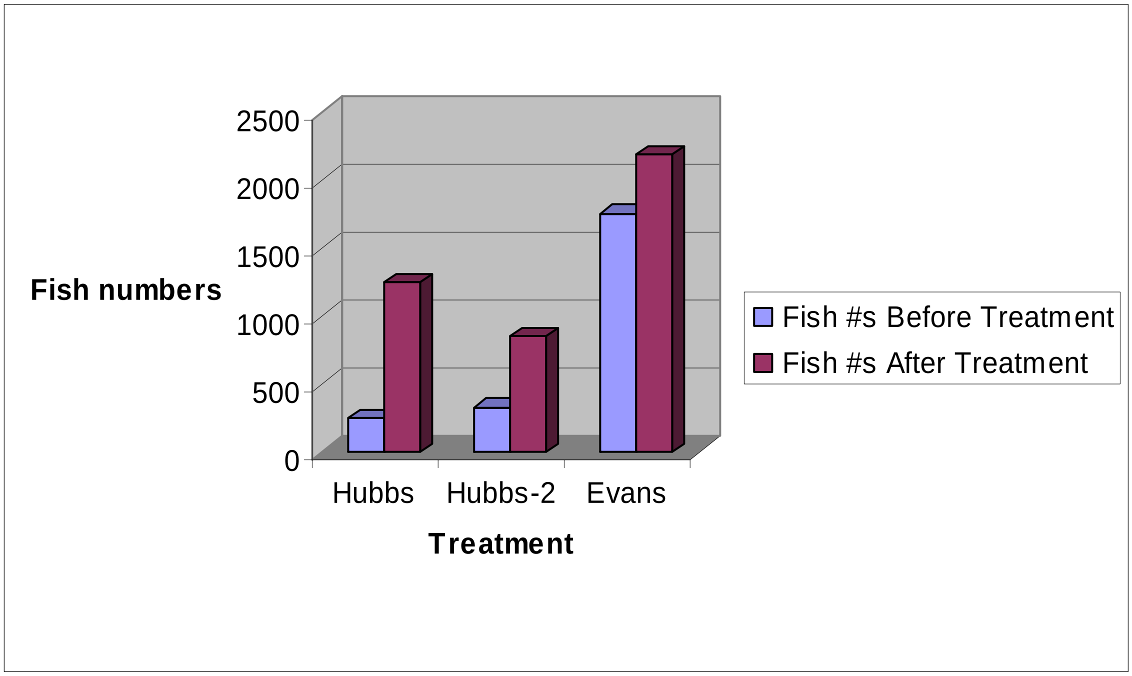
Thistle Creek is managed by DWR for sport fishing and for non–game species. DWR monitoring found fewer numbers, smaller individuals, and less habitat diversity in Thistle Creek than desired for their management goals.

Photo 3. Lower Thistle Creek is a popular destination for anglers.

The absence of adequate fish habitat is linked directly to poor channel condition, including the lack of sinuosity and unstable streambanks. Lack of sinuosity can translate into higher water velocity and ability to erode streambanks. Unstable banks are a key source of in-channel sediment.

Figure 2 displays data on fish populations that was collected before and after a stream restoration project illustrating the effects of sediment on game fish populations.

Figure 2 . Fish numbers before and after stream restoration



Before the restoration, 250 fish per mile were counted. Within a year after restoration 1,250 fish per mile were tallied. Figure 3 shows how fish biomass responded to stream restoration projects. Trout biomass is one of the defined targets/endpoints identified for determining attainment of beneficial uses.

Figure 3 . Fish biomass (lbs/acre) before and after stream restoration

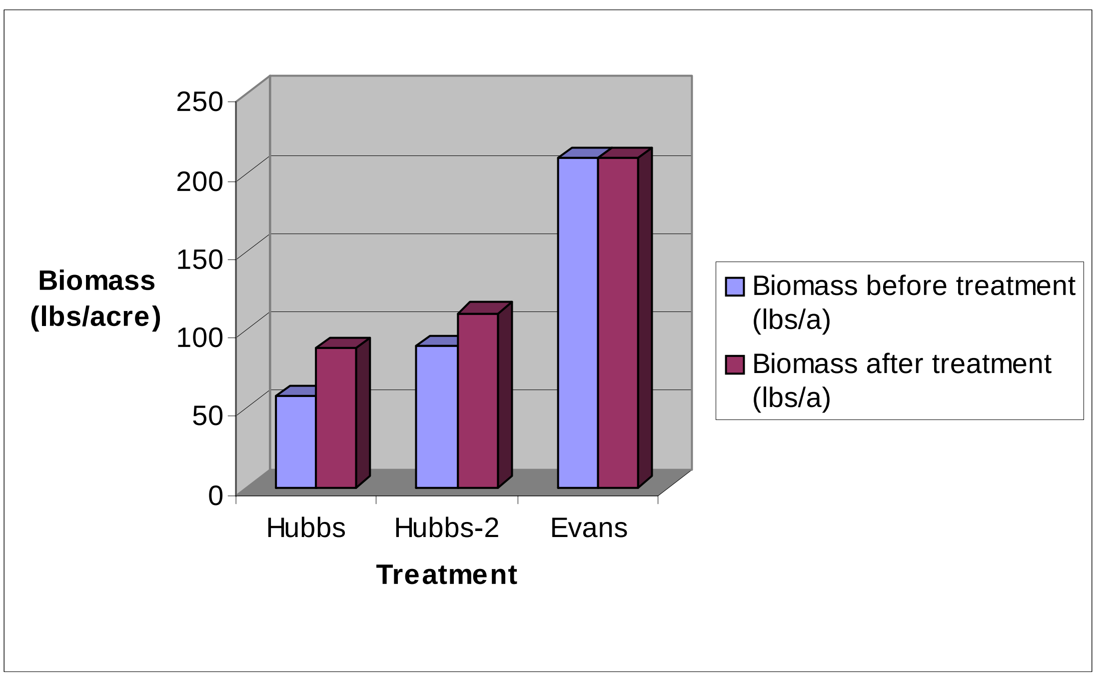


Photo 4. Before restoration (left) the fish count was 250 per mile on this reach of lower Thistle Creek. In a different view but the same reach, one year after restoration (right), numbers rose to 1,250 fish per mile.

POLLUTION ASSESSMENT

Source Inventory

In summer 2001, an inventory of watershed pollution sources estimated 72,000 tons of sediment enters Thistle Creek each year. The two main sources of sediment were identified as upland soil erosion and streambank instability. Table 2 shows these sources with their background and target loads for the Thistle Creek sub-watershed.

Table 2. Summary of background and target sediment sources

Sediment Source	BACKGROUND (before BMPs) Tons/Year	TARGET (after BMPs) Tons/Year	Load Reduction Tons/Year
Upland soil movement	54,000	45,000	9,000
Unstable streambanks	18,000	13,000	5,000
TOTAL	72,000	58,000	14,000

Upland soil erosion

Upland soil erosion is the foremost sediment contributor, delivering an estimated 54,000 tons each year. Steep slopes, poor plant cover, wildfires, highly to severely erosive soils, the number and size of active and historic landslides, and effects of the 524 miles of roads within the sub-watershed all contribute substantial amounts of sediment to the stream.

Point Sources

There are no permitted point source dischargers within the Thistle Creek sub-watershed.

Non-point Sources

All of the upland soil erosion in Thistle Creek is attributed to non-point sources. These sources include the poor plant cover, wildfires, landslides, naturally erosive soils, and lack of grazing management.

Photo 5. Highly erosive soils and the reduced ability of upland plant communities to hold soil in place are major contributors of sediment to the stream.

Past and current management practices have affected the upland plant communities by favoring shrub and tree growth, leaving the highly erosive soil surface exposed to sheet and rill erosion. The understory production of grass and herbaceous plants was measured at 37 to 40 pounds of plant material per acre on an area targeted for improvement. On adjacent land that had been treated, plant production was increased 10-fold, ranging from 250 to 500 pounds/acre.

Overall upland soil loss was estimated by combining the Pacific Southwest Inter-Agency Committee (PSIAC) methodology with soil erosion ratings from the soil survey (USDA Soil Conservation Service, 1981). PSIAC is an indirect sampling method, commonly used by NRCS to estimate soil movement on uncultivated lands based on geology, soils, topography, climate, hydrology and management. An average erosion rate was then applied to area soils based upon low, moderate, high or severe erosion potential.

Photo 6. The suppressed presence of grasses and broad-leafed plants in upland plant communities exposes more soil to erosion.

Streambank Instability

Stream channel instability is estimated to contribute 18,000 tons each year of sediment to Thistle Creek. Although sediment occurs naturally in stream systems, excessive sediment can impair the stream's beneficial uses. Landslides also contribute substantial quantities of sediment, but in ways that are difficult to quantify.

In 1983, the Thistle Slide dammed Thistle Creek and subsequently flooded the small community of Thistle. The affects of that event still influence stream channel instability today. The 1983 flood waters scoured and downcut parts of the upper Thistle Creek channel, leaving a broad, oversized stream channel with raw cutbanks. In the lower reaches, as Thistle Lake backed up the channel, thick deposits of sediment were deposited. After the lake receded, the stream channel eroded through these deposits in route to its confluence with Soldier Creek.

Past and current stream channel management practices including channelization, irrigation diversions and irrigation return flows continue to introduce sediment into the stream channel.

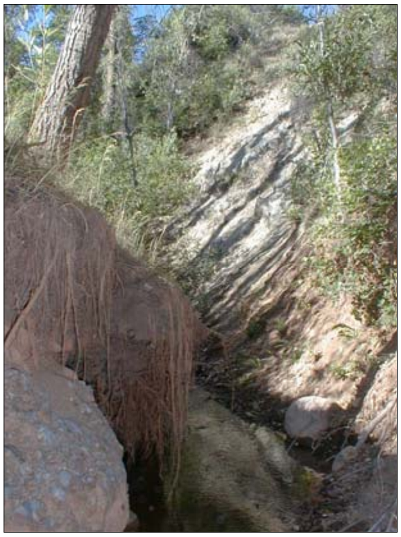


Photo 7. Unstable streambanks on this tributary contribute 5,000 tons of sediment annually to Thistle Creek . The 1983 floods likely initiated the this on-going sediment source.

Streambank instability was measured using the Ventura Channel Evaluation methodology developed by NRCS. This method measures volume of soil loss based on height, length and lateral recession rate of unstable streambanks. To estimate streambank instability, streambank erosion was inventoried along typical stream reaches of the main channel and its perennial tributaries. The inventory provided estimates of sediment loss in tons/mile for each reach sampled. Erosion rates were then applied to similar reaches within the entire perennial channel.

Photo 8. Diverted irrigation water (left) cut a new channel over 300 feet long and up to 15 feet deep (center). At the diversion's confluence with Thistle Creek (right), it is conservatively estimated to yield over 2,000 tons of sediment per mile annually.

Figure 4. Map showing location of streams, storet sites and erosion rates (tons/mile)

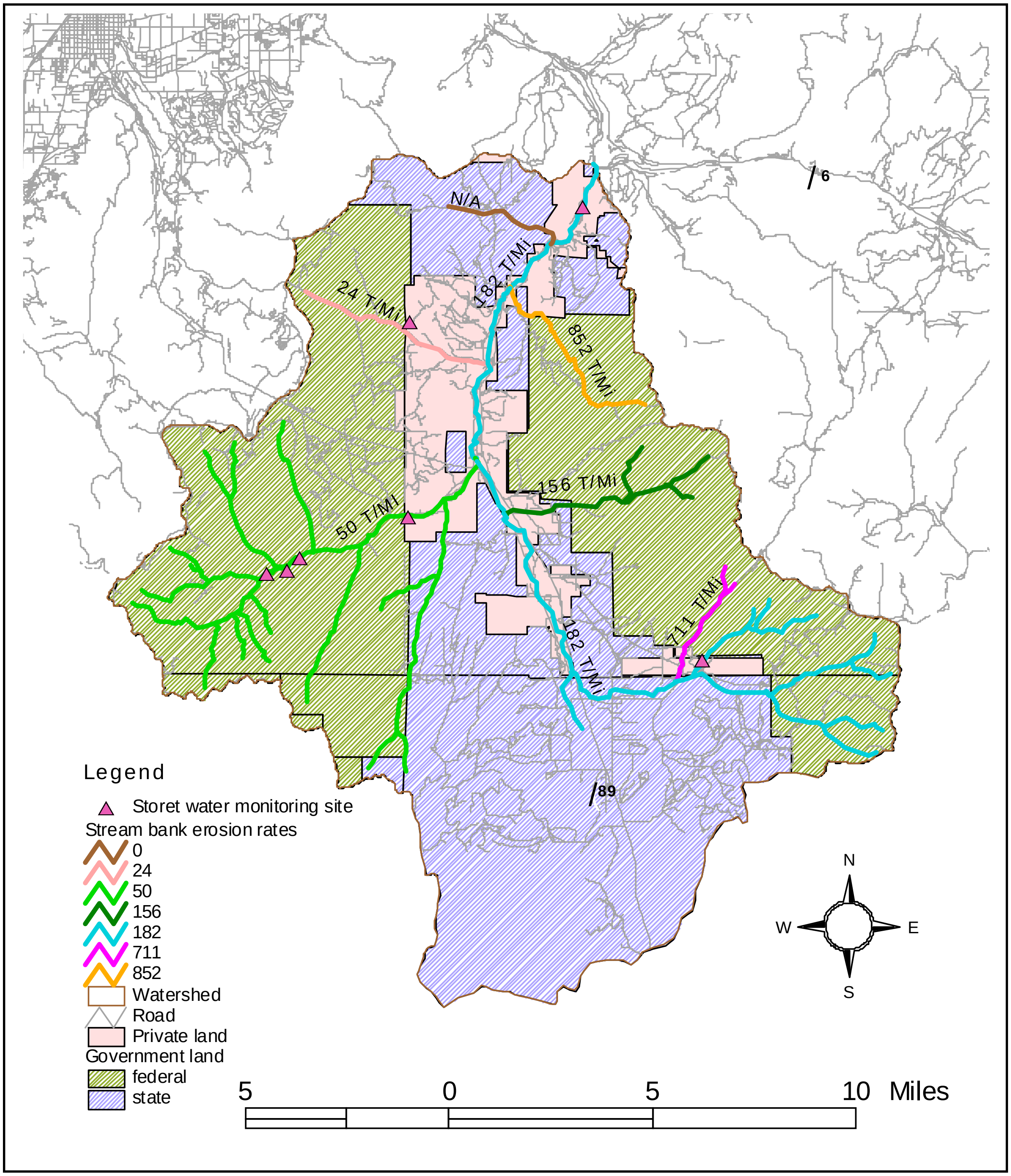


Table 3. Streambank erosion estimates

Stream Name	Erosion Rate Tons/Mile	Miles	Current Bank Erosion Rate Before BMPs (Tons/Year)	Target Bank Erosion Rate After BMPs (Tons/Year)
Bennie Creek	24	5.1	123	118
Blind Canyon Creek	852	5.4	4,599	4,029
Clear Creek	711	3.7	2,630	939
Crab Creek	No data	1.5	No data	No data
Dry Creek	156	8	1,248	1,145
Nebo Creek	50	44.8	2,218	2,198
Thistle Creek	182	37.5	6,842	4,364
TOTALS	-	106	17,660	12,793

Total Maximum Daily Load Allocations

Table 4. Total maximum daily load for sediment

Pollutant	Waste Load Allocation	Load Allocation	Margin of Safety	Total Maximum Daily Load
Sediment	N/A	58,000 t/y	Implicit	58,000 t/y

LOAD ALLOCATIONS

Table 5 shows how load reduction will occur through the implementation of BMPs prescribed by the Thistle Creek sub-watershed CRMP.

SEASONAL VARIATION

Upland soil loss greatest during spring snowmelt and summer thunderstorms. Summer thunderstorms are common. Streambank instability is greatest during high flows associated with spring snowmelt. Occasionally there are high summer flows, but summer storms capable of producing high instream flows are infrequent.

MARGIN OF SAFETY

The Margin of Safety is accounted for implicitly through conservative assumptions used in developing sediment loading values in that 20% of upland soil moving off site will enter the stream channel (Evenstad, 2000).

Table 5. CRMP objectives and their effects on sediment load reduction

CRMP Objective #	BMPs to apply	Acres	Sediment Reduction (Tons/Year)
1	35 miles of 60 foot buffer	255	2,400
	35 miles of BMPs applied	5,600	
2	8 miles of stream restoration	—	5,000
4	Reseed 2,000 acres	2,000	6,700
	16,000 acres BMPs applied	16,000	
5	Improve plant cover on 1,500 acres	1,500	500

Critical Condition

The critical condition for TSS and TP occurs during peak flows and high runoff events typically associated with spring runoff and intense summer thunderstorms.

Monitoring Plan

An inter-agency monitoring plan is included in the Thistle Creek sub-watershed CRMP (pp.23-32). This plan relates directly to one of eleven resource objectives for the watershed and assigns monitoring responsibility to the agency with the responsibility for that resource. The following table 6 indicates which agency/organization is responsible for monitoring each resource.

Table 6. Summary of CRMP monitoring plan

Resource to Monitor	Responsible Agency	Monitoring Task/Frequency
Water quality	USDA Forest Service Division of Water Quality	Grab samples collected from 7 sites mostly from March-November, but sometimes year around, collected irregularly but about every other year; Collects grab samples & processes all water samples
Fish habitat	DWR	Continue with on-going habitat quality index (HQI) collected at established sites along Thistle Creek about every 5 years; On restored sites HQI and fish population data collected before & then annually after project completion
Riparian & channel condition	DWR NRCS & Timp-Nebo SCD NRCS & Timp-Nebo SCD	Parts of HQI address riparian condition & will be collected on above mentioned schedule; Ventura streambank stability data was collected in 2000, as reaches are restored they will be re-evaluated; Conservation plan adherence will be monitored during & after project implementation
Upland plant community & big game winter range	DWR USDA Forest Service	On-going upland plant community monitoring, on 5 year schedule; On-going monitoring program but collects range condition & trend data for grazing allotments on irregular schedule
Agricultural practices	NRCS & Timp-Nebo SCD	Before project– develops conservation plan & provides NRCS specifications; During – field check to assure specs are adhered to & recommendations are suitable; After – field check & final approval based upon adherence to specs & proper function
Comprehensive nutrient management plans (CNMP)	NRCS & Timp-Nebo SCD	Before project– develops CNMP & provides NRCS specifications; During – field check to assure specs are adhered to and recommendations are suitable; After – field check & final approval based upon adherence to specs & proper function
Noxious weeds	Utah County Weed Department	Provides annual treatment of noxious weeds on private, state & federal lands; Tracks weeds by species, infestation size & location
Conservation education	Utah State University, Utah County Extension Service	On-going — bi-annual newsletter provides conservation information to landowners; Intermittent — public meetings, resource brochures, public field & work days

As a coordinated effort, key CRMP agencies/organizations are responsible for monitoring CRMP effectiveness, based on the resource to be monitored. For example, DWR is responsible for assessing fish habitat parameters. To do this they employ Habitat Quality Index (HQI) monitoring, which they have been using on Thistle Creek for over 10 years. HQI data is collected about every 5 years at specific locations along the channel. Specifically for the CRMP, HQI has also been used to assess fish habitat before and after stream reaches have been restored.

To assess the effectiveness of agricultural practices, such as irrigation systems or prescribed grazing, Natural Resources Conservation Service (NRCS) already has a strategy in place. Landowners must install prescribed practices to NRCS specifications. When installation is complete, NRCS will do a field check to assure the proper installation and function of each prescribed practice before making official notification. If state or federal funding has been used in the installation any practices this official notification is mandatory before those funds are released to the landowner.

Public Participation

The development of Thistle Creek TMDL has been openly discussed at Spanish Fork River watershed work group meetings for several years. On October 12, 2000 a public meeting was held in Birdseye, Utah where participants were informed of the TMDL process for Thistle Creek. Comments to assist in TMDL development were requested, but none were received. The bi-annual watershed newsletter featured a follow-up article on the TMDL and again requesting comments. No comments were received.

In February 2002 and again in March 2006, the Draft Thistle Creek sub-watershed TMDL was made available for public comment. No comments were received during either public comment period.

Photo 9. The CRMP assigned resource monitoring responsibility to relevant agencies, but inter-agency data collection is encouraged.

Implementation Plan

The Thistle Creek Sub-watershed CRMP is the implementation plan for this TMDL.

The Thistle Creek Sub-watershed coordinated resource management plan identified over 80 Best Management Practices (BMPs) for their potential to improve water quality in the sub-watershed. Table 7 lists those BMPs most commonly prescribed to improve Thistle Creek water quality.

Table 7. Most commonly prescribed BMPs

NRCS #	Best Management Practices (BMPs)
584	Stream channel stabilization
580	Streambank protection
643	Restoration and management of declining habitat
314	Brush management
556 & 528A	Prescribed grazing
442, 443 & 444	Irrigation system
499	Irrigation water management
590	Nutrient management

BIBLIOGRAPHY

Evenstad, Norm, personal communication, Natural Resources Conservation Service, October 2000

Soil Conservation Service. Soil Survey of Sanpete Valley Area, Utah: Parts of Utah and Sanpete Counties. U.S. Department of Agriculture. 1981.

Utah Administrative Code R317-2

Utah DWR, 1998 (Utah list of sensitive species)

Don Wiley, Division of Wildlife Resources fish biologist, personal communication, February, 2002