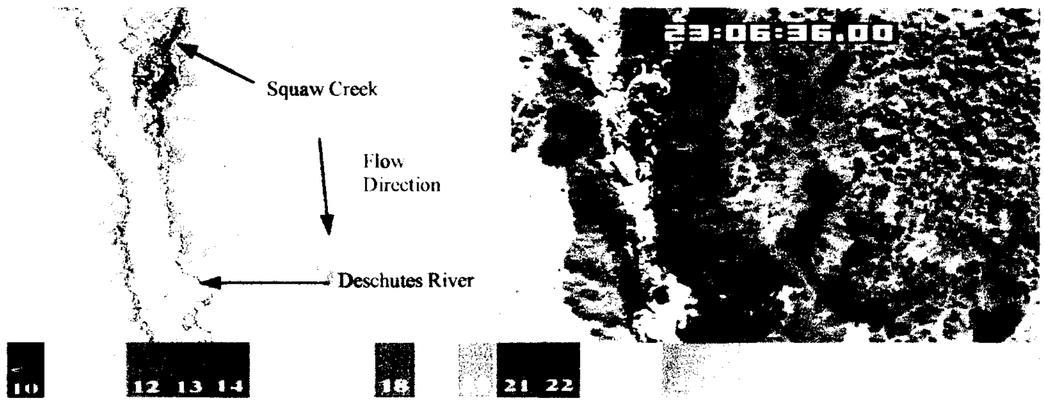
97-211



# Squaw Creek

# Monitoring and Education Project

Fall 1997 through Summer 2000




Squaw Creek Confluence with Deschutes River

## Cooperators

Deschutes National Forest
Upper Deschutes Watershed Council
Black Butte Ranch
Sisters Schools
St. Francis School, Bend
Bend Community School
OR Department of Fish and Wildlife
Oregon State University
Portland General Electric
Oregon Water Trust

Lower Squaw Creek

Macroinvertebrate Monitoring

# Squaw Creek Monitoring
# Project #97-211

Final Report

## Introduction

The Squaw Creek Monitoring project was initiated in response to the community's desire to improve the health of the watershed. The Deschutes Soil and Water Conservation District conducted a 1994 Squaw Creek watershed assessment that identified the physical, biological and social processes and potential management actions for this 161,478-acre watershed. Public input during the assessment lead to the development of management recommendations for the watershed, including bank stabilization and actions related to protecting water quality. This assessment guided the Upper Deschutes Watershed Council's effort to implement stewardship activities, including this monitoring project.

## Background

Squaw Creek flows off the glacial Cascade Mountains over 9,000 feet in elevation through steep, narrow canyons to an outwash area near the town of Sisters, and then back into narrow canyons down to near 2,100 feet of elevation at the confluence with the Deschutes River. The stream is a dynamic system easily influenced by precipitation levels and snowmelt timing. Two thirds of the precipitation falls between March and April, with the annual flood season occurring between November and April. The flashy nature of this stream is a result of rain-on-snow events and warm spring temperatures.

Following the floods of 1964, the stream between the Squaw Creek Irrigation District (SCID) diversion and Camp Polk Road underwent straightening and channeling for flood control. The stream channel re-engineering activities reduced the large woody debris, eliminated channel complexity, degraded off-channel and pool fish habitat, and decreased bank stability. Winter and spring flows cause the stream channel to meander, braiding through bedload deposition areas in an effort to reestablish a streambed and moving vast quantities of gravel, sediment, and some woody debris. This instability has contributed to water quality and fish habitat challenges.

Currently, Squaw Creek is listed on the Department of Environmental Quality's 303d list for flow modification and elevated temperatures. The Squaw Creek Irrigation District's conservation program and opportunities for water leases or acquisitions provide promise for increasing instream flow in Squaw Creek. The improvement of stream flows to a level adequate for reconnecting the upper and lower creek sections and improving instream and riparian habitat becomes very attainable.

Historically, this subwatershed sustained significant anadromous fish and native trout populations. Today, strong support from watershed residents, fish management agencies, and the City of Sisters is placing increased significance on enhancing habitat for anadromous fish and rainbow trout. Coupled with Portland General Electric and Oregon Department of Fish and Wildlife goals to pass anadromous fish above the Pelton-Round Butte dam project in the near future, the watershed community's restorative planning efforts must begin today.

Measuring stream flow, temperature, and additional water quality parameters establishes baseline data, establishing the reference point needed for assessing restoration activity effectiveness. Additionally, this current-condition data will help guide all future management plans that will target the improvement of water quality, restoration of riparian health, enhancement of stream channel structure, and establishment of a viable, anadromous and resident fishery. Through working cooperatively, the watershed community will sustain for future generations the quality of life that all realize today.

## Project Outcomes

The project included three specific activities: Watershed Education; Watershed Monitoring; and Thermal Infrared Monitoring and Color Videography. Outcomes for each activity will be discussed.

### Education

The project involved over 400 students from three different schools during the two-year project. The teachers were extremely pleased with the level of achievement attained for the three instructional objectives identified by the project. The first objective was to introduce students to data collection in the field and analysis of that data in a classroom setting. The second asked the students to present data findings to peers and interested community members, both in written and oral forms. The third objective was to integrate students from early grades through high school into a process of ecological understanding and appreciation.

Cheryl Butler has actively involved her students in OWEB projects in cooperation with the USFS since 1990. Her most recent endeavor has been the school district wide involvement in this Squaw Creek Monitoring project. Students in the 5th, 6th, and 7th grade collected stream data to determine the health of our local stream. This field involvement meets the state's 5th, 8th, and 10th grade benchmark for life science in the common curriculum goal area of diversity and independence.

Field days at the stream involved High School students mentoring the younger students in data collection methods. These students received training in Ms. Butler's science class and were selected to become "Stream Team" leaders when they reached high school. The commitment of this team was vital to the success of the project.

Results of the project were presented to peers and the community. Each teacher selected the process to evaluate the project for his or her classroom. Oral presentations, written reports and video presentations were used along with the state's scoring guide. Cheryl Butler and Matt Adams did an oral presentation in the fall to a Central Oregon Community College class and to the Upper Deschutes Watershed Council. 7th grade students manned a display of the project at the Squaw Creek History Fest in the spring of 1998. The "Stream Team" led a presentation for Sisters School Board members in October 1999. A Sisters Schools report is attached in Appendix C.

St. Francis students spent over 22 hours of class time during the 1998/99 in support their fieldwork. The students covered the following lesson topics: What is pH?; What is a healthy stream?; Life cycle of a salmonid?; What is a watershed?; What is groundwater?; What is a water cycle?; Pollution and Watersheds; Water Use Values; and an introduction to the project by the council coordinator and project manager. The students created an "inside out" view of their stream, hanging fish, plant, and channel features from the ceiling of their classroom. Presentations by the students were made to parents and peers.

The Bend Community School spent their science class time learning about watersheds, water and vegetation monitoring methods, and the biological science required to support the fieldwork. Presentations were given to their peers and a data report generated (attached Appendix D).

Each participating teacher felt the project achieved the defined instructional goals, including the following: provided hands-on experience and a real-world context for student learning; acquainted students with the physical, historical, and cultural characteristics of the watershed; enhanced critical thinking and problem solving skill;, encouraged cooperative as well as independent learning; increased the knowledge of science and scientific technique; and developed a sense of individual and community responsibility toward stewardship of our natural resources. Students were also able to share this knowledge with family members and friends, helping a larger segment of the watershed community learn about the watershed within which they work and play.

## Monitoring

The project initially identified more monitoring parameters to be measured than was ultimately achieved. Following one year of turbidity monitoring, project leader Mike Riehle, USFS, discontinued this monitoring activity. Squaw Creek experiences elevated turbidity only during glacial events, such as a moraine failure. As well, Riehle excluded conductivity monitoring. The frequency of monitoring was also reduced following discussion with Larry Marxer, Oregon Department of Environmental Quality. An 8$^{th}$ site, Indian Ford Creek, was added the second year based on first year macroinvertebrate profiles at site 5. Indian Ford Creek is known to lose a significant quantity of flow to a geologic fracture in the bed of the creek, which "springs" up on Squaw Creek near site 5.

The USFS and Oregon Department of Fish and Wildlife conducted stream habitat surveys the length of Squaw Creek as the monitoring project was beginning (report attached in Appendix C). Fish surveys were added during the second year of the study as well. To understand changes in the stream channel resulting from the 1968 channeling activities, USFS staff assessed historic channel location compared to current channel location. This report is attached as Appendix E.

The attached report summarizes the monitoring sites, activities, and results, Appendix A.

## Thermal Infrared Monitoring and Color Videography

The public has consistently asked for specific information concerning the thermal importance of point sources, riparian vegetation, channel morphology, flow, and groundwater. Forward Looking Infrared (FLIR) data collection and analysis offers a rare opportunity to visually display complex watershed processes. FLIR imagery can be used to educate stakeholders, visually depict important hydrologic processes, provide site-specific information, and begin restoration progress and tracking. No other temperature related tool offers this combination of important contributions to the current temperature discussions. By using the FLIR data, watershed stakeholders will then be able to develop workable and locally accepted stream-related best management practices for the entire Squaw Creek drainage.

The initial phase of this project established continuous temperature monitoring data at eight study sites throughout the watershed. While these monitoring sites provide temporally continuous data, this type of monitoring furnishes no insight into the spatial variability in temperatures. The combination of the temporally and spatially continuous data will provide a powerful tool for generating a longitudinal heating profile that depicts thermal effects of tributaries, identifies cool water thermal refugia, and source (heating) areas.

Absolute maximum summertime stream temperatures may vary by several degrees annually, however, past data collection projects have established that the longitudinal temperature patterns of heating and cooling remain spatially fixed. Simply stated, an area of cool thermal refugia will likely persist year after year (barring significant landscape or channel changes). Similarly, source areas are likely areas of heating year after year. By mapping the extent of source (heating) and cool thermal refugia areas in the Squaw Creek watershed, a baseline for long-term recovery tracking will be established.

While time and effort is dedicated to studying degraded systems, much can be learned from healthy intact stream systems. A unique opportunity exists to compare thermodynamic regimes at a watershed scale. Sufficient information will be established by the FLIR project to compare the temperature profile of relatively non-impacted healthy stream systems with other more impacted/degraded systems.

In addition to recovery tracking, non-impacted and impacted system comparatives, and as an outreach tool, the FLIR data will help identify cold-water refugia for juvenile and adult migration and support the reintroduction of anadromous fish and improvement in native fish populations. The identification of causal factors related to elevated and cooler temperature areas (i.e. groundwater inflow) will facilitate the identification of conservation areas and focus restoration and protection for these areas. The FLIR data will assist watershed restoration and enhancement project planning and prioritization and focus future monitoring activities. Finally, the data will support statewide/regional water quality planning processes to ameliorate the impact of Non Point Source (NPS) pollution, including the Healthy Streams Partnership, Senate Bill 1010 planning, and Total Maximum Daily Load (TMDL) allocation planning.

The attached report summarizes the FLIR monitoring project results, Appendix B.

## Community Participation and Acknowledgement

The Upper Deschutes Watershed Council would like to thank the community members and resource management individuals who have played an important role in the success of the project. Their participation was integral in assuring project outcomes were achieved, even more than originally identified. Special thanks go to the private landowners who willingly opened up their streamside locations to our students and project staff, allowing access to Squaw Creek that added to our learning experience.

For the Education and Monitoring aspects of the project, a special thank you is extended to Cheryl Butler from the Sisters School district for helping to initiate the project and coordinating the students. Mike Riehle, Jens Lovtang, and Brad Houslet of the Deschutes National Forest, Sisters Ranger District provided the critically needed field coordination and project management, field trip supervision, and conducted monitoring tasks. Teachers Colleen Lynch, Julie Robertson, Carol Packard, Wes Estvold, Heidi Smith, David Hewett, and Glen Herron for providing classroom and field instruction for the students. The Sisters High School and Middle School "Stream Team" members Matt Adams, Besse Ward, Michelle Elpi, Casey Glick, Anton Ruis, Carolyn Franks, Nathan Harpham, Megan McGuire, and Amber Leis mentored our younger students, which was critical to the success of the field trips. The table in Appendix F attempts to capture all the names of those who participated in the success of this project. Apologies are extended to those who were missed.

For the Thermal Infrared Monitoring and Color Videography phase of the project, the Council would like to thank Mike Riehle and Brad Houslet, USFS Sister Ranger District, Kyle Gorman, Oregon Water Resources Department, Steve Marx, Oregon Department of Fish and Wildlife, and Bonnie Lamb, Matt Boyd and other staff, Oregon Department of Environmental Quality for their technical and field assistance. many thanks are also extended to Andrew Purkey and Ed Goodman, Oregon Water Trust, John Esler, Portland General Electric, and Loy Helmly and Dayton Hyde, Black Butte Ranch, for providing the additional funding needed to implement the FLIR flight.

Through community efforts, public awareness and stewardship activities in this unique, beautiful Why-chus (Squaw Creek) subwatershed have been increased. Together, residents are making a difference for their community's future well-being and quality of life. The information gathered from this project will only serve to further help the community develop effective watershed projects.

## Project Accounting

The Squaw Creek Monitoring Project was funded through many sources. The Oregon Watershed Enhancement Board supplied the funds needed to initiate the project. The US Forest Service, Sisters Ranger District provided the most significant level of funding, including cash dollars, staff time, and equipment and supplies. The Sisters School District, Oregon State University, and Portland General Electric also assisted in funding the education and monitoring phases of the project through staff time and resources. Students, community members, and volunteers provided time contributions essential to the success of the project.

The following table summarizes contributions for the Education and Monitoring phase of the project by partner: in-kind, other funds, and OWEB funds.

## *Squaw Creek Monitoring Project 1997-1999*

| Project Partner | Hours | Rate | Mileage | Rate | OWEB Funds | In-kind Funds | Other Funds | Total |
|---|---|---|---|---|---|---|---|---|
| Sisters Schools | | | 160.94 | 2.00 | 321.88 | | | 321.88 |
| Teachers | 164.0 | 21.50 | | | | 3,526.00 | | 3,526.00 |
| Parents | 200.0 | 15.00 | | | | 3,000.00 | | 3,000.00 |
| Students | 3,844.0 | 6.50 | | | | 24,986.00 | | 24,986.00 |
| St. Francis School | | | 500.00 | 0.30 | | 150.00 | | 150.00 |
| Teachers | 50.5 | 21.50 | | | | 1,085.75 | | 1,085.75 |
| Parents | 60.0 | 15.00 | | | | 900.00 | | 900.00 |
| Students | 252.0 | 6.50 | | | | 1,638.00 | | 1,638.00 |
| Students class time | 507.0 | 6.50 | | | | 3,295.50 | | 3,295.50 |
| Bend Community School | | | 232.00 | 0.30 | | 69.60 | | 69.60 |
| Teacher | 33.0 | 21.50 | | | | 709.50 | | 709.50 |
| Parents | 32.0 | 15.00 | | | | 480.00 | | 480.00 |
| Students | 231.0 | 6.50 | | | | 1,501.50 | | 1,501.50 |
| Sisters Subst. Teachers | 24.0 | 15.62 | | | 374.96 | | | 374.96 |
| OR Water Res. | 80.0 | 21.25 | 360.00 | 0.30 | | 1,808.00 | | 1,808.00 |
| Deschutes SWCD | 6.50 | 12.56 | 40.00 | 0.30 | 81.63 | 12.00 | | 93.63 |
| ODFW | 128.0 | 25.00 | 500.00 | 0.30 | | 3,350.00 | | 3,350.00 |
| USFS, Sisters RD | 1,331.5 | 25.00 | 2,000.00 | 0.30 | | 11,287.50 | 22,000.00 | 33,287.50 |
| Central OR Flyfishers | 4.0 | 15.00 | 60.00 | 0.30 | | 78.00 | | 78.00 |
| Portland General Elec. | 48.0 | 21.25 | 1,000.00 | 0.30 | | | 1,320.00 | 1,320.00 |
| Watershed Council | 271.0 | 17.01 | 283.00 | 0.30 | 4,696.27 | | | 4,696.27 |
| OSU | 448.0 | 8.00 | 600.00 | 0.30 | | | 3,764.00 | 3,764.00 |
| Watershed Residents | 205.0 | 15.00 | 1,000.00 | 0.30 | | 3,375.00 | | 3,375.00 |
| ***Contracted Services*** | | | | | | | | |
| Laboratory Services | | | | | 1,470.00 | | 1,500.00 | 2,970.00 |
| GIS Service | | | | | 4,395.00 | | 500.00 | 4,895.00 |
| ***Supplies/Materials*** | | | | | | | | |
| Printing Costs | | | | | 270.38 | 300.00 | | 570.38 |
| Photography | | | | | 140.15 | | 500.00 | 640.15 |
| Misc.-Repairs; Papers | | | | | 283.96 | 350.00 | | 633.96 |
| Student Recognition | | | | | 188.00 | | | 188.00 |
| ***Equipment*** | | | | | | 1,000.00 | | 1,000.00 |
| HOBO's | | | | | 873.62 | | | 873.62 |
| Water Quality Equipment | | | | | 310.00 | | | 310.00 |
| Misc. | | | | | 118.32 | | 500.00 | 618.32 |
| | 7,919.50 | | 6,735.94 | | 13,524.17 | 62,902.35 | 30,084.00 | 106,510.52 |

| | |
|---|---|
| Total Hours | 7,919.50 |
| Total Miles | 6,735.94 |
| Total OWEB Funds | 13,524.17 |
| Total In-kind Funds | 62,902.35 |

For the Thermal Infrared Monitoring and Color Videography phase several partners provided funding. The Oregon Watershed Enhancement Board supplied a portion of the funds needed for the project. The USFS Sisters Ranger District provided a cash contribution and technical assistance. Portland General Electric, Black Butte Ranch, and Oregon Water Trust also contributed cash dollars that allowed this final project phase to be implemented. The Oregon Department of Environmental Quality provided staff time and equipment for additional on-the-ground monitoring before, during and following the FLIR flight. Finally, community volunteers provided time contributions essential to the success of the project.

The following table indicates contributions by partner: in-kind, other funds, and OWEB funds.

**_Forward Looking Infra Red Monitoring-Summer 2000_**

**_Grant #97-211_**

| Project Partner | Hours | Rate | Mileage | Rate | OWEB Funds | In-kind Funds | Other Funds | Total |
|---|---|---|---|---|---|---|---|---|
| OR Water Res. | 4.0 | 21.25 | | 0.325 | | 85.00 | | 85.00 |
| USFS, Sisters RD | 12.0 | 25.00 | | 0.325 | | 300.00 | 2,000.00 | 2,300.00 |
| ODFW | 4.0 | 25.00 | | 0.325 | | 100.00 | | 100.00 |
| Portland General Elec. | | | | | | | 2,000.00 | 2,000.00 |
| OR Dept. Enviro. Quality | 95.0 | 25.00 | 618.00 | 0.325 | | 2,575.85 | | 2,575.85 |
| Black Butte Ranch | | | | | | | 1,000.00 | 1,000.00 |
| Watershed Residents | 12.0 | 15.00 | | | | 180.00 | | 180.00 |
| Oregon Water Trust | | | | | | | 2,000.00 | 2,000.00 |
| ***Project Administration*** | | | | | 2,331.72 | | | 2,331.72 |
| ***Project Coordination*** | 53.75 | 20.79 | 162.00 | 0.325 | 1,170.11 | | | 1,170.11 |
| ***Contracted Services*** | | | | | | | | |
| Watershed Sciences | | | | | 7,500.00 | | | 7,500.00 |
| ***Supplies*** | | | | | | | | |
| Printing | | | | | 100.00 | | | 100.00 |
| | 180.75 | | 780.00 | | 11,101.83 | 3,240.85 | 7,000.00 | 21,342.68 |

| | |
|---|---|
| Total Hours | 180.75 |
| Total Miles | 780.00 |
| Total OWEB Funds | 11,101.83 |
| Total In-kind Funds | 3,240.85 |
| Total Other Funds | 7,000.00 |
| **Total Project Budget** | **21,342.68** |

# Appendix A

## Squaw Creek Education and Restoration Project

## USFS Report

# Squaw Creek Education and Restoration Project
# 1998-1999

March, 2000

Michael D. Riehle and Jens Lovtang
Deschutes National Forest
Sisters, OR

**A Cooperative Project with:**

Deschutes National Forest
Upper Deschutes Watershed Council
Sisters School District
St. Francis School, Bend
Bend Community School
Oregon Department of Fish and Wildlife
Oregon State University
Portland General Electric

# Executive Summary

**From 1998 through 1999, a cooperative monitoring and restoration project was initiated on Squaw Creek** by the Upper Deschutes Watershed Council (UDWC), Sisters School District, Bend Community School, St. Francis School, Oregon Department of Fish and Wildlife (ODFW), Oregon State University (OSU), Portland General Electric (PGE) and the Deschutes National Forest (DNF). For two years, middle and high school students monitored water quality in the field four times each year and planted willows once each year. Teachers, high school student leaders, and biologists from the DNF and PGE instructed the students in field techniques for dissolved oxygen, pH, flow, stream temperature, stream bank stability and riparian plant typing. Biologists and volunteers sampled fish populations in 1999 and linked fish habitat surveys to valley bottom vegetation.

Using flow data collected by the students, we found a strong relationship between summer stream flow and high summer stream temperatures. Using this relationship, **an estimated 27 cubic feet per second would be needed to maintain summer stream temperatures** below the state criteria. Squaw Creek is listed as a 303(d) water quality limited stream by Oregon Department of Environmental Quality because of high water temperatures. As a result of irrigation diversions, instream summer flow is now limited to 2 cubic feet per second downstream of the town of Sisters. Additional flow may be needed to improve redband trout habitat. A critical period of low flow and high water temperatures also occurred in April, during the spawning season of redband trout.

Other water quality concerns raised by student monitoring included low dissolved oxygen during April and in August. Stream bank stability was low in stream reaches where summer flows were low. Willow and cottonwood were planted in May of 1999 but were washed away by a flood in November 1999. Good redband and steelhead trout habitat was linked to low floodplain areas with cottonwood-lined flood channels that spread floodwater and reduce stream bank erosion. Water withdrawals reduce trout habitat by decreasing water depth. Fish surveys found fewer adult and young redband trout in the diverted reach near Sisters than in other reaches sampled.

**Recommendations for future monitoring** include more temperature, fish population and flow measures in the diverted reaches to estimate the flow needed for trout habitat and to document the benefits of restoration projects. Improved floodplain delineation will help prevent future encroachment of the floodplain and will protect trout habitat.

**Recommendations for restoration** include securing summer instream flow to meet water temperature and trout habitat requirements. Recreating stream channel meanders in some cases may reduce channel instability downstream. Reconnecting floodplains to the main channel will help reduce stream bank erosion and promote stream bank vegetation. Planting of riparian vegetation could follow increases in reliable summer flow. Also, early season withdrawals need to be carefully timed so that they do not reduce the flow to harmful minimums during redband trout spawning season.

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# Acknowledgements

Many people have played important roles in the success of this project. Special thanks go to Cheryl Butler from the Sisters School District for initiating the project and coordinating the students and to Barbara Lee from the Upper Deschutes Watershed Council for securing cooperative funding and for her ability to link the community together. Thanks go out to the high school and middle school "Stream Team"; Matt Adams, Besse Ward, Michelle Elpi, Casey Glick, Anton Ruis, Carolyn Franks, Nathan Harpham and Laura Leis. We would also like to thank the teachers for preparing their classes for our field trips, and the parents and other volunteers for making the field trips fun and successful. Thanks go to the private land owners for allowing access to Squaw Creek at sites 3, 4 and 5 and to the Deschutes Basin Land Trust for access to Indian Ford Creek at site 8. Their willingness to open their land for the students to learn more about their watershed is much appreciated.

This project was funded by the USDA Forest Service Challenge Cost Share Program and grants from Oregon Watershed Enhancement Board (OWEB). Steve Marx and Dave Warner of Oregon Department of Fish and Wildlife provided equipment and assistance for electrofishing. Kristy Groves, Jon Hyde and other students of Oregon State University sampled fish on the lower Squaw Creek sites. Portland General Electric provided critical personnel time for Jens Lovtang to complete the project in 1999 and provided much needed equipment for electrofishing. Nate Dachtler, Rod Bonacker, Brad Houslet and Ken Merrill (volunteer) assisted in fish sampling. Brad Houslet managed the temperature monitoring program.

# Introduction

Squaw Creek flows through the community of Sisters and has been the center of attention for local residents in recent years. As more people vacation and move into the area, the demand for scenic and recreational opportunities is on the rise. After the 1964 flood, the channel was straightened and wood was removed in a failed attempt to control the erosion and channel movement. Stream stability has been an issue for landowners along the stream ever since (Army 1978) and stream instability has reduced the quality of fish habitat.

Watershed uses have been characterized by a variety of studies in recent years. Some of the more broad scale studies were the Watershed Assessment by the Deschutes Soil and Water Conservation District in 1994 (Curtis 1994) and the Sisters/Why-Chus Watershed Analysis by the USDA Forest Service in 1998 (USFS 1998). The goals outlined for Squaw Creek by the Why-chus Watershed Analysis include: 1) restore flows for reconnecting the upper and lower segments, 2) recover water quality sufficient to meet state water quality standards and support fish and other aquatic species, 3) restore riparian habitat on public and private lands to improve stream stability, water temperatures, and fish habitat quality, 4) reduce conflicts between irrigation needs and aquatic species and 5) encourage development that is compatible with functioning aquatic systems and that does not limit future restoration efforts. In 1997, the USDI Bureau of Reclamation and the Oregon Water Resources Department completed the Upper Deschutes River Basin Water Conservation Study (BOR and OWRD 1997). This study looked to improve the reliability of irrigation supplies and to improve the availability of water for other uses, including instream flows, through increased water use efficiency.

Concurrent with these assessments, changes in the management of the watershed were being made. In 1988, the stream segment upstream of Sisters was designated as a National Wild and Scenic River. In 1996, the Oregon Department of Environmental Quality (ODEQ) listed the remaining segment of Squaw Creek as water quality limited under section 303(d) of the Clean Water Act because of temperature violations and flow modifications. In response to environmental concerns, the Oregon Water Trust was invited to help secure nearly 2 cubic feet per second (cfs) of water for instream flow through the town of Sisters.

Today, Squaw Creek supports native redband trout, bull trout, non-native brook trout and brown trout, as well as native populations of suckers, dace, and sculpin. Prior to construction of the Pelton Round Butte Dam complex, Squaw Creek played an important role in the spawning and rearing of steelhead trout and chinook salmon. Efforts are now underway for possible reintroduction of steelhead and spring chinook into the stream above the dams. Squaw Creek could play an important role in their successful re-establishment, especially if improvements to water quality and habitat can be made.

## Project Purpose

With the above management goals in mind, the Squaw Creek Education and Restoration Project was designed to: 1) teach students and the community about the importance of healthy streams and watersheds, 2) monitor the condition of Squaw Creek to describe baseline conditions of water quality and fish habitat, 3) provide students with hands on learning opportunities of land stewardship 4) identify high priority areas for stream restoration.

Beneficial uses for Squaw Creek include public and domestic water supply, irrigation, livestock watering, anadromous fish passage, salmonid fish spawning and rearing, resident fish and aquatic life, wildlife and hunting, fishing, boating, water contact recreation and aesthetics (Table 1). These diverse uses are often in conflict. On Squaw Creek, water withdrawals near the town of Sisters exceed the availability of water needed to allow fish and aquatic life to thrive.

Water quality parameters were selected to monitor the relationship between stream flow and beneficial uses (Table 1). Along with flow, water temperature was a primary concern because the stream was known to exceed ODEQ water temperature standards. Because warm water holds less oxygen in solution than cool water, dissolved oxygen was also measured. Fish and invertebrates need high levels of oxygen. If high levels of nutrients combine with warmed water, algae can grow and increase the pH of the water. Data on pH was used to determine if this was a problem. The diversity and abundance of aquatic invertebrates was examined to assess a variety of water quality conditions, including possible organic enrichment.

For fish habitat, Oregon Department of Fish and Wildlife and the USDA Forest Service surveyed Squaw Creek in 1997. Mapping of valley bottom vegetation and stream channel features was done from low elevation air photos taken in 1998 to assess stream bank condition in relation to fish habitat. Students made additional measurements of the stream bank stability and coverage of riparian vegetation in May/June of 1999. The students experimented with willow and cottonwood plantings along exposed stream banks in both years. Oregon Department of Fish and Wildlife, USDA Forest Service and Oregon State University surveyed fish populations in the summer and fall of 1999 to link the habitat information with fish densities.

Table 1. Beneficial uses of Squaw Creek and the measurements used to assess them (beneficial uses from **OAR 340-41**).

| Beneficial uses of Squaw Creek | Measurements of water quality and fish habitat | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Flow | Temp | DO | pH | *E. coli* | Fish Habitat bank stability | Riparian Vegetation | Fish Habitat survey | Fish Habitat mapping | Macro-invertebrates | Fish Population |
| Public and Domestic Water Supply | X | | | X | | | | | | | |
| Irrigation and Livestock Watering | X | | | | | | | | | | |
| Anadromous Fish Passage | X | X | X | X | | X | X | X | X | X | X |
| Salmonid Fish Spawning and Rearing | X | X | X | X | | X | X | X | X | X | X |
| Resident Fish and Aquatic Life | X | X | X | X | | X | X | X | X | X | X |
| Fishing | X | X | X | | X | X | X | X | | X | X |
| Water Contact Recreation/Boating | X | | | X | X | | | | | | |
| Aesthetic Quality | X | | | | | X | X | | X | | X |

## Study Area Description

Squaw Creek flows off the glacial Cascade Mountains over 9000ft in elevation through steep narrow canyons and out onto the outwash area near Sisters (USFS 1998). In the vicinity of Sisters, the stream historically meandered through broad, flat valley bottoms for over 12 miles. Much of the channel is now confined by boulder riprap and berms. The canyon narrows below Camp Polk, but opens slightly just upstream of the Crooked River National Grassland. The canyon narrows again once on the Grassland, flowing into a deep canyon near Alder Springs and then into the Deschutes River canyon, near 2100ft elevation. Nearly 82% of the 151,650 acre watershed is managed by the Deschutes National Forest and Crooked River National Grassland.

Study Sites

Eight sites were selected along the length of Squaw Creek, each representing a particular reach of Squaw Creek (Figure 1).

- **Site 1** is located above all major diversions on Squaw Creek, near the OWRD gauging station, approximately four miles upstream of Sisters. It is the best representation of unaltered water quality.

- **Site 2** is located approximately 2 miles upstream of Sisters, at the FS road 4606 footbridge. This site is below the Squaw Creek Irrigation District (SCID) diversion, the major diversion on Squaw Creek.

- **Site 3** is located at the Sisters City Park. This site represents the stretch of Squaw Creek with the lowest flow. This stretch was typically de-watered during the height of the irrigation season prior to 2 cfs being secured instream. The fish sampling site was downstream of the Highway 20 bridge where there is high channel instability.

- **Site 4** is located upstream of the Camp Polk Road bridge, about 3 miles downstream of Sisters. Springs enter Squaw Creek upstream of this site, and add approximately 5 cfs to the stream. This site is in an area with good riparian vegetation cover.

- **Site 5** is located downstream of the Camp Polk bridge. This section of stream was channeled and trenched, and has resulted in bank erosion, loss of fish habitat and riparian vegetation.

- **Site 6** is approximately 12 miles downstream from Sisters, in Squaw Creek Canyon, on the Crooked River National Grassland. This site is below all major diversions and represents a fairly undisturbed reach of the creek, but with low flow and high water temperatures.

- **Site 7** is located just downstream of Alder Springs, a large spring complex about 2.5 miles above Squaw Creek's confluence with the Deschutes River.

- **Site 8** is located on Indian Ford Creek on land owned and managed by Deschutes Basin Land Trust. The site is located near the junctions of Camp Polk Road and Indian Ford Road, approximately 3 miles upstream from Squaw Creek. Above this site, the flows are reduced by water diversions and the meadows are used for livestock pastures. Indian Ford Creek joins Squaw Creek between Sites 3 and 4.

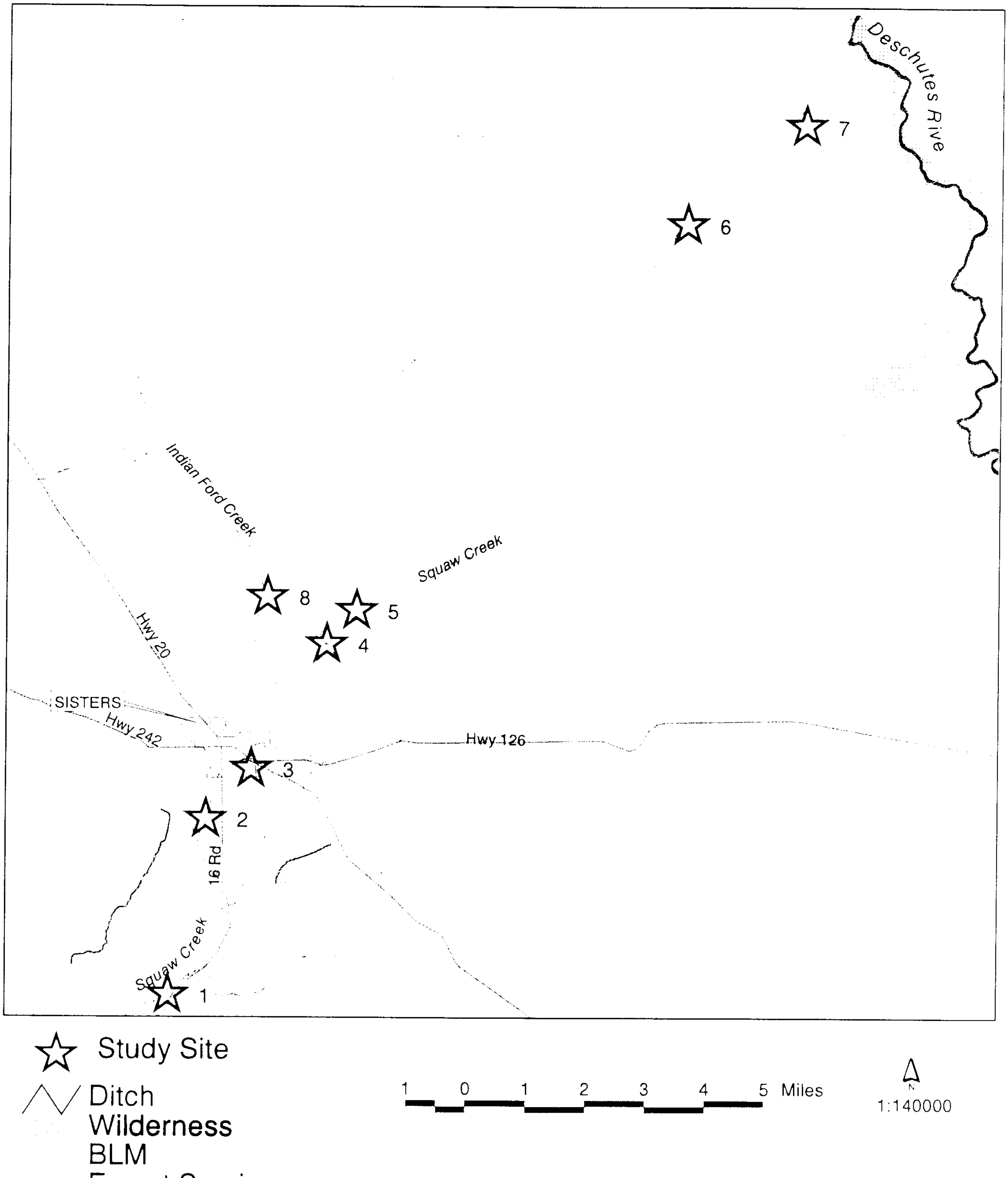


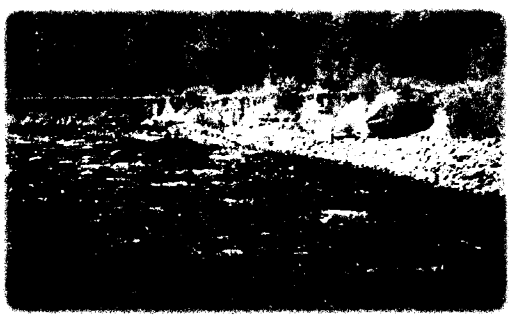

Figure 1. Location map of water quality and fish monitoring sites on Squaw Creek and Indian Ford Creek during 1998 and 1999

# Squaw Creek Monitoring Sites

# 1998 - 1999

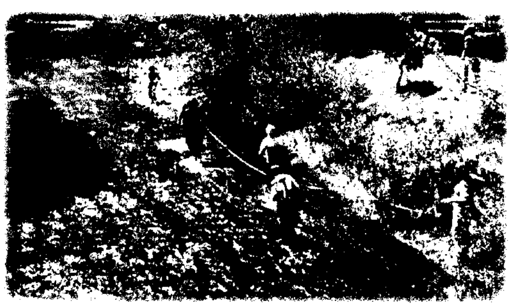
Site 1

Site 7



Site 2


Site 8



Site 3

Site 6

Site 4

Site 5

Each site (except sites 6 and 7) was assigned to one teacher and their class (Table 2). Due to the remoteness of sites 6 and 7, data were collected by USFS biologists. Each class took field trips to their sites to collect data, assisted by a Forest Service biologist. Parents and high school volunteers also helped out with the field trips.

Table 2. Class and teacher responsibilities for each site.

| Site # | Teacher | School and Class |
|---|---|---|
| 1 | Colleen Lynch | St. Francis School, Bend, sixth grade. |
| 2 | Glen Herron | Sisters High School |
| 3 | Kathy Kemper | Sisters Elementary School, fifth grade. |
| 4 | Cheryl Butler | Sisters Middle School, seventh grade. |
| 5 | Carol Packard | Sisters Middle School, sixth grade. |
| 6 and 7 | USFS | Sisters Ranger District Biologists |
| IF | Julie Robertson | Bend Community School, fifth - eight grades. |

Stream Survey Reaches

Squaw Creek was divided into different reaches during the stream survey based on valley shape and the geology of the stream channel (Dachtler 1997, Burke 1997). In some cases the reaches were designated based on land ownership where access was limited. Most of Squaw Creek was surveyed for fish habitat from the mouth to the first falls in the wilderness. Private land without access was not surveyed and comprised a total of 7.2 miles of the 24.7 miles considered in this study. For this project, reaches 1 through 13 were used, spanning the stream from the mouth to the flow gage above the main irrigation diversion (Figure 2).

Stream Flow

Monthly flow increases in Squaw Creek in June when the mountain snows rapidly melt (Figure 3). Peak flows commonly occur when rain falls on snow throughout the watershed, primarily in the late fall and spring. The lowest flow naturally occurs in late winter or early spring, when most water is locked up in snow or ice. Currently, the lowest flows now occur below the private water diversions near Sisters during the late summer and early fall primarily due to water being diverted out of the natural channel for crop irrigation and livestock watering.

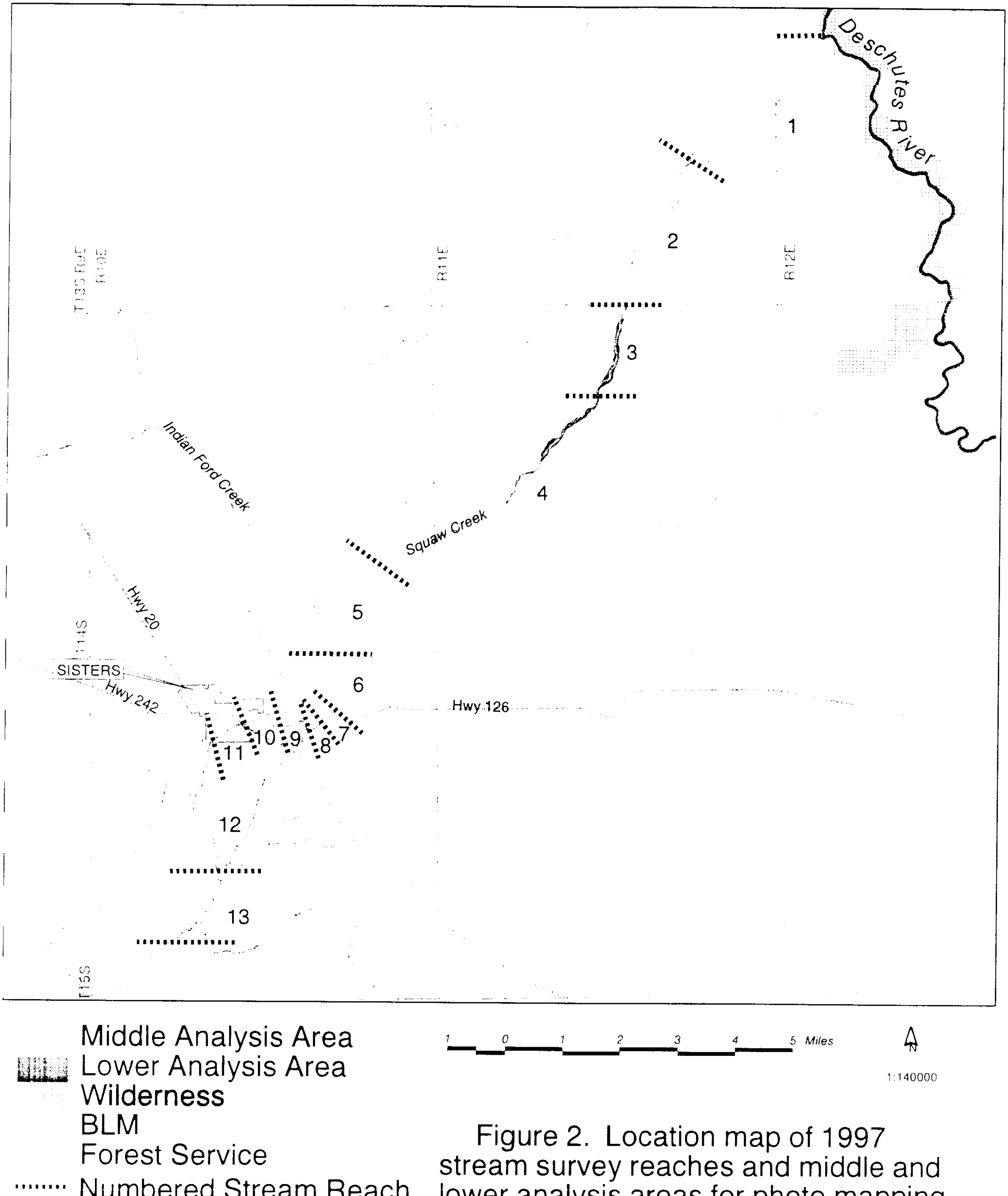



Figure 2. Location map of 1997 stream survey reaches and middle and lower analysis areas for photo mapping on Squaw Creek

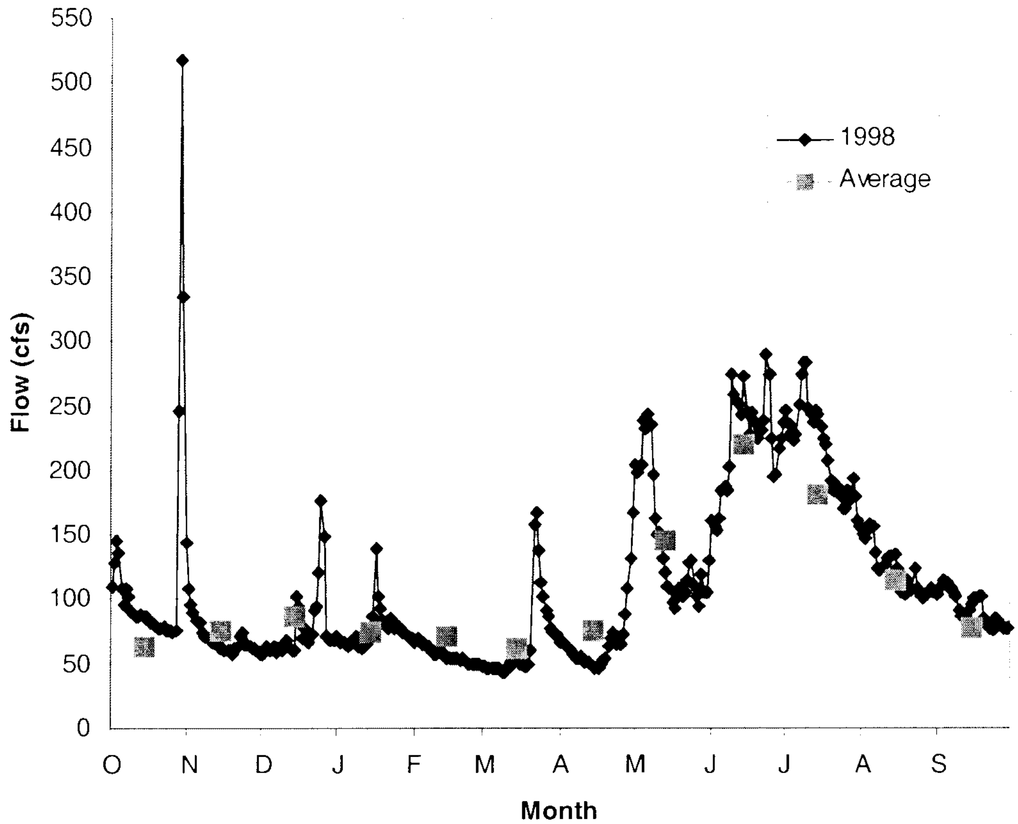



**Figure 3. Average monthly flow (gage 14075000) for the water years 1925 through 1998 (square symbols), plotted with the 1998 average daily flow (diamond symbols) for Site 1 of Squaw Creek.**

## Schedule of Activities

Data was collected four to five times during the year at each study site (Table 3). The data collected by each class and by Forest Service personnel included flow, temperature, pH, dissolved oxygen, macroinvertebrates, photo points and bacteria counts (provided by a contract lab). Riparian planting occurred in the spring of each year. Stream bank stability and riparian transects were conducted in the spring of 1999. Electrofishing and snorkel counts were added in 1999 to assess fish use at representative study sites.

Table 3. Schedule of data collections on Squaw Creek for 1997 -1999.

| | 1997 | | | 1998 | | | | | | | | | | | | | 1999 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Task | Oct | Nov | Dec | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
| Training | X | | | | | | | X | | | | | X | | | | | | | X | X | X | | | |
| Temperature | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Flow | X | | | | | | | X | | X | | X | X | X | | | | | | X | | X | | X | X |
| Dissolved Oxygen | X | | | | | | | X | | X | | X | X | X | | | | | | X | | X | | X | X |
| PH | X | | | | | | | X | | X | | X | X | X | | | | | | X | | X | | X | X |
| Photo points | X | | | | | | | X | | X | | X | X | X | | | | | | X | | X | | X | X |
| Invertebrates | X | | | | | | | X | | X | | X | X | X | | | | | | X | X | | | | |
| E. coli | | | | | | | | X | | X | | X | | X | | | | | | X | | X | | X | |
| Riparian planting | | | | | | | | X | | | | | | | | | | X | | X | | | | | |
| Streambank Stability | | | | | | | | | | | | | | | | | | | | | X | X | | | |
| Riparian Survey | | | | | | | | | | | | | | | | | | | | | X | X | | | |
| Fish Sampling | | | | | | | | | | | | | | | | | | | | X | | | | X | X |

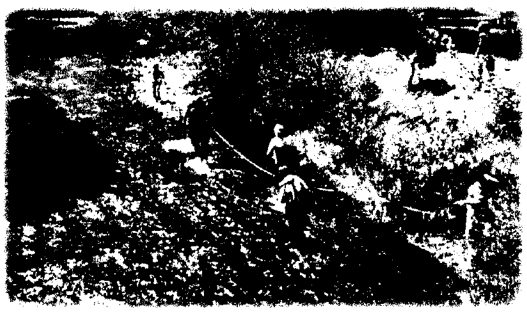
# Methods of Monitoring

# Squaw Creek

pH measurement

Flow measurement

Willow planting crew



Stream bank stability measurement

Dissolved oxygen measurement

Riparian plant typing

Macroinvertebrate sampling

# Data Collection Methods

Water Quality

Flow is the volume of water flowing in the creek, measured in cubic feet per second (cfs). Flow was calculated using the USGS methodology of dividing the stream cross section into at least 10 equal cells, and measuring the width, depth and velocity of each cell. Velocity was measured at 60% of stream depth using a digital Marsh - McBirney FLO-MATE velocity meter (accuracy ± 2%) and a depth staff. Area of each cell (width x depth) multiplied by the velocity (ft/sec) calculates the flow (cfs) in each cell. Adding the flow from each cell together gives the total amount of flow in the stream.

From the flow transects and stream survey, we looked at the width and depth of the stream. Not all wetted channel is suitable for fish. There needs to be enough water depth for the fish to have cover for security. In general, stream habitat is most suitable for trout between 2 ft and 3.5 ft (Beecher et al. 1993, Dambacher 1991, Raleigh et al. 1986, Raleigh et al. 1984). Water depth of 1.0 to 1.5ft could be considered a minimum for stream dwelling trout.

Water temperatures were measured using electronic Hobo-temp data loggers (by Onset Corporation) with an accuracy of 0.7 °C. The Hobo-temps were set to record the water temperature every 48 minutes and then placed in the stream at each of the sites. The data was downloaded from the Hobo-temps to a computer and summarized every two to three months. Each class also recorded the water temperature at their site during each of their field trips, using a hand-held glass, alcohol thermometer, to calibrate the dissolved oxygen measures. The average of the daily maximum temperatures of the seven warmest days of the year were used to compare to the ODEQ standards (7-day average maximum temperature). The ODEQ criteria for water temperature in the Deschutes Basin is 17.8°C (64°F) for rearing salmonid fishes and 12.8°C (55°F) for spawning/incubation/emergence of cold water salmonids.

Dissolved Oxygen (DO) was measured in the field using a 30 mL titration kit by Hach Corporation. A 300 ml titration kit meeting the Oregon Department of Environmental Quality (ODEQ) methodology was used for the October 1998 and all of the samples in 1999 (accuracy is ± 0.2 mg/L). Only results from the 300ml kit were used in this report. ODEQ criteria for dissolved oxygen is 11mg/L for salmonids from spawning to emergence, unless conditions of altitude preclude reaching 11 mg/L, then the standard is 95%

saturation. For cold water aquatic resources, the dissolved oxygen should not fall below 8.0 mg/L, unless altitude precludes attainment of this standard, then dissolved oxygen should not fall below 90% saturation.

Measurements of pH were taken in the field using a Hach color wheel kit. Results were accurate to the nearest 0.5 pH unit. ODEQ criteria for pH is 6.5 to 8.5 for the Deschutes Basin.

Photos were taken at each of the sites upstream, across and downstream at each station. Students used photos to compare the condition of riparian vegetation and stream bank from one season to the next.

A contract laboratory performed *Esherichia coli* (E.coli) tests. Water samples were taken by USFS personnel and delivered to the lab for analysis. Results are expressed as colonies found per 100 mL of water. ODEQ criteria for *E. coli* is the 30 day log mean of 126 organisms per 100mL, based on a minimum of five samples. No single sample shall exceed 406 E. coli per 100mL.

Students sampled macroinvertebrates using a dip net. Three samples each were collected from fast water riffles and slow water habitats. The macroinvertebrates were then separated into different kinds based on easily identified physical characteristics. Multiple indices were then calculated (Table 4).

The Sisters Ranger District collected separate samples and used a contract laboratory for more detailed analysis of macroinvertebrates (Vinson 1998, Vinson 1999a, Vinson 1999b). Three samples were taken in each of three riffles using a Hess net with a 250 micron mesh size in September of 1997and 1998, and in May/June of 1999. The samples were combined in the field for each site. The Lab results are presented in this report.

Table4. Macroinvertebrate indices for student samples

| Index | How to Calculate |
| --- | --- |
| Mayfly/Stonefly/Caddisfly Richness | The number of different mayflies, stoneflies and caddisflies |
| Taxa Richness | The total number of different kinds of macroinvertebrates |
| Midge richness | The total number of different kinds of midges |
| Macroinvertebrate Richness | The total number of individual macroinvertebrates |

## Fish Habitat Survey and Mapping

Fish habitat was surveyed using two methods. One method was the stream inventories conducted on foot by ODFW and USFS. These surveys used the method adapted by ODFW and Region 6 of the USDA Forest Service. Measurements of stream habitat were based on pool and riffle habitat types. These data were summarized in a rating system developed by ODFW called HABRATE, which rates habitat quality as good fair or poor for the five different life stages of steelhead trout (Burke et al., unpublished report).

The other method used to record stream habitat was air photo mapping. The valley bottom was mapped by dividing the valley floor into plant types, such as cottonwood and willow, and different channel features, such as islands and gravel bars (Appendix A). These mapped areas were divided into the same stream reaches established during the ground-based surveys. The HABRATE habitat ratings for each reach were compared to stream channel features and valley bottom vegetation mapped from air photos (Riehle et al., unpublished data).

## Fish Populations

Fish counts were made by snorkeling representative sites in 1999. The study sites chosen were Site 1, 3, 4, 6b and 7. Because of the possibility of reduced numbers of fish from angling at site 6, the fish sampling was relocated 1 mile downstream and labeled site 6b. Snorkel counts were completed in April, July, August and September. Two snorkelers moved upstream together. For each 150-200m (500-650ft) site, the pool and riffle habitats were counted separately and the surface area of the habitat was measured. Due to the unusual high summer flows, electrofishing was only conducted in September and October. Two backpack-mounted electroshockers were used in tandem and block nets were used to prevent fish from escaping the section. Comparisons were made between the two techniques to establish a correction factor for snorkeling.

# Results

## Flow

Flow was average in 1998 but unusually high in 1999 (Figure 4 and 5). With the May 1, 1999 snow pack at a record 320% of normal, August flow in Sisters was nearly 160cfs, compared to the average of 113 cfs. September flow dropped considerably in both years to just under 2 cfs in Sisters, but by site 4 at Camp Polk Road, added flow of 6-7cfs entered Squaw Creek from Indian Ford Creek and groundwater springs. Flow downstream of Camp Polk Road dropped as low as 9 cfs and continued to drop 6 cfs at the National Grassland road crossing at site 6.

A low flow period also occurred during April and May. Flow at sites 2 and 3 dropped to near 10 cfs as irrigation diversions were opened but before the mountain snowmelt began. This naturally low flow combined with the beginning of irrigation season resulted in high water temperatures for a brief period and reduced spawning and incubation habitat quality for fish and other aquatic life. In April of 1990, a fish kill resulting from low flow was reported between Sisters and the main diversion (Riehle 1990).

## Water Temperature

Stream temperatures were above state water quality standards for both the period for redband trout spawning/incubation and for the period of redband trout rearing for all sites below the diversions (site 1) (Figure 6). Sites 3 through 6 exceeded rearing standards in 1998. Although 1999 was a high water year, flows dropped to a low flow in late August, and exceeded the rearing temperature standard only in site 6. Squaw Creek is listed on the ODEQ 303(d) list for high water temperatures.

The relationship between August flows and the seven-day average for maximum temperatures during summer was significant (Figure 7). Using this plot, the summer flow necessary to keep the temperature below the state standards in 1998 and 1999 was approximately 27 cfs. Since this relationship is based on data from one average year and one high water year, it may not apply to all years, and could be considered a low estimate for flows needed to comply with state water temperature standards.

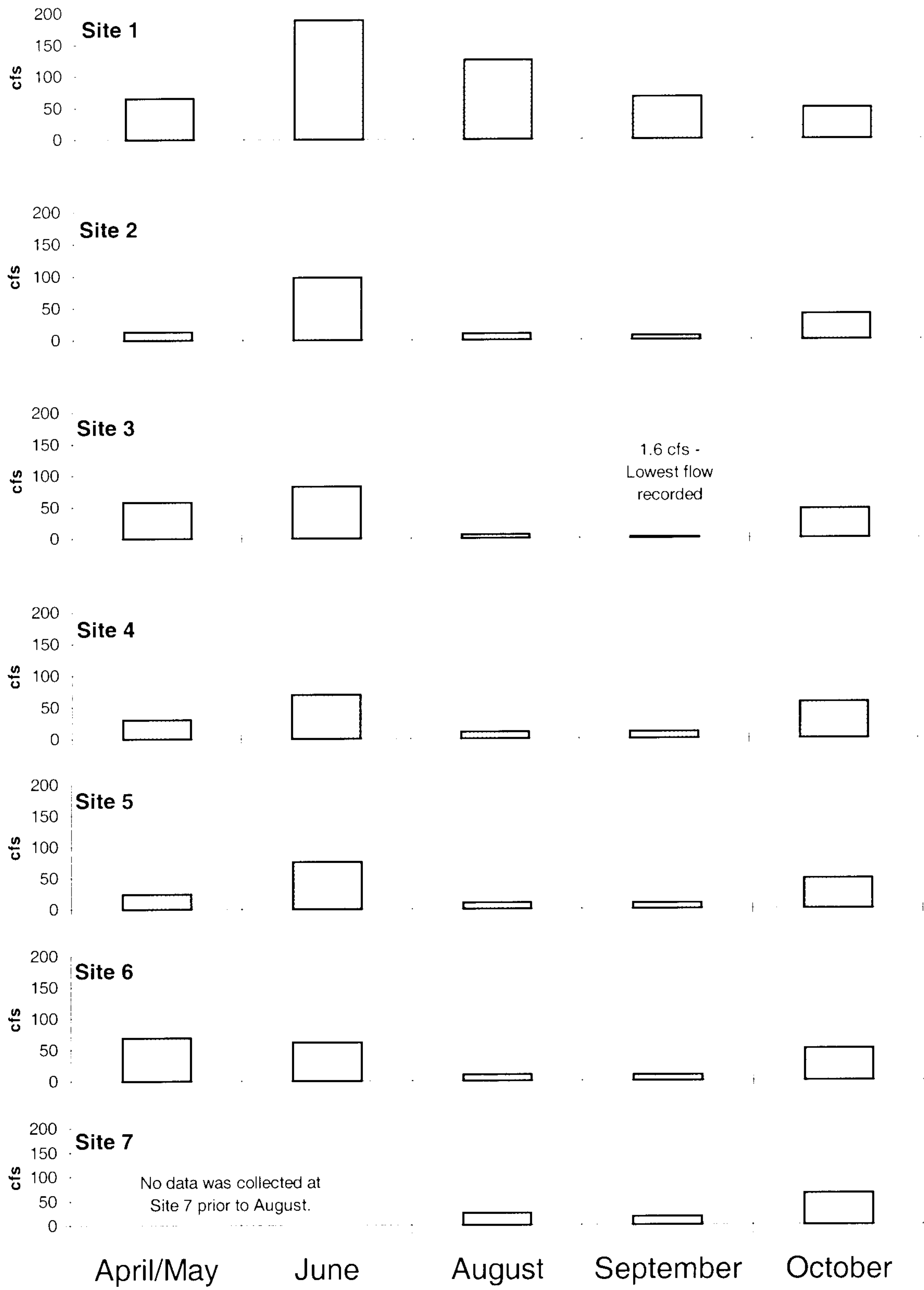



Figure 4. Flow measurements on Squaw Creek for 1998.

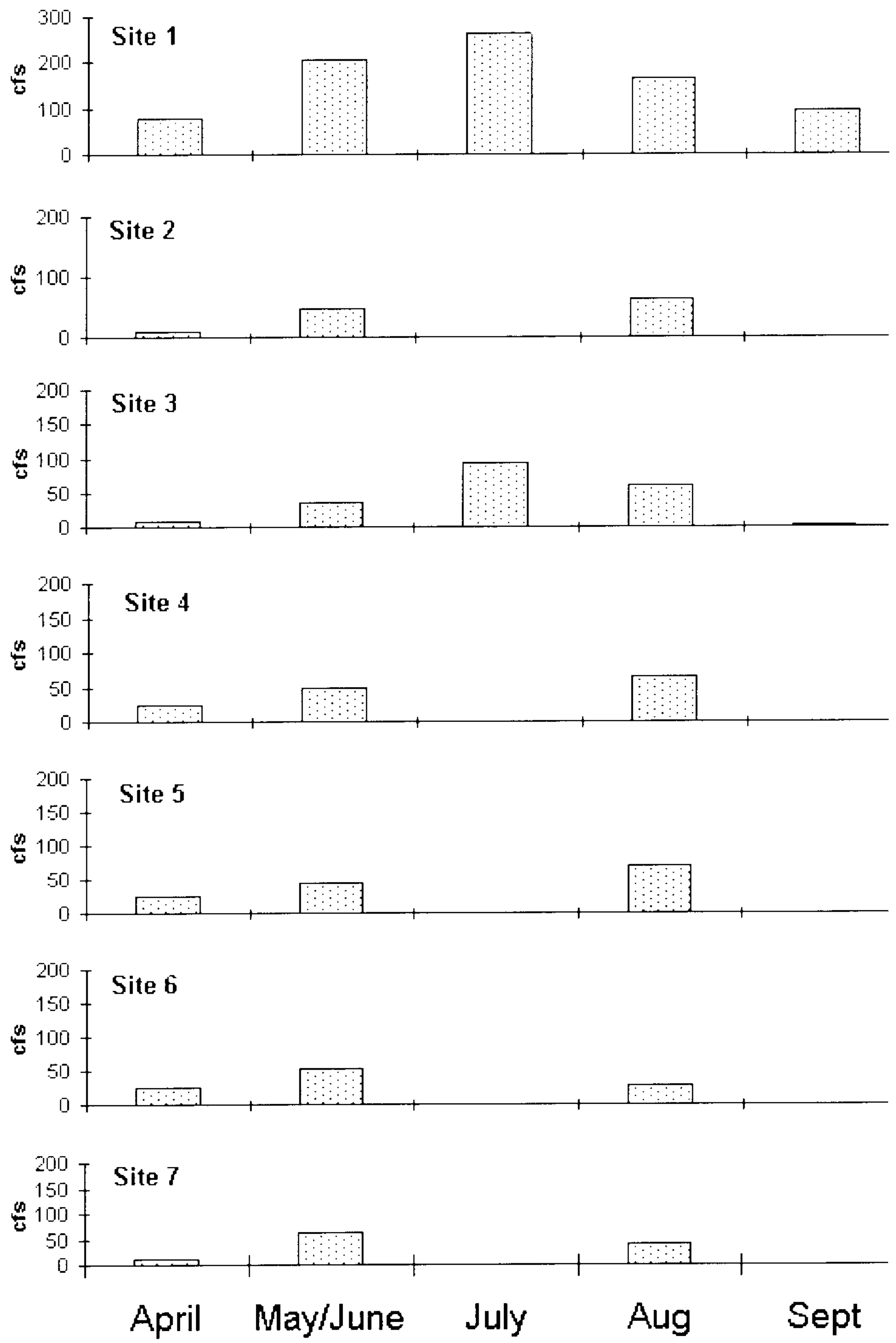



Figure 5. Flow measurements on Squaw Creek for 1999.

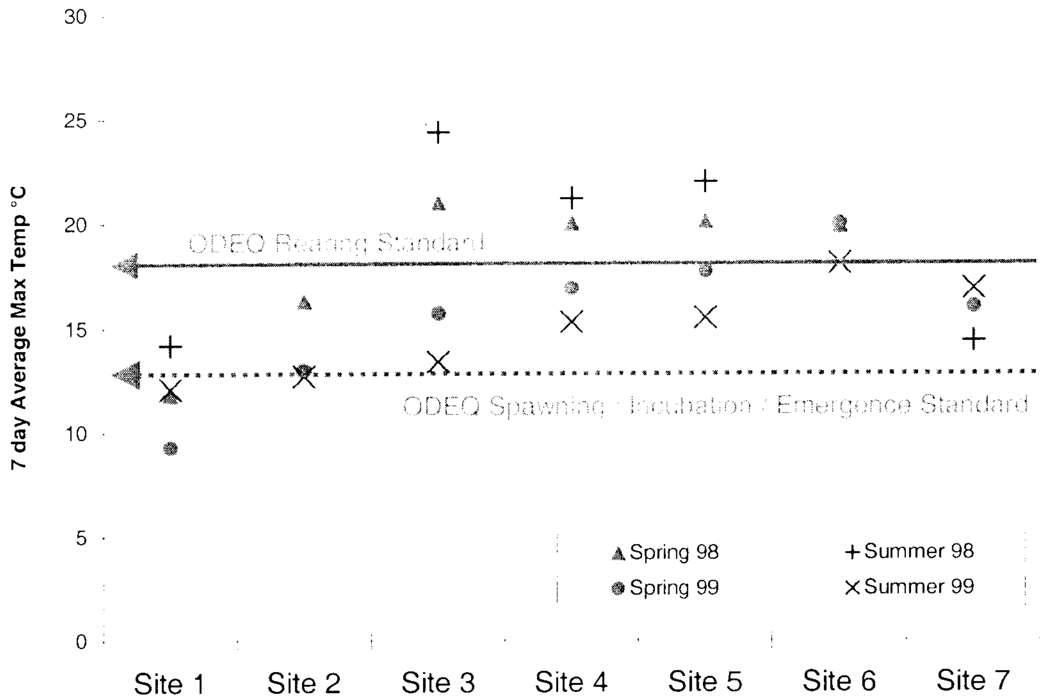



**Figure 6. The seven-day average maximum temperature of Squaw Creek in relation to ODEQ standards for summer salmonid rearing (solid line) and springtime spawning/incubation periods (dashed line).**

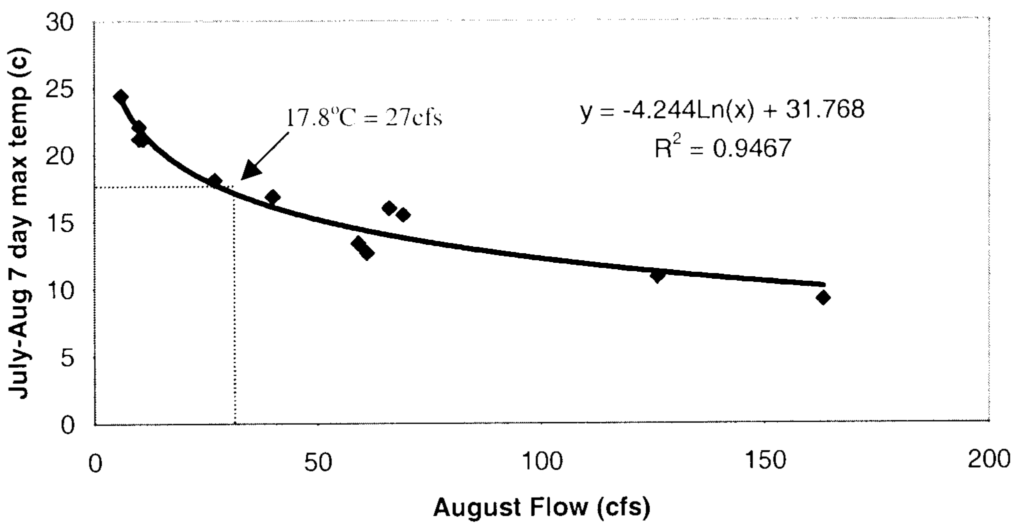



**Figure 7. The relationship between stream flow and average seven-day maximum temperature for all sites of Squaw Creek during August of 1998 and 1999.**

## Dissolved Oxygen and pH

The availability of oxygen in the water did not show as strong a correlation with flow in 1999 but may be stronger in lower water years, when riffles have less turbulent mixing and long shallow pools become still and warm. The pH measurements varied little through the year, ranging from 6.5 to 7.5 and were not correlated with flow or dissolved oxygen, at least for the years of this study. The percent saturation of dissolved oxygen was below the state standards for spawning and incubation during April at site 4 and site 6 (Figure 8). This is a concern for site 4 because spawning activity occurs in the springtime at this site. For the rearing period of 1999, all sites except site 6 fell within the standards, although more samples would be needed to establish the statistical significance of these findings (Figure 9).

*E. coli* bacteria

In April, the *E. coli* bacteria counts in Squaw Creek were less than 10 count/100mL. Counts increased in June, peaked in August and decreased in October (Figure 10). Peak counts of *E. coli* bacteria in Squaw Creek were below ODEQ standards for contact recreation (30-day log mean 126 colonies/100ml of five samples). Indian Ford Creek had a peak of over 200 colonies/100ml in June of 1999 (Figure 11). This period was associated with high water and may have resulted from runoff and flooding over highly grazed pastures along the meadows of Indian Ford Creek. The bacteria from Indian Ford Creek enter Squaw Creek between sites 3 and 4. In June, site 4 had more bacteria than at site 3. This effect may be reduced in August or low water years, when flows of Indian Ford Creek are reduced.

Macro-invertebrates

Aquatic invertebrates intolerant of pollution, high temperatures and fine sediment were the most abundant in site 1 and site 5 and less abundant at sites 2, 3 and 6 (Figure 12). Moderate abundance was found at site 4. Long lived types of macroinvertebrates were found to increase downstream in Squaw Creek, possibly a reflection of warmer water temperatures and more stable flows below Camp Polk springs. Long lived taxa may be impacted by frequent stream gravel movement in unstable reaches at sites 2 and 3(Figure 12). At these sites, the macroinvertebrate community was dominated by few, pollution-tolerant invertebrates. Sites 2 and 3 are considered water quality impacted, or enriched, because their HBI index scores were above 5. The maximum possible index score for the most polluted waters is 10 (Hilsenhoff 1987).

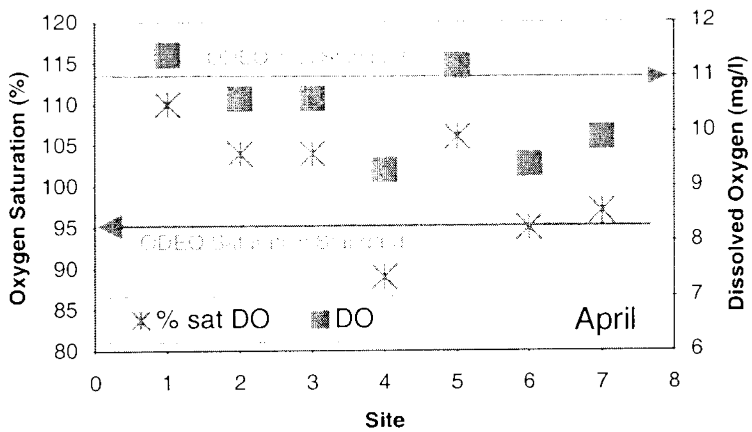



**Figure 8. Dissolved oxygen and oxygen saturation of Squaw Creek during April of 1999. ODEQ standards are given for salmonid spawning/incubation.**

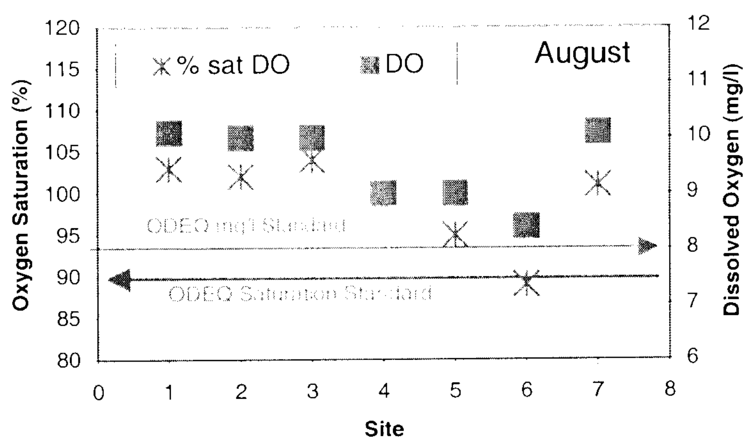



**Figure 9. Dissolved oxygen and oxygen saturation of Squaw Creek during August of 1999. ODEQ standards are given for rearing salmonids.**

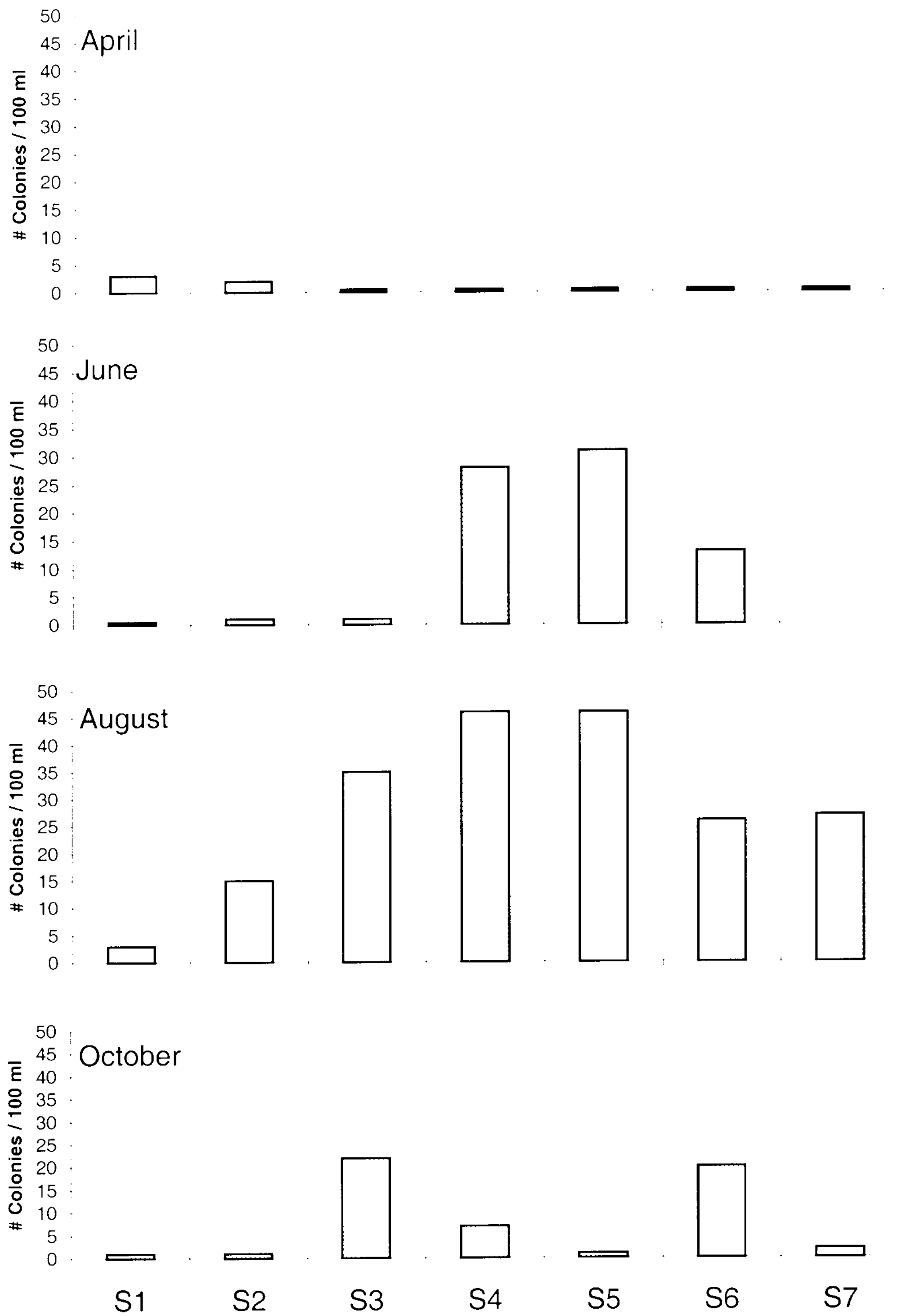



Figure 10. Results of *E. coli* samples taken from Squaw Creek in 1998.

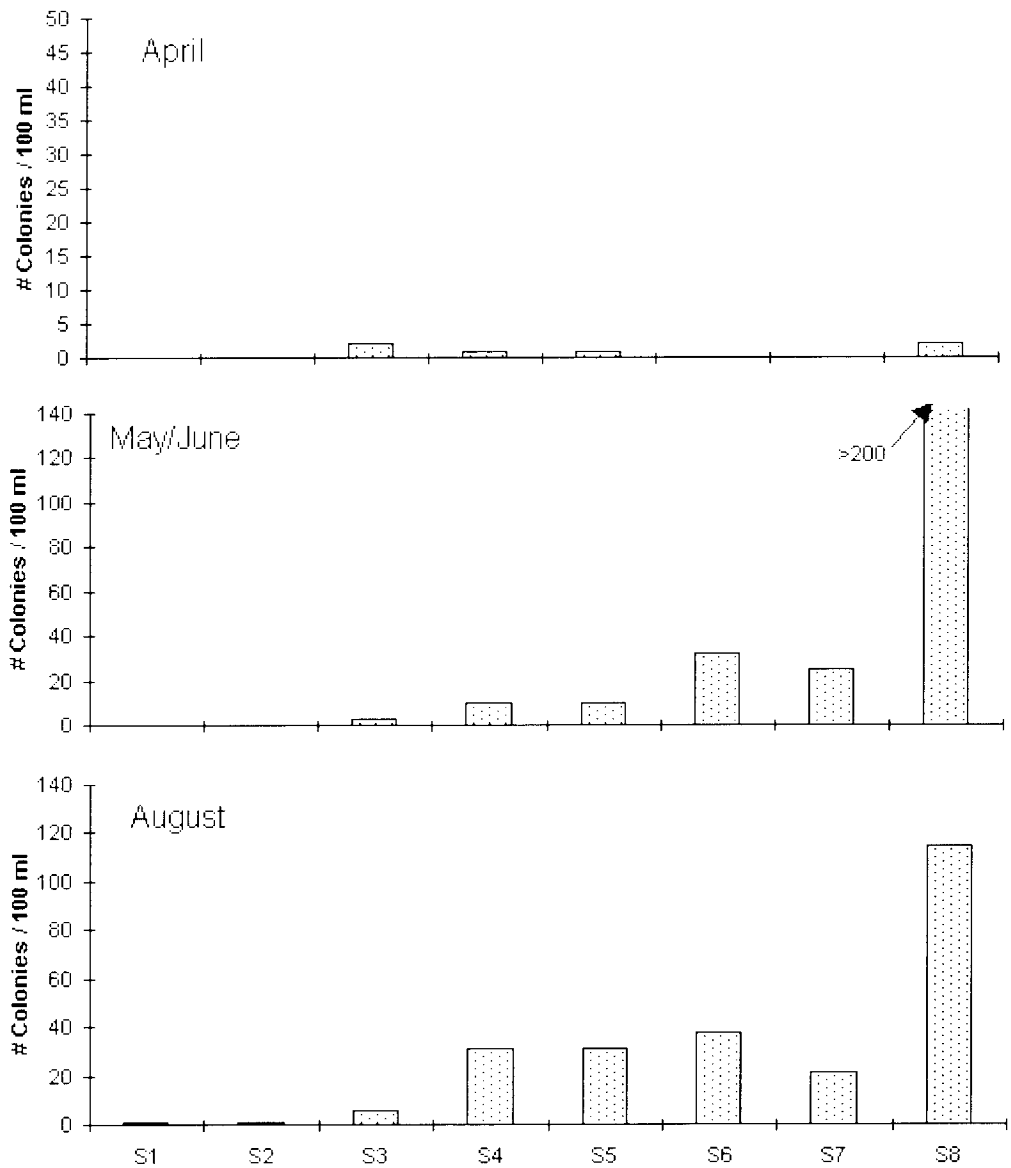



**Figure 11.** Results of *E. coli* samples taken from Squaw Creek (sites 1-7) and Indian Ford Creek (site 8) in 1999.

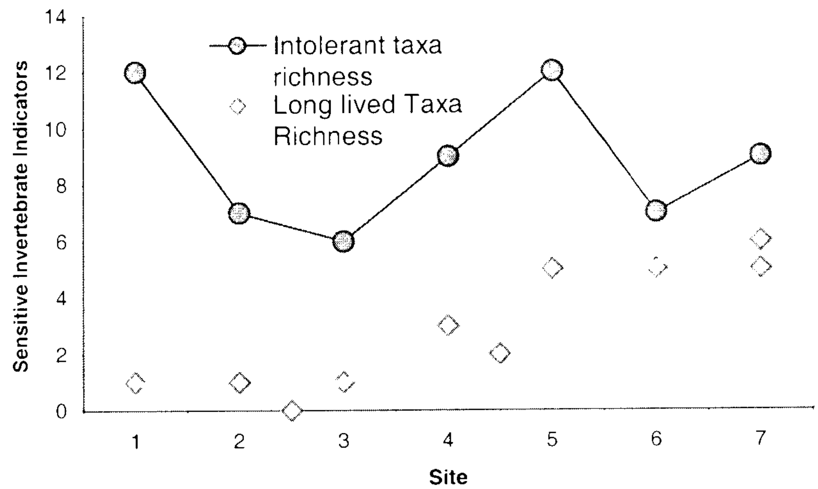



**Figure 12. Intolerant and longed lived macroinvertebrates collected in Squaw Creek in 1998 and 1999.**

Fish Habitat

As flow increases above 50-60 cfs, the average depth in riffles changes less rapidly (Figure 13). The 1.0 to 1.5ft riffle minimum depth for trout was not reached until there was over 50 cfs at the flow transects on Squaw Creek. These general observations are based on a few transects where flow measurements were taken. More transects would be needed to describe this relationship for the entire stream with its different habitat types.

Pools and riffles have a range of water depths. In the reaches near Sisters (reaches 11 and 12), we found the highest percentage of pool habitat but the lowest average depth (Figure 14). This trend for increased pool habitat and shallow water is a reflection of low instream flow from irrigation diversions. Dachtler (1997) found during two consecutive surveys of reach 12, that a drop from 29 to 7 cfs increased the area for pools from 17 to 27%. Stream surveys conducted at low flow tend to increase the proportion of long, slow, shallow pools in the inventory (Hilderbrand et al. 1999). These shallow pool habitats have little value for trout. Datchler (1997) found that reduced flow reduced the area of off-channel pools by 65% and pool depth decreased by 1/3 foot. Hawkins et al. (1997) found the higher water temperatures were associated with a high percentage of shallow pools in California mountain streams. Pool depth is considered high quality (>3ft depth) above the diversions in reaches 13, where natural flows are maintained. Downstream of Camp Polk at reach 7, pool depth increases due to added water from the springs (Figure 14).

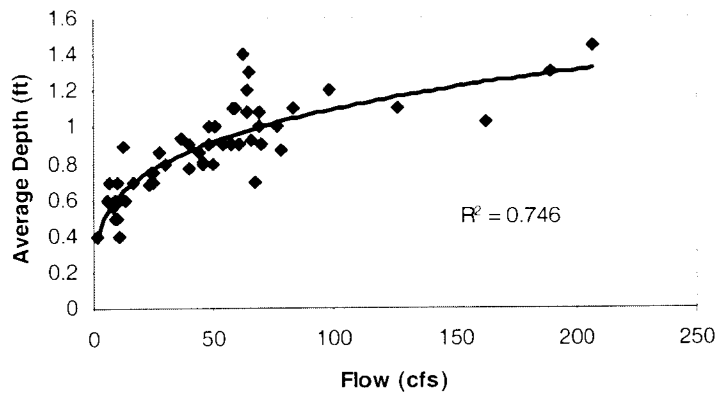



Figure 13. Average riffle depth at flow transects of Squaw Creek.

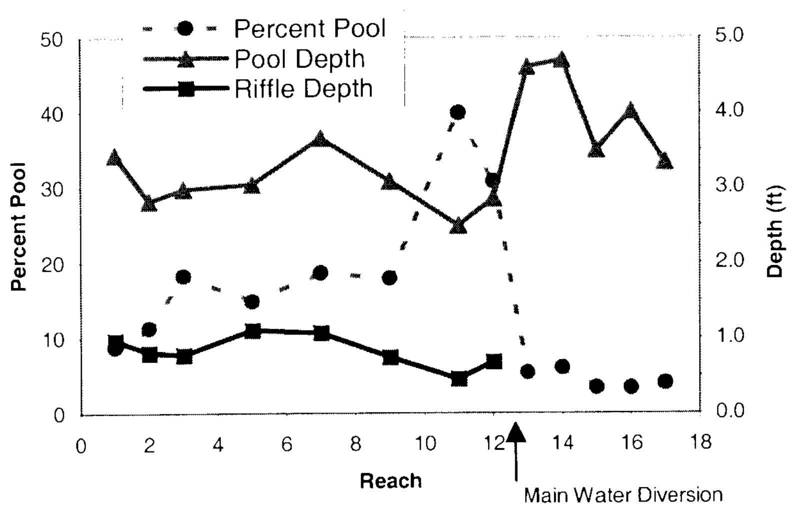



Figure 14. Percent pool, pool depth and riffle depth of different reaches along Squaw Creek in 1997 (data from Dachtler 1997 and Burke 1997).

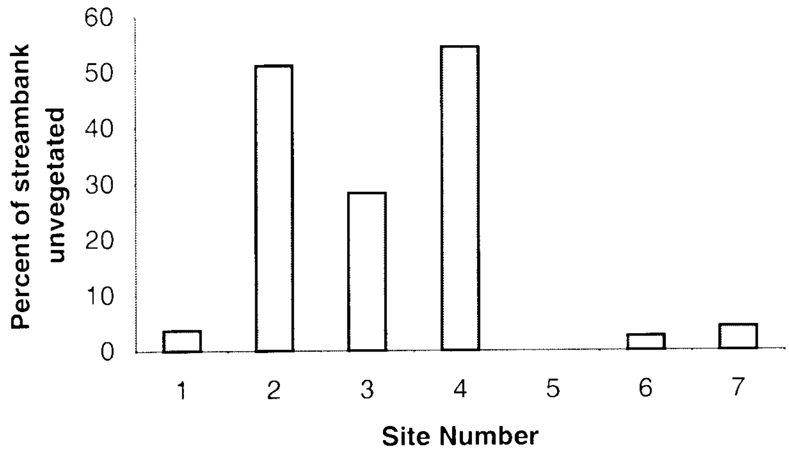



**Figure 15. Percent of stream bank that was unvegetated at monitoring sites along Squaw Creek. Site 5 was not sampled.**

Riparian Vegetation

The students found 25 to 50 percent unvegetated stream banks at site 2 through 4 (Figure 15). Sites 1, 6 and 7 had few unvegetated stream banks. The instability in the middle reaches can be related to development, channelization, valley shape and/or reduced summer flows. At site 4, where the cottonwood floodplain occurs, the bank disturbance was low, but upstream of the cottonwoods, cut banks increased the overall percentage of unvegetated, unstable banks. Willows and cottonwoods planted by the students along an unvegetated cut bank at site 2 was largely washed away during a flood event in November of the same year. This exercise displayed the difficulty in restoring a site once the riparian vegetation and floodplain is lost.

Unvegetated stream banks provide reduced habitat quality for young steelhead or redband trout. Stable, well-vegetated banks provide cover for trout. High quality habitat for young steelhead in Squaw Creek was linked with reaches with few unvegetated gravel bars (Figure 16). Gravel bars without vegetation can be considered an indicator of high movement of streambed gravel or high stream instability. Riparian vegetation with cottonwoods can hold stream banks together during floods and is associated with higher quality cover for young steelhead (Figure 17). The percentage of the riparian vegetation was highest at site 4, 7 and 8 (Figure 18). Site 4 has a large cottonwood gallery that extends far out from the stream. This area floods often and water flows into channels that run through the trees and riparian vegetation. Site 7 is near a set of springs and has a healthy riparian area.

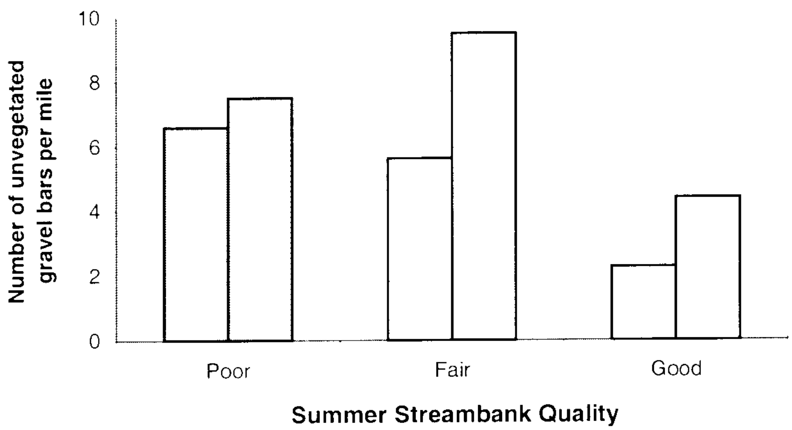



Figure 16. Unvegetated gravel bars and associated with steelhead summer habitat quality from Habrate.


Figure 17. Cottonwood acres associated with age-1 steelhead habitat quality from Habrate.

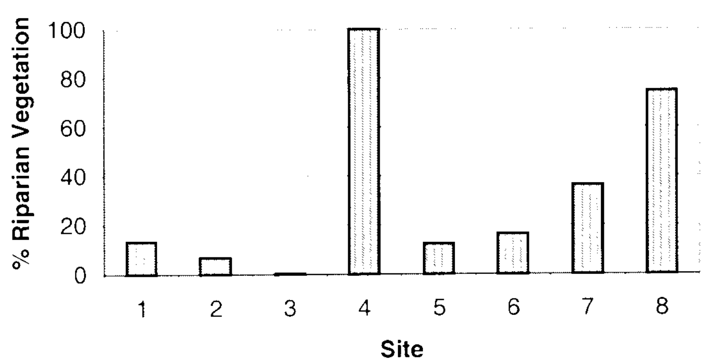



Figure 18. Percentage of transect that had riparian vegetation within the first 100ft from Squaw Creek (site 1-7) and Indian Ford Creek (site 8).

Fish Populations

The fish assemblage was dominated by redband trout at all sites (Figure 20). Brown trout were not found at sites 1 and 3 during snorkel counts. Brook trout made up over 20 percent of the fish observed during snorkel counts at site 4. Comparing the two methods of fish sampling, we found more species with electrofishing (Figure 20). Sculpin in site 1 and longnose dace in site 4 and 6 were more numerous in the electrofishing sample.

The largest redband trout were most numberous at site 4, where fish over 200mm long (approximately 8 inches) comprised 20% of the fish caught electrofishing. Site 3 had the lowest proportion (8%) of young redband under 100mm (4 inches), which may reflect poor reproduction in that area. Snorkeling and electrofishing found similar proportions of fish by size class except for large fish, where snorkeling tended to over estimate the contribution of large redband trout (>200mm) by a factor of two or three.

Changes in the abundance of redband trout observed snorkeling could be related to the reduced effectiveness of snorkeling at high flows. Densities increased from July to September in sites 1, 4 and 6 (Figure 21). In all sites but site 7, counts of fish declined from April to July. July had the highest flow of any snorkel counts. An increase in redband at site 7 in July may be related to fish moving into the area for spawning during May and June. Low water in September may have concentrated fish in pools where snorkeling is most effective. Snorkel counts are displayed as fish per length of stream to reduce the effect of decreasing stream width on the density estimate.

Electrofishing densities based on total fish caught were near 5 to 7 redband trout per 100 $m^2$ (4.6 to 6.4 fish/1000$ft^2$) for sites 3 and 4 in September and site 6 in October (Figure 22). Higher densities of redband trout, up to 35 fish/100$m^2$ (32 fish/1000$ft^2$) were sampled at site 6 in September. This high density may have been exaggerated by low flow concentrating fish in pools combined with the fact that only pools were sampled at that time. Also, one backpack shocker was used in September where two were used in all other samples.

Few comparisons between snorkeling and electrofishing could be made due to the limitations of high water during most of the summer. When a large area of stream was sampled, the difference between fish caught electrofishing and fish observed snorkeling was near a 1:1 ratio. When low numbers of fish were found, ratios were more variable (Figure 23). Mullner et al. (1998) found that snorkel counts could be calibrated with electrofishing depletion estimates for small Wyoming streams. Although depletion estimates were not made for Squaw Creek because certain assumptions of the technique were not met, calibrations could be made in the future if more data were collected.

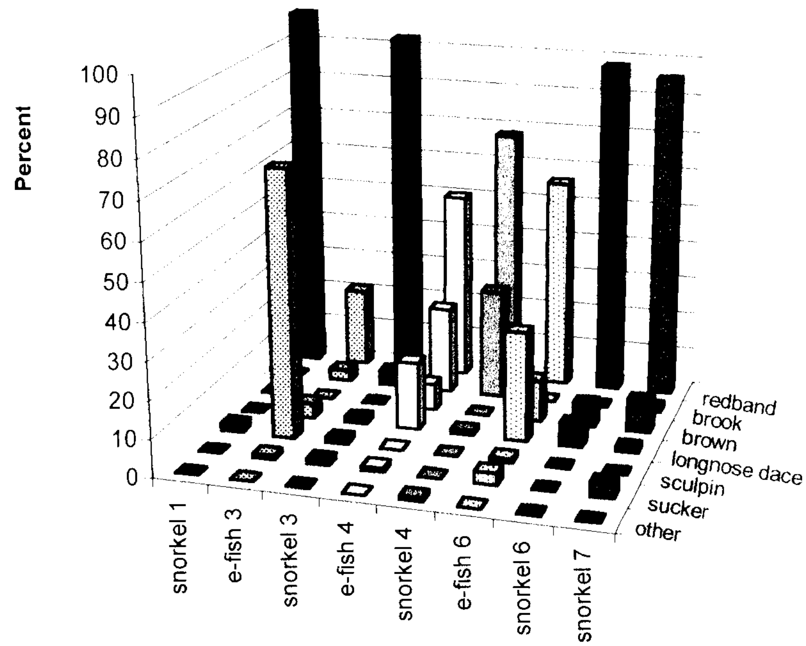



**Figure 20. Composition of fish observed snorkeling (dark shading) compared to electrofishing samples (light shading) on Squaw Creek in 1999.**

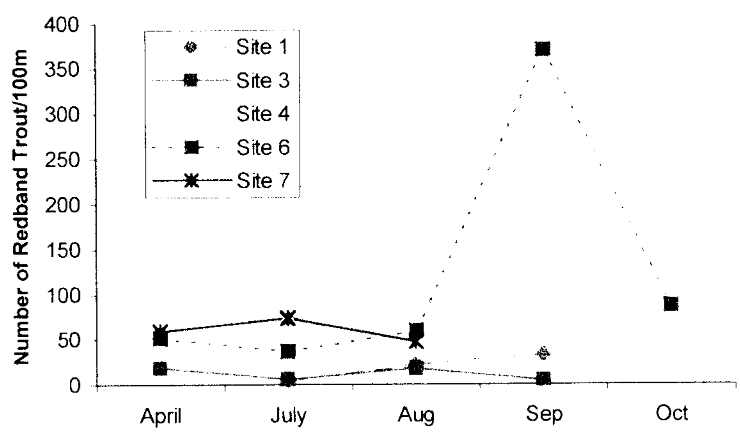



**Figure 21. Number of redband trout observed while snorkeling per 100meters (1076 feet) of Squaw Creek.**

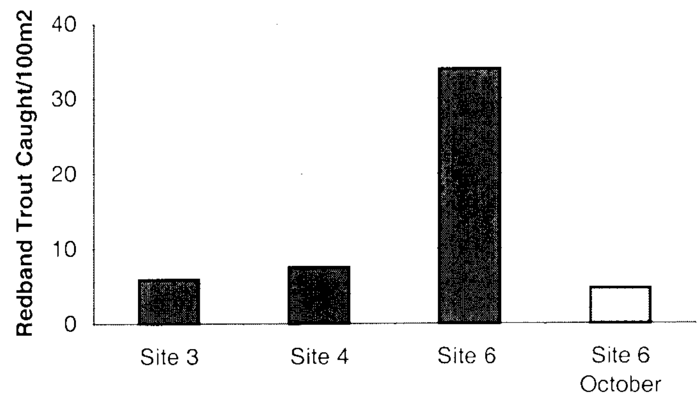



Figure 22. Density of redband trout caught while electrofishing in sites 3, 4 and 6 on Squaw Creek.

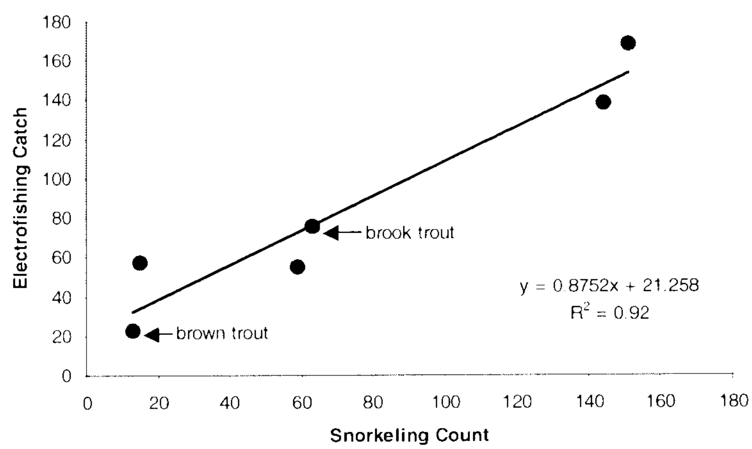



Figure 23. Comparision of number of redband trout, brook trout and brown trout caught while electrofishing and observed while snorkeling. Unlabeled data points are of redband trout.

## Conclusions and Recommendations

As Squaw Creek flows downstream out of the wilderness, water quality is high. Water temperature at **site 1** is cold due to its sources in the mountain snow and cold water springs such as Pole Creek. This cool temperature may limit the diversity of macroinverebrates and fish. Flows supplied by snowmelt remain high into August, buffering the effect of the August sun. Shade from forest vegetation helps to maintain the cool water temperature and high dissolved oxygen.

As water is removed for irrigation downstream, the wetted channel becomes shallow. Shallow water in **site 2** is more exposed to the air and sun, warming the water as it flows to Sisters. Stream banks become less stable because of the reduced riparian vegetation.

The confinement of the floodplain increases in Sisters at **site 3** and instability increases. Bridges and development have squeezed the stream, causing deposition and channel instability immediately downstream. Water depth is shallow due to low flows, making much of the stream too shallow for trout. Water temperatures in Sisters can exceed that suitable for trout in some years.

Below site 3, Indian Ford Creek's nutrient rich, warm water combines with the spring water of the Camp Polk area. At the Camp Polk **site 4**, a healthy riparian floodplain functions to spread floodwaters. The macroinvertebrate community is diverse and abundant, possibly benefiting from stable spring flow, the moderate temperatures and organic matter inputs from the riparian vegetation and Indian Ford Creek. Trout are drawn to the spring water, the moderated temperatures and abundant invertebrates. **Site 5** below Camp Polk Road has similar water quality and productivity but fish habitat is limited because of the narrow, confined channel left after channelization.

The Crooked River National Grassland **site 6** has stable flow and good habitat but is limited by low flow, high water temperatures and low dissolved oxygen. Flow, temperature and oxygen are recovered by coldwater inputs from Alder Springs at **site 7**. Diversity of macroinvertebrates and fish are high. Connectivity to the Deschutes River and the increase in water quality allows bull trout to move from the Deschutes River into Squaw Creek to rear.

The above description of conditions is based on the results of this and past monitoring efforts. Our measurements indicate that we need to work to improve the water quality, stream bank stability and fish habitat in Squaw Creek. Even during high water years, Squaw Creek does not meet state water quality standards for temperature during trout spawning/incubation or rearing seasons. There is a strong correlation between the low summer stream flow and the water temperature. Our estimate of 27 cfs should be considered a low estimate for flow restoration because of the data used from the high water year of 1999. Using a stream temperature model, Houslet (1998) estimated that nearly 40 cfs would be needed in Sisters to maintain favorable August water temperatures in Squaw Creek.

Two periods of water temperature violations were found, one in April/May when natural flow is low and irrigation begins, and the other in August. Low flows and high temperatures in April were thought to be the cause of a fish kill in the area of Sisters in 1990 (Riehle 1990). The April high temperatures could possibly be avoided by timing early season withdrawals to avoid the brief natural low-flow periods.

More flow is needed to increase the average water depth than is needed to maintain favorable water temperature. Sufficient water depth is needed for fish to use stream bank cover. Lower flows leave the channel dry along the stream bank, reducing riparian vegetation. Added flow will support riparian vegetation, leading in time to more stable stream banks. More measurements are needed to pinpoint what flow is needed for the best depth and fish habitat quality.

For the years we studied, dissolved oxygen was mostly above the ODEQ standards, other than site 3 and 4 in springtime and site 6 in August. *E. coli* bacteria counts from Squaw Creek met standards for contact recreation, although Indian Ford Creek is a source of bacteria to Squaw Creek. The pH measures showed no signs of major algae blooms. However, these results could be affected by the high water during 1999.

Riparian vegetation was more abundant along stream banks that are connected to low floodplains, which allows floods to spread and reduce the stress on stream banks. Fish habitat quality was linked to more stable, vegetated stream banks. Development has already reduced the ability of the stream to spread floodwaters in many reaches and stream banks have eroded as a result. Therefore, floodplain planning and management is of great importance to reduce erosion and maintain fish habitat.

Redband trout are found throughout the stream, both above and below the diversions. With more work, a better relationship could be drawn between snorkeling and electrofishing that would allow monitoring of fish populations by snorkeling. For the first time, fish have been documented in Squaw Creek in the town of Sisters in a reach which was previously dry during the summer. The 2 cfs secured for instream flow helped sustain redband trout in Sisters through the entire year-- the first step to the recovery of aquatic connectivity in Squaw Creek. The Sisters site had a low percentage of young and adult fish compared to the other sites with more reliable flows, suggesting that there is more flow restoration needed to sustain a fishery.

Recommendations for restoration opportunities include (see Appendix A for locations): 1) secure summer instream flow to meet state water temperature and dissolved oxygen standards throughout the stream, 2) secure instream flow to maintain trout habitat requirements throughout the stream, 3) prevent floodplain encroachment to allow floodwaters to spread, 4) sustain summer flow to support riparian vegetation, especially from the main diversion to Camp Polk Rd, 5) reconnect flood plain channels to the stream where possible to allow flood water spreading to reduce bank erosion, 6) plant riparian vegetation along stream banks where adequate floodplain channels provide stable areas for planting, 7) coordinate early season water withdrawals to avoid the low flow periods in the springtime to protect redband spawning habitat.

Recommendations for future monitoring include: 1) Continue stream temperature and fish population monitoring to follow the results of restoration efforts and confirm the results of this study during normal water years, 2) assess the required flow to support fish habitat and, 3) gage stream flow at the Sisters city park, 4) provide better floodplain delineation for floodplain management.

The Squaw Creek Education and Restoration Project began as a way to involve local students in watershed assessment and restoration. The project grew and came to be more than an outdoor classroom. The monitoring conducted has provided useful information that has increased our understanding beyond that of the 1998 USFS Watershed Analysis. The insights gained can be used to guide future restoration projects. This monitoring can also serve to measure the benefits from the restoration projects already implemented.

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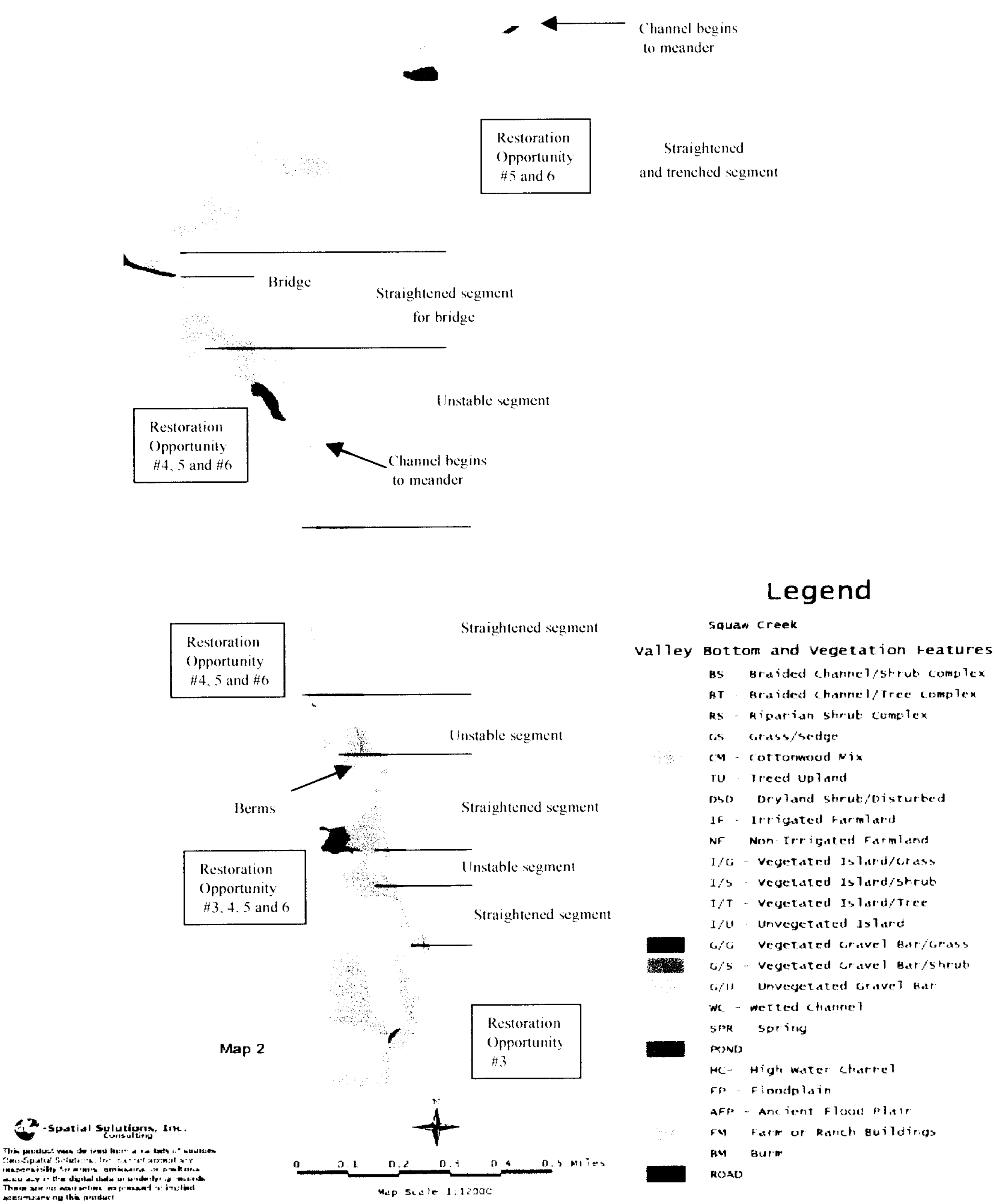
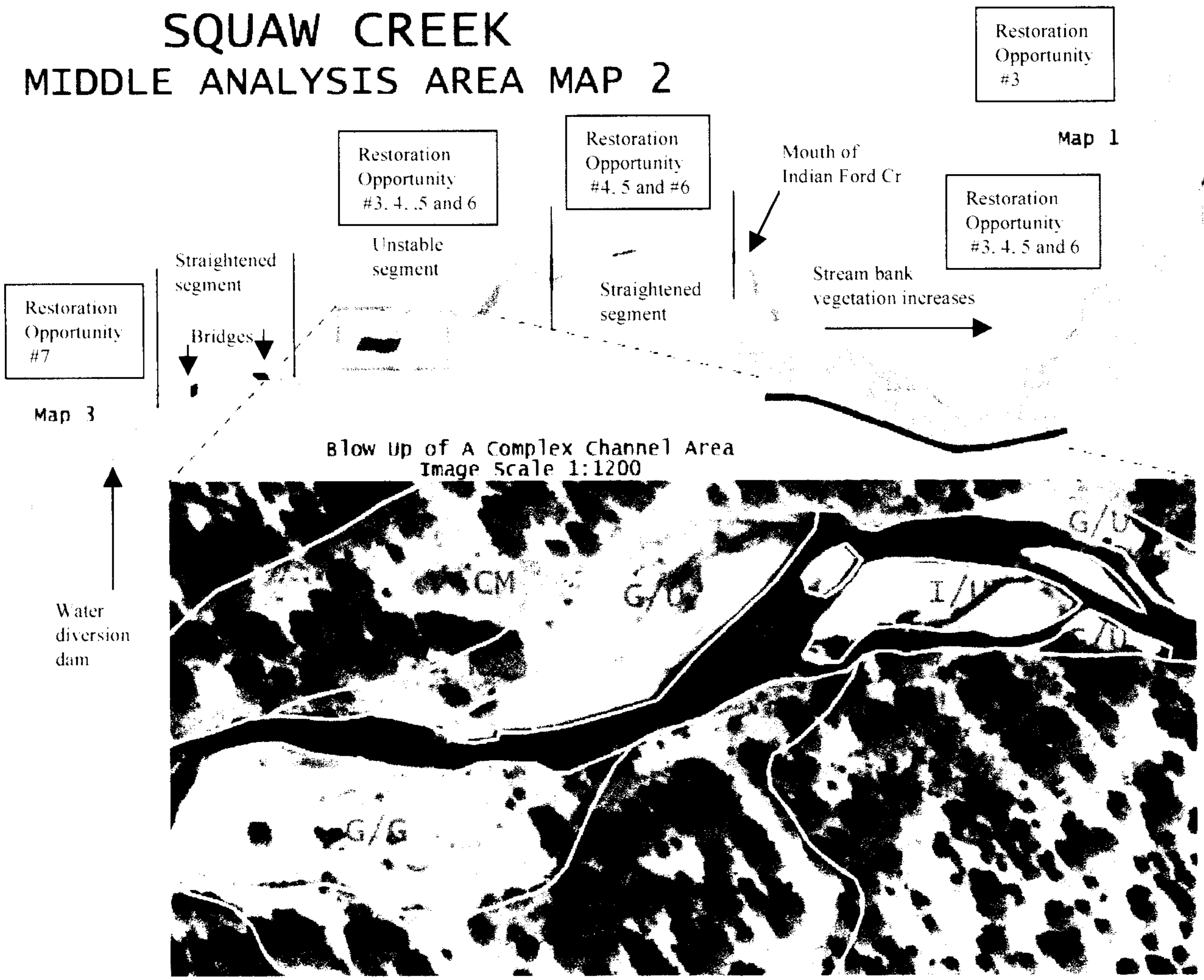
# Appendix A- Habitat Mapping

# SQUAW CREEK
## MIDDLE ANALYSIS AREA MAP 1



# SQUAW CREEK
## MIDDLE ANALYSIS AREA MAP 2




## Legend

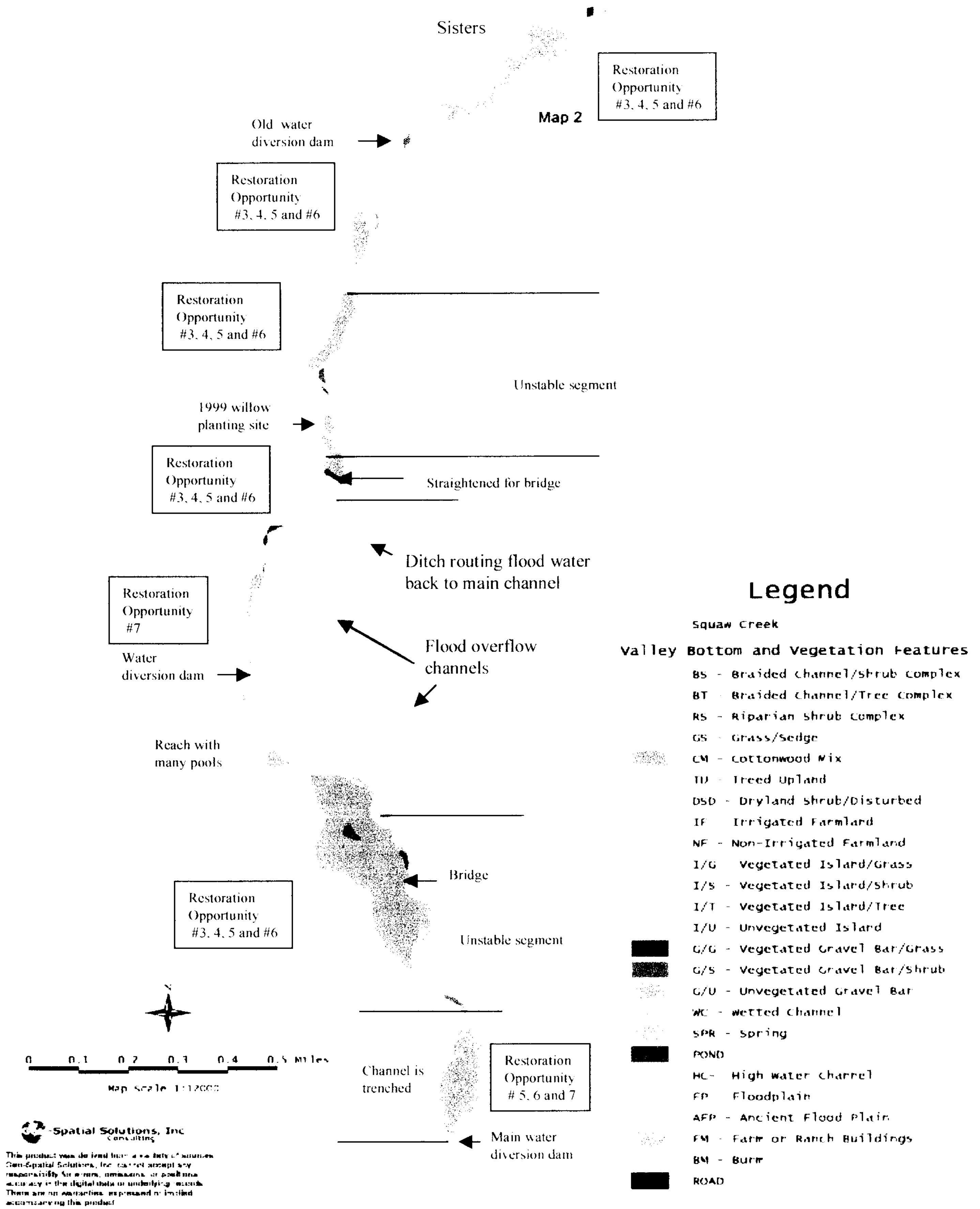
Squaw Creek

Valley Bottom and Vegetation Featur

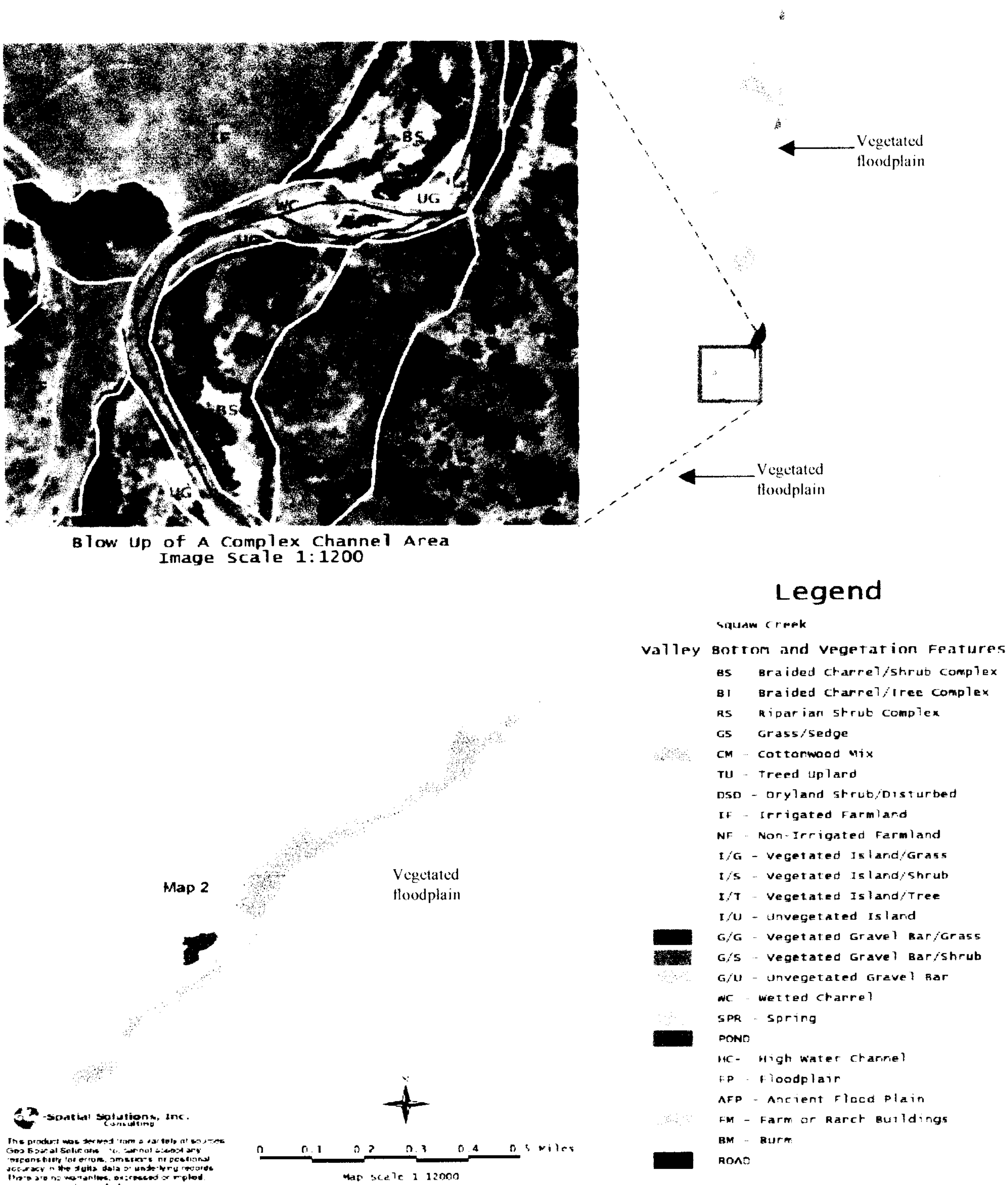
- BS - Braided Channel/Shrub Comple
- BT - Braided Channel/Tree Complex
- RS - Riparian Shrub Complex
- GS - Grass/Sedge
- CM - Cottonwood Mix
- TU - Treed Upland
- DSD - Dryland Shrub/Disturbed
- IF - Irrigated Farmland
- NF - Non-Irrigated Farmland
- I/G Vegetated Island/Grass
- I/S Vegetated Island/Shrub
- I/T Vegetated Island/Tree
- I/U Unvegetated Island
- G/G - Vegetated Gravel Bar/Grass
- G/S Vegetated Gravel Bar/Shrub
- G/U Unvegetated Gravel Bar
- WC - Wetted Channel
- SPR - Spring
- POND
- HC- High water Channel
- FP - Floodplain
- AFP - Ancient Flood Plain
- FM Farm or Ranch Buildings
- BM Burm
- ROAD

Spatial Solutions, Inc. Consulting

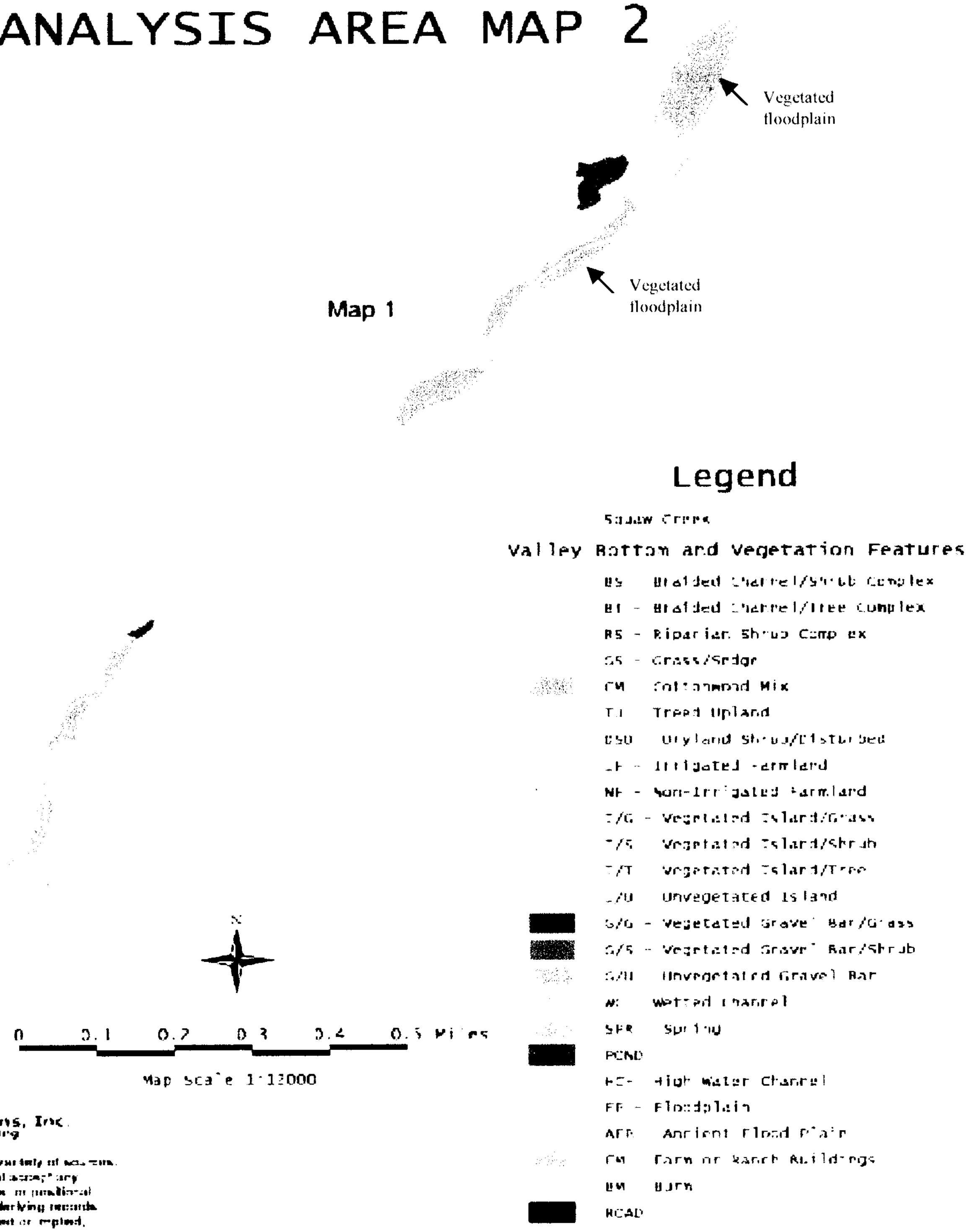
# SQUAW CREEK
## MIDDLE ANALYSIS AREA MAP 3



# SQUAW CREEK
## LOWER ANALYSIS AREA MAP 1



# SQUAW CREEK
## LOWER ANALYSIS AREA MAP 2




Geo-Spatial Solutions, Inc. Consulting

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# Appendix B

# Squaw Creek Monitoring

# Thermal Infrared Monitoring and Color Videography

# Watershed Science, Inc. Report

# Aerial Surveys in the Upper Deschutes River Basin
## Thermal Infrared and Color Videography

July 28, 2000

Report to:

Upper Deschutes Watershed Council
P.O. Box 1812
Bend, OR 97709-1812

By:

Watershed Sciences
712 NW 4th Street
Corvallis, OR 97330

# Table of Contents

## Introduction

Forward Looking Infrared (FLIR) has been demonstrated as a reliable, cost-effective, and accessible technology for monitoring and evaluating stream temperatures from the scale of watersheds to individual habitats (Karalus et al., 1996; Norton et al., Faux et al., 1998). In 2000, the Upper Deschutes Watershed Council contracted with Watershed Sciences, LLC (WS, LLC) to map and assess stream temperatures in Squaw Creek, Indian Ford Creek, and a short segment of the Deschutes River.

Traditional methods for monitoring stream temperatures have relied on in-stream temperature monitors. These monitors provide temporally continuous data, but furnish no insight into the spatial variability in temperatures. Remote sensing using FLIR offers a method to map stream temperatures across entire stream networks at the time of the survey. FLIR technology has proven to be a highly portable and cost-effective method to collect very detailed data over large areas in very little time. The combination of temporally and spatially continuous data provides very powerful tools for understanding the dynamics of stream temperature hierarchically across multiple scales (pools → reaches → streams → watersheds). Current research has identified cool versus warm streams within a watershed, cool reaches within a stream, and cool habitats within a reach (McIntosh et al., 1995; Torgerson et al., 1995; Torgerson et al., 1999).

The results and analysis presented here are at the watershed and tributary scales. This report provides longitudinal temperature profiles for each stream surveyed as well as a discussion of the thermal features observed in basin. FLIR and associated color video images are included in the report in order to illustrate significant thermal features. An ArcView GIS[1] database provided with this report includes all of the images collected during the survey and is structured to allow analysis at finer scales.

## Methods

### *Data Collection*

The Upper Deschutes Watershed Council contracted with Watershed Sciences, LLC of Corvallis, Oregon to collect and analyze thermal infrared and visible video imagery in the Upper Deschutes River Basin during the summer of 2000. Figure 1 illustrates the extent of the survey and Table 1 summarizes the time and distance for each survey stream. Squaw Creek along with Indian Ford Creek and a segment of the Deschutes River were surveyed on July 28, 2000. Data collection was timed to capture maximum daily stream temperatures, which typically occur between 2:00 PM and 5:00 PM.

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[1] Geographic Information System

Table 1. Time and distance for the Upper Deschutes River Surveys on 7/28/00

| Stream | Time | Distance (miles) |
|---|---|---|
| Deschutes River | 3:57 – 4:04 PM | 6.2 |
| Squaw Creek | 4:06 – 5:00 PM | 36.2 |
| Indian Ford Creek | 2:08 – 2:43 PM | 14.1 |
| Total Miles | | 56.5 |

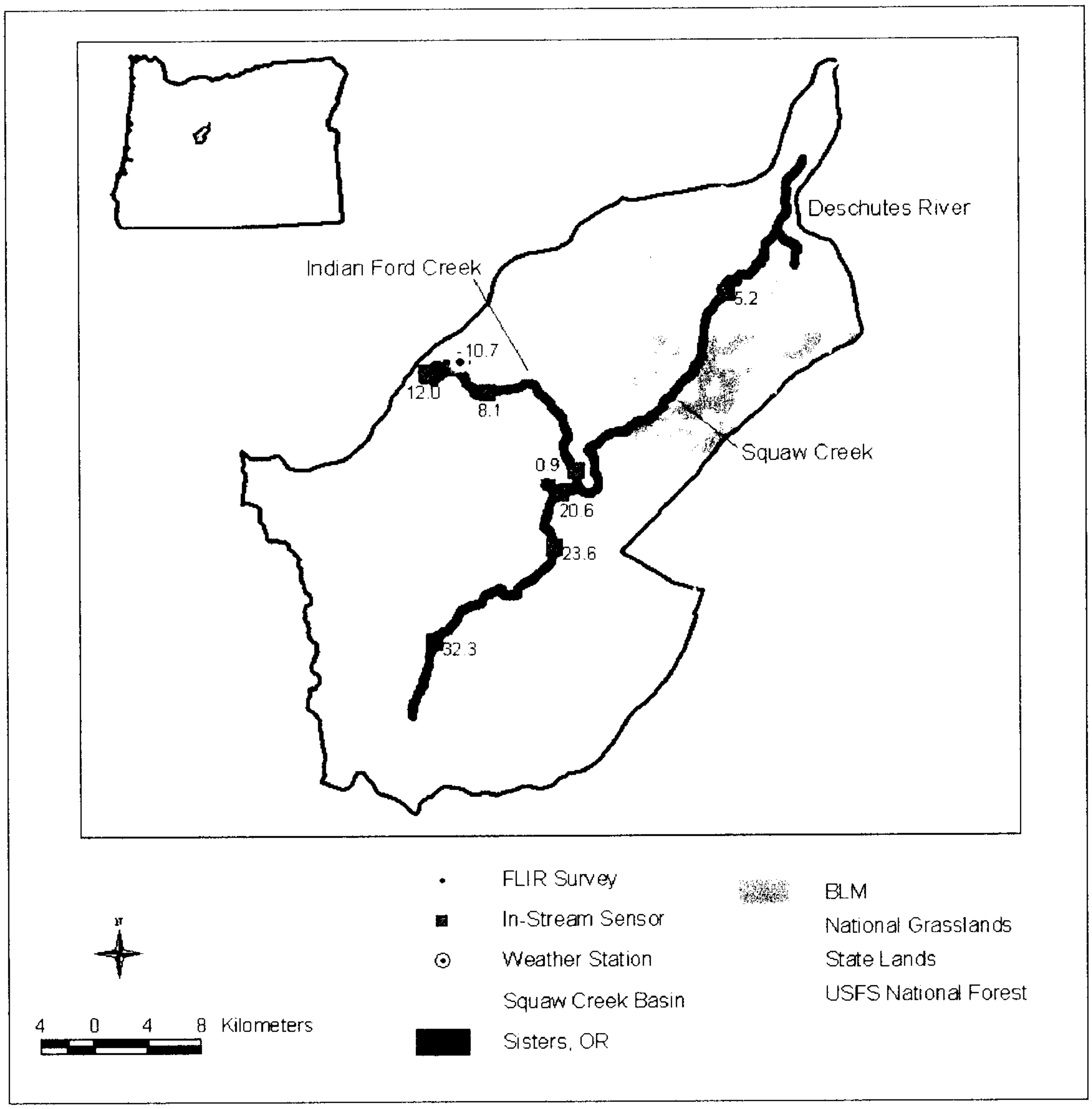


Figure 1 – Map of the Upper Deschutes Basin and streams surveyed with FLIR and visible band color video on 28 July 2000. The map also shows river miles associated with in-stream sensors.

Data were collected using a FLIR and a Day TV video camera co-located in a gyro-stabilized mount that attached to the underside of a helicopter. The helicopter was flown longitudinally over the center of the stream channel with the sensors in a vertical (or near vertical) position. All streams were surveyed upstream and flight altitude was selected based on the estimated average stream channel width. In general, the flight altitude was selected so that the stream channel occupied approximately 20% of the image frame. Squaw Creek and the Deschutes River were flown at an average altitude of 1400 ft (420 meters) above ground level. Indian Ford was surveyed at an average altitude of 800 ft (250 meters).

FLIR data were collected digitally and recorded directly from the sensor to an on-board computer. The FLIR detects emitted radiation at wavelengths from 8-12 microns and records the level of emitted radiation in the form of an image. Each image pixel contains a measured value that can be directly converted to a temperature. The raw FLIR images represent the full 12 bit dynamic range of the instrument and were tagged with time and position data provided by a Global Positioning System (GPS). Each thermal image frame covers a ground area of approximately 100 x 150 meters and has a spatial resolution of < 0.5 meters/pixel. For all other streams each thermal image covers a ground area of approximately 100 x 150 meters and has a spatial resolution of about 0.25 meters/pixel.

Day TV images were recorded to an on-board digital videocassette recorder at a rate of 30 frames/second. GPS time and position were encoded on the recorded video. The Day TV sensor was aligned to present the same ground area as the thermal infrared sensor. The GPS time coding provides a means to correlate Day TV images with the FLIR images during post-processing.

Eight in-stream temperature data loggers (Onset Stowaways) were distributed in the basin during the survey to ground truth (i.e. verify the accuracy) the radiant temperatures measured by the FLIR. The data loggers also provide a temporal context for interpreting the FLIR imagery. The ground truth locations are shown in Figure 1. The in-stream data loggers were removed after the flight and the temperature information downloaded to a computer.

Meteorological conditions were recorded using a Hobo Pro Temperature/Relative Humidity data logger. The data logger was located in Black Butte Meadow, which was the approximate midpoint of the survey. The data logger was deployed on July 19, 2000 and retrieved on July 30, 2000. Table 2 summarizes the conditions for the time of the survey and Figure 2 shows the measured air temperatures centered on July 28, 2000. A maximum air temperature of 28.3 °C (82.7°F) occurred at 2:55 PM.

Table 2. Meteorological Conditions for 28 July 2000 recorded at the weather station located in Black Butte Meadow, OR.

| Time | Average Temperature | Average Relative Humidity | Sky Conditions | Winds |
|---|---|---|---|---|
| 2:07 – 2:55 | 27.7 °C (81.9°F) | 38% | Clear | Variable |
| 4:00 – 5:00 | 27.2 °C (81.0°F) | 40% | Clear | Variable |

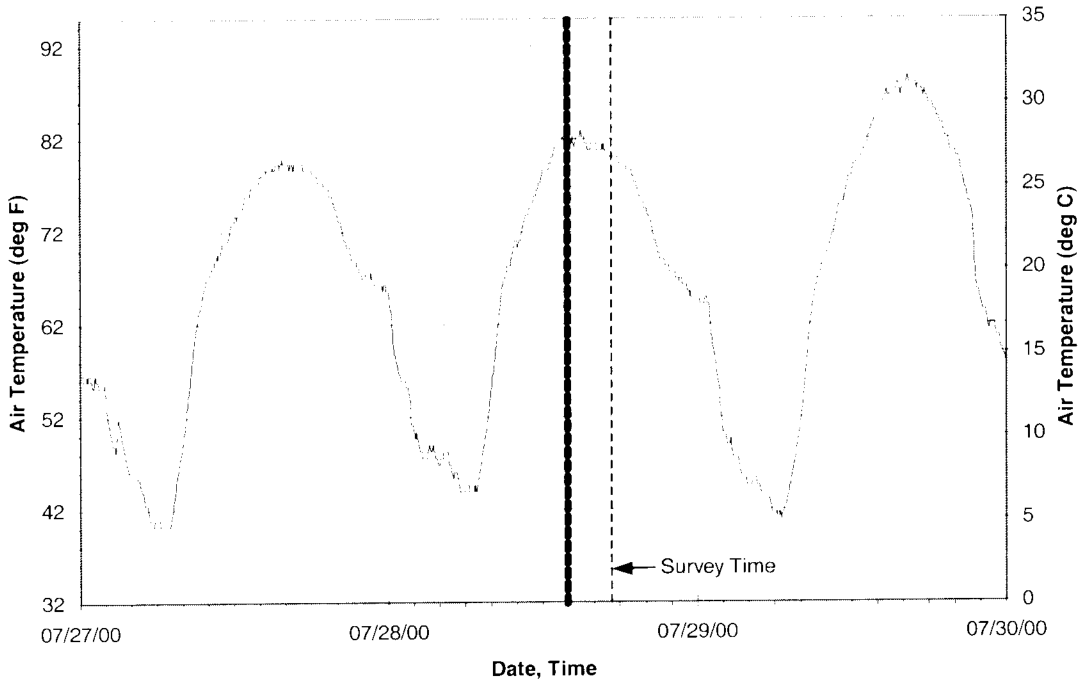


Figure 2 – Air temperature versus time in the study area for a 3-day span centered on the day of the FLIR survey.

## *Data Processing*

A computer program was used to scan the FLIR imagery and create an ArcView GIS point coverage containing the image name, time, and location it was acquired. The coverage provided the basis for assessing the extent of the survey and for integrating with other spatially explicit data layers in the GIS. This allowed WS, LLC to identify the images associated with the ground truth locations. The data collection software was used to extract temperature values from these images at the location of the in-stream recorder. The radiant temperatures were then compared to the kinetic temperatures from the in-stream data loggers.

The image points were associated with a river kilometer using the dynamic segmentation features of Arc/Info GIS software. The river kilometers were derived from 1:100K "routed" stream covers from the Environmental Protection Agency (EPA). The route measures provide a spatial context for developing longitudinal temperature profiles of stream temperature.

In the laboratory, a computer algorithm was used to convert the raw thermal images (radiance values) to ARC/INFO GRIDS where each GRID cell contained a temperature value. A GIS program used to display the GRID associated with an image location selected in the point coverage. The GRID was color-coded to visually enhance temperature differences, enabling the user to extract temperature data. The GRIDS were classified in one-degree increments over the temperature range of 5 to 30°C. Temperatures < 5°C are black, temperatures between 30 and 50°C were colored in shades of gray (darker tones -> lighter tones), temperatures > 50°C are white.

Figure 3 illustrates a color coded GRID displayed in the ArcView environment. This GRID illustrates the confluence of Squaw Creek and the Deschutes River. The legend on the left of the "Grid View" specifies the temperature range associated with each color. The other view window shows the point coverage with the displayed GRID location highlighted in yellow. Each green point in the "Thermal Survey" view represents another image location.

Figure 4 illustrates the temperature GRID displayed in Figure 3 with its corresponding day TV image. Prominent thermal features are identified in each image. The Deschutes River and Squaw Creek are clearly visible in the image due to the high thermal contrast with the warmer terrain features. This is the standard format currently used to interpret and analyze the thermal image data.

Once in the GRID format, the images were analyzed to derive the minimum, maximum, and median stream temperatures. To derive these measures, an ArcView program was used to sample the GRID cell (temperature) values in the stream channel. Ten sample points were taken longitudinally in the center of the stream channel. Samples were taken on every 5$^{th}$ image to provide complete coverage without sampling the same water twice (there is approximately 40-60% overlap between images). Where there were multiple channels, only the main channel (as determined by width and continuity) was sampled. In cases where the channel was obscured by vegetation, as was the situation on many of the tributaries, the next image where the stream channel was clearly visible was sampled. For each sampled image, the sample minimum, maximum, median, and standard deviation was recorded directly to the point coverage attribute file.

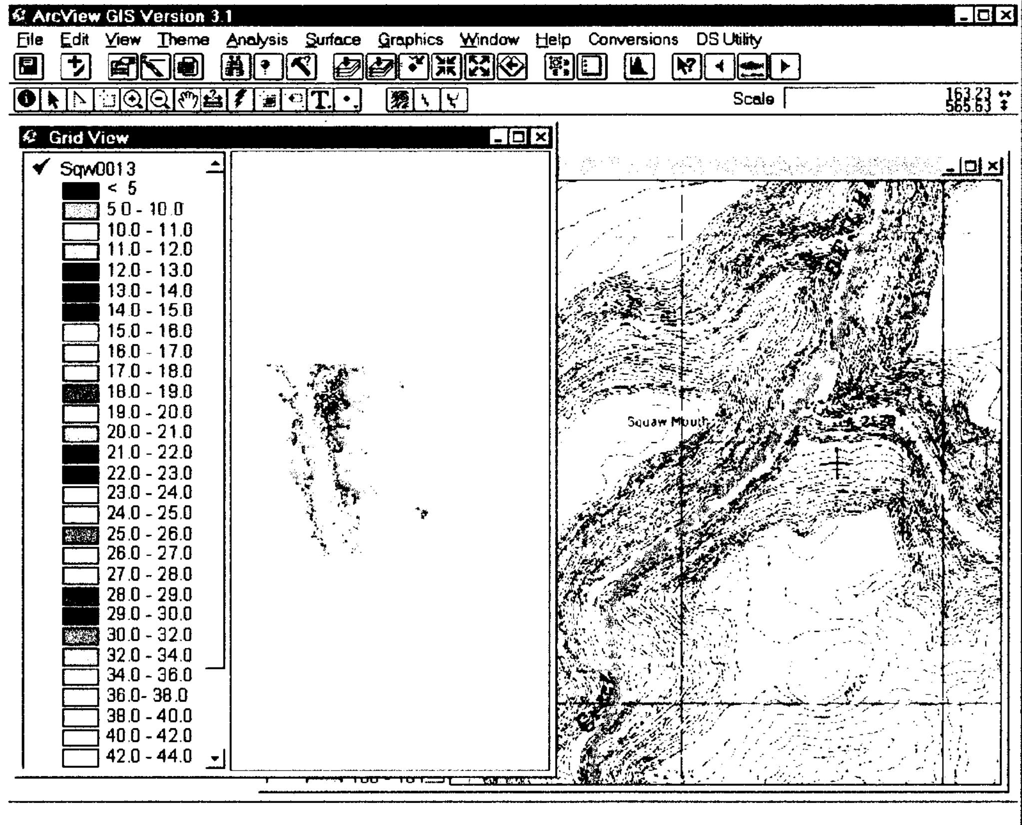


Figure 3 – ArcView display showing a color-coded temperature GRID in one window and the geographic location of the GRID in the other. The orientation of the image is always in the flight direction.

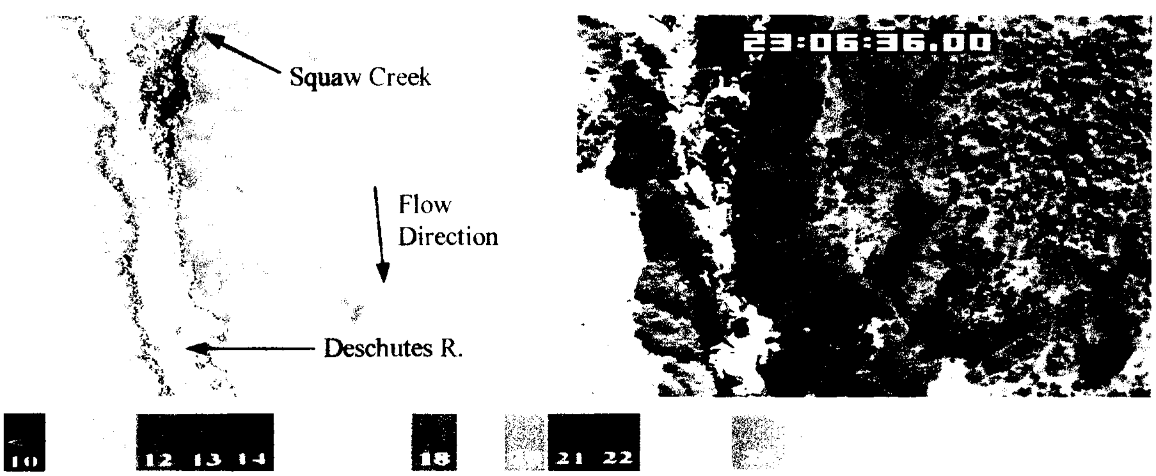


Figure 4 – Temperature Grid (left) and Corresponding Day TV image (right) showing the confluence of Squaw Creek and the Deschutes River. The temperature scale used for the FLIR image is shown at the base of the imagery.

The temperature of tributaries and other detectable surface inflows were also sampled from images. These inflows were sampled at their mouth using the same techniques described for sampling the main channel. If possible, the surface inflows were identified on the USGS 24K base maps. The inflow name and median temperature were then entered into the point coverage attribute file.

Day TV images corresponding to the FLIR images were extracted from the database using a computer-based frame grabber. The images were captured to correspond to the thermal infrared images and provide a complete coverage of the stream. The video images were "linked" to the corresponding thermal image frame in the ArcView GIS environment.

### *Data Limitations*

FLIR systems measure thermal infrared energy emitted at the water surface. Since water is essentially opaque to thermal infrared wavelengths, the sensor is only measuring the water surface temperature. This is typically not an issue on streams where the water column is thoroughly mixed. Field measurements conducted on the Middle Fork of the John Day River, OR and on the Klamath River, CA confirmed that thermal stratification was insignificant or not present even in the deepest pools. However, stratification has been observed behind impoundments and in deep slow moving channels.

Thermal stratification is usually detectable on the FLIR images and there was no apparent stratification on the Deschutes River or Squaw Creek. However, some of the ponds located along Indian Ford Creek showed some distinctive signs of stratification.

Obtaining accurate temperatures from the FLIR images depends on having enough pixels "in the water". Indian Ford Creek is extremely narrow in some locations making accurate temperature readings difficult. The analysis identifies areas where WS, LLC could not make accurate measurements or where confidence in the measurements is low.

## Results

### *Thermal Accuracy*

Temperatures from in-stream data loggers were compared to radiant temperatures derived from the imagery for the Upper Deschutes River basin (Table 3). The data were assessed at the time the image was acquired. The radiant values represent the median of 10 points sampled from the image at the data logger location. Radiant temperatures from thermal imagery of the Squaw Creek were within ±0.6°C of in-stream temperatures recorded by data loggers. There were no data loggers in the surveyed portion of the Deschutes River. However, the thermal accuracy assessment of Squaw Creek is considered applicable to the Deschutes River due to proximity in time and distance. These results are consistent with average accuracy of ±0.4°C recorded during FLIR surveys throughout Oregon since 1994.

Figure 4 shows the change in temperature that occurred at these locations during the course of the survey. Because the FLIR survey is a snapshot of the stream temperature profile, Figure 4 provides a context for comparing temperature recorded at the beginning and end of the flight. In addition, the figure illustrates the time at which the survey was conducted in relation to diurnal temperature patterns. Survey timing on 28 July 2000 was slightly before daily maximum water temperature in Squaw Creek, which generally occurred between 5:30-6:00 PM. The largest temperature change during the flight (0.65°C) was recorded at the town of Sisters (rm 20.6).

Table 3. Comparison of ground-truth water temperatures with radiant temperatures derived from thermal infrared images, 28 July 2000. Temperatures are reported in °C *(°F)* and river mile (rm) measures are cited for locations.

| **Location** | **Image frame** | **Time PM** | **Stream Temp. ($T_s$)** | **Radiant Temp. ($T_r$)** | **Difference ($T_r - T_s$)** | **$\Delta T_s$ during survey** |
|---|---|---|---|---|---|---|
| *Squaw Creek* | | | | | | |
| Rd 6360 (rm 5.2) | sqw0223 | 4:13 | 26.4 *(79.5)* | 26.9 *(80.4)* | -0.5 *(-0.9)* | 0.35 |
| Sisters (rm 20.6) | sqw0905 | 4:37 | 20.5 *(68.9)* | 20.5 *(68.9)* | 0.0 *(0.0)* | 0.65 |
| Squaw Cr. Canal (rm 23.6) | sqw1057 | 4:43 | 14.4 *(57.9)* | 14.2 *(57.6)* | 0.2 *(0.3)* | 0.15 |
| FS Rd 1514 (rm 32.3) | sqw1408 | 4:54 | 13.2 *(55.8)* | 12.6 *(54.7)* | 0.6 *(1.1)* | 0.31 |
| *Indian Ford Creek* | | | | | | |
| Airport (rm 0.9) | if0128 | 2:09 | 20.8 *(69.4)* | 21.3 *(70.3)* | -0.5 *(-0.9)* | 1.20 |
| Route 20 (rm 8.1) | if0942 | 2:24 | 16.9 *(62.4)* | 15.8 *(60.4)* | 1.1 *(2.0)* | 0.21 |
| BB* Corral (rm 10.7) | if1284 | 2:31 | 19.1 *(66.4)* | 19.5 *(67.1)* | -0.4 *(0.7)* | 0.86 |
| Near Spring (rm 12.0) | if1464 | 2:34 | 6.5 *(43.7))* | 5.9 *(42.6)* | 0.6 *(1.1)* | 0.16 |

*BB = Black Butte

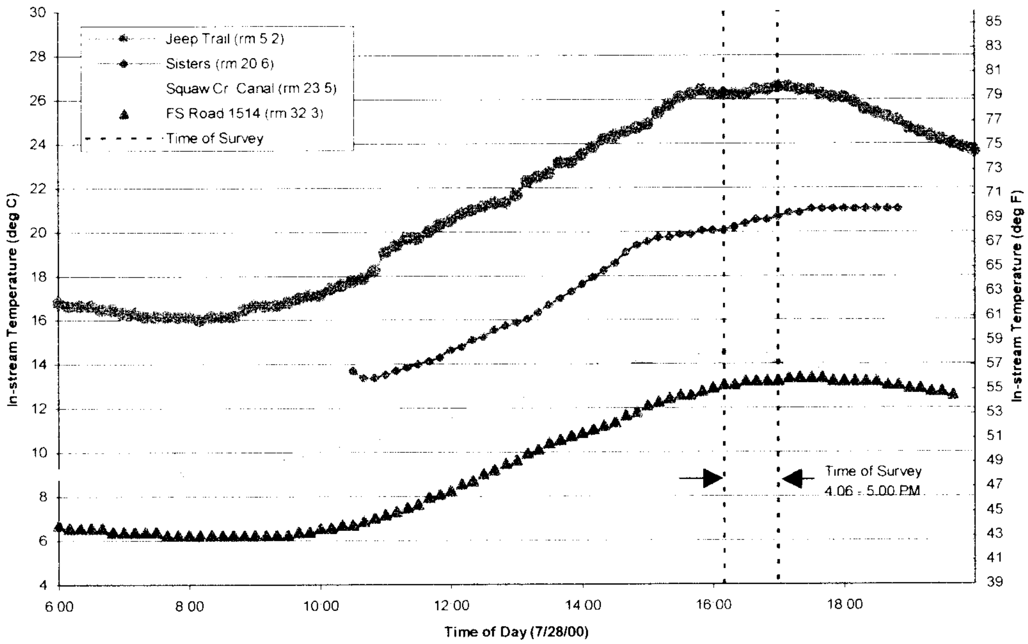


Figure 4 - Diurnal temperature curves from in-stream data loggers during thermal survey of Squaw Creek. Dashed vertical lines specify the timing and duration of the FLIR survey with respect to diurnal temperature fluctuations.

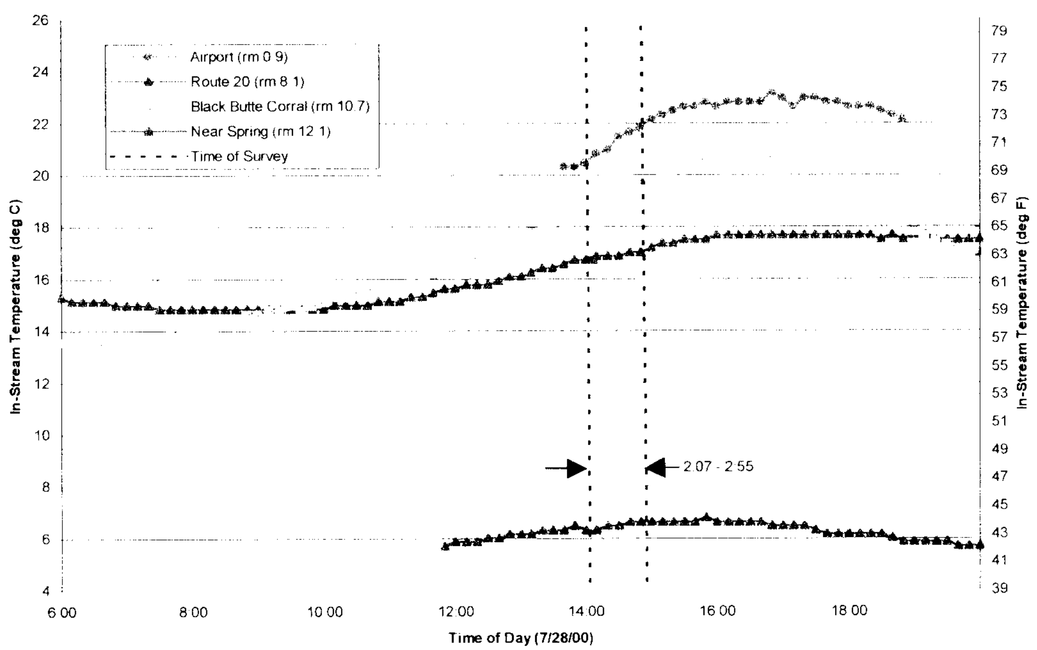


Figure 5 - Diurnal temperature curves from in-stream data loggers during thermal survey of Indian Ford Creek. Dashed vertical lines specify the timing and duration of the FLIR survey with respect to the diurnal temperature fluctuations.

### *Temperature Profiles*

## Deschutes River

The median temperature for each sample frame from the inflow to Lake Billy Chinook (rm 120) to approximately 2 ¼ miles upstream of the Squaw Creek confluence were plotted versus river mile (Figure 6). Figure 6 shows how temperature varied longitudinally along this reach and identifies the location and temperature of tributary and spring inflows.

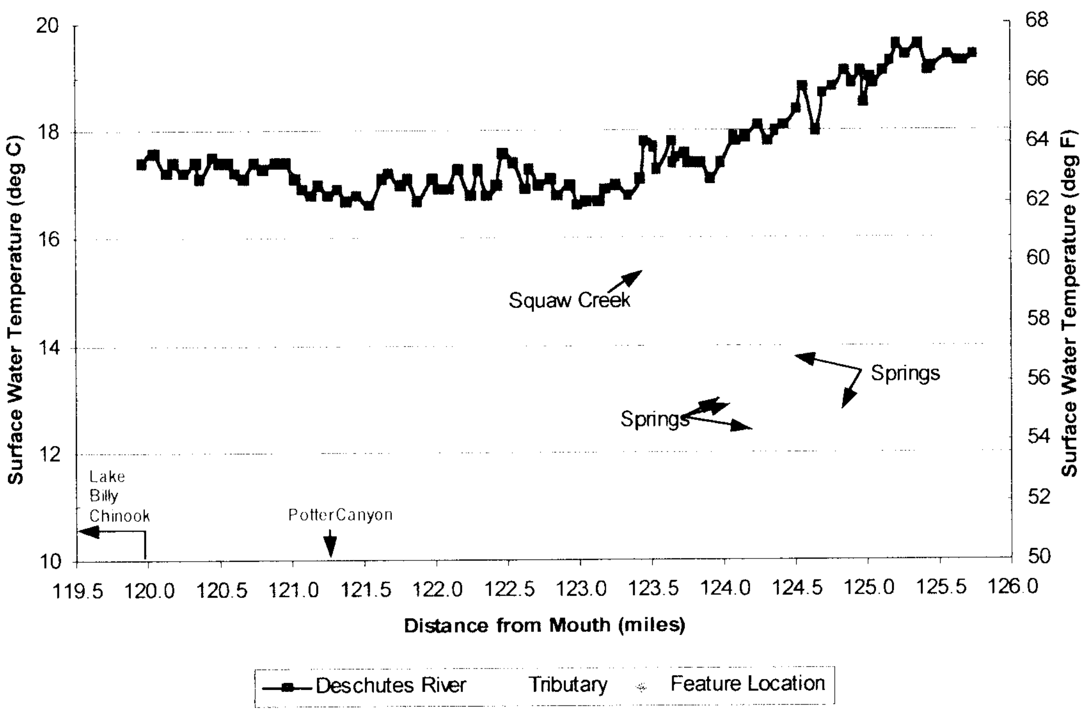


Figure 6 - Median stream temperature versus river mile for the Deschutes River. Tributaries and other surface inflows are identified.

Although only a short section of the Deschutes River was surveyed, the data showed some interesting results. A cooling trend of approximate 2°C was observed between rm 125.7 and rm 123.4. A series of 5 spring inflows were detected between river miles 124.0 and 125.0, which were not identified on the USGS 1:24k topographic maps (Figure 7). The springs along with Squaw Creek are sources of thermal cooling (15.5°C) to the Deschutes River (17.8°C).

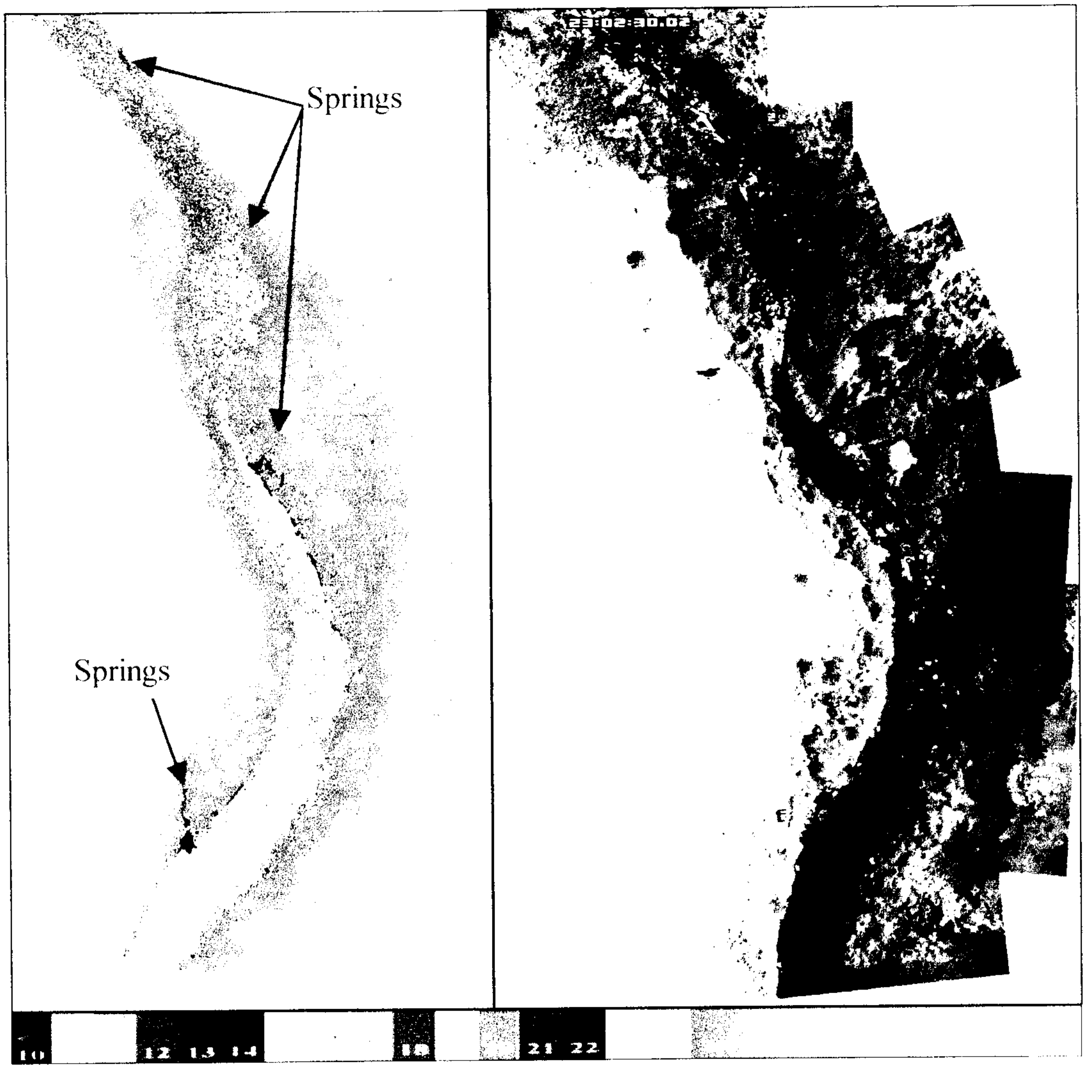


Figure 7 - FLIR/color video image (mosaic frames: des141 – des149) showing a series of spring inflows on the Deschutes River near river mile 124.0.

## Squaw Creek

A longitudinal temperature profile was developed for Squaw Creek from the mouth to the Squaw Creek falls, a distance of 36.1 miles (Figure 8). The plot also includes the temperature of tributaries and other surface inflows that were visible in the imagery. Tributaries are labeled in Figure 8 by river mile with their name and temperature listed in the associated table. Only surface inflows that could be positively identified in the imagery were included. In some cases, tributaries and other surface water inflows may be obscured by riparian vegetation or outside the sensor field of view. Figure 9 shows the longitudinal temperature profile mapped over a shaded relief map of the watershed. This map provides an additional spatial context for viewing and analyzing the data.

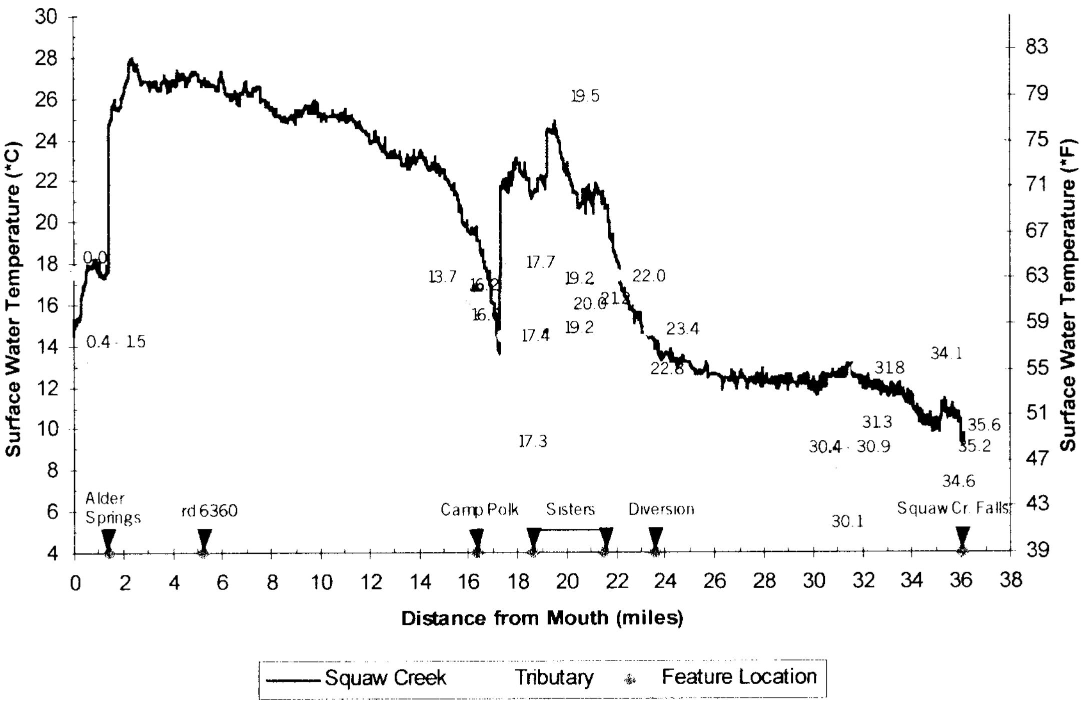


Figure 8 – Median stream temperature versus river mile for Squaw Creek. Tributaries and side channels are described in Table 4.

Stream temperatures in the headwater areas were comparable to groundwater temperatures (7-9°C). Eleven tributary and spring inflows were detected in the first 5.5 miles downstream of Squaw Creek falls. Nine of these inflows contributed flows ranging from –0.5°C to –6.5°C cooler then Squaw Creek. The North Fork Squaw Creek was the only tributary contributing significantly warmer flows (+2.7°C). While some fine-scale variability was observed, the longitudinal temperature profile showed no detectable change between river miles 30.0 and 26.3. There were also no surface inflows detected through this section.

Squaw Creek showed an almost exponential increase in stream temperatures over the next 4.8 river miles (rm 26.3 to rm 21.5). From river mile 26.3 to the Squaw Creek Canal diversion (rm 23.5), stream temperatures increase at a rate of 0.5°C/mile. At the Squaw Creek canal diversion (rm 23.5) the rate of longitudinal heating increased to 2.7°C/mile (*7.6°C over 2.8 river miles*) in the downstream direction before leveling off at river mile 21.5. Three surface water inputs were detected in this section including inflow from a side channel (rm 23.4), a spring (rm 22.8), and an unidentified tributary (rm 22.0). The three surface water inputs contributed cooler water and influenced local temperatures, but did not alter the longitudinal heating pattern.

Table 4 – Tributaries and other surface inflows identified during the FLIR survey of Squaw Creek (LB = left bank, RB = right bank looking upstream).

| Tributary | River Mile | Tributary Temp °C (*°F*) | Squaw Cr Temp °C (°F) | Difference °C (*°F*) (trib-mainstem) | FLIR Image |
|---|---|---|---|---|---|
| Deschutes River | 0.0 | 17.6 *(63.7)* | 14.8 *(58.6)* | 2.8 *(5.0)* | sqw0014 |
| Spring (RB) | 0.4 | 13.1 *(55.6)* | 16.9 *(62.4)* | -3.8 *(-6.8)* | sqw0030 |
| Spring (LB) | 0.5 | 13.4 *(56.1)* | 17.2 *(63.0)* | -3.8 *(-6.8)* | sqw0034 |
| Spring (RB) | 1.2 | 13.4 *(56.1)* | 17.4 *(63.3)* | -4.0 *(7.2)* | sqw0055 |
| Spring (RB) | 1.3 | 13.0 *(55.4)* | 17.3 *(63.1)* | -4.3 *(-7.7)* | sqw0058 |
| Alder Springs (LB) | 1.4 | 13.1 *(55.6)* | 17.6 *(63.7)* | -4.5 *(-8.1)* | sqw0063 |
| Alder Springs (RB) | 1.4 | 13.1 *(55.6)* | 24.1 *(75.4)* | -11.0 *(-19.8)* | sqw0065 |
| Spring (LB) | 1.5 | 13.7 *(56.7)* | 24.9 *(76.8)* | -11.2 *(-20.2)* | sqw0067 |
| Spring (RB) | 13.7 | 17.4 *(63.3)* | 22.7 *(72.9)* | -5.3 *(-9.5)* | sqw0586 |
| Spring (RB) | 16.0 | 16.1 *(61.0)* | 19.9 *(67.8)* | -3.8 *(-6.8)* | sqw0675 |
| Camp Polk Springs (RB) | 16.2 | 16.6 *(61.9)* | 19.4 *(66.9)* | -2.8 *(-5.0)* | sqw0687 |
| Spring (RB) | 16.4 | 16.6 *(61.9)* | 19.1 *(66.4)* | -2.5 *(-4.5)* | sqw0693 |
| Spring (RB) | 17.3 | 9.4 *(48.9)* | 21.7 *(71.1)* | -12.3 *(-22.1)* | sqw0768 |
| Spring (RB) | 17.4 | 14.5 *(58.1)* | 22.0 *(71.6)* | -7.5 *(-13.5)* | sqw0774 |
| Unknown Tributary (RB) | 17.7 | 18.1 *(64.6)* | 22.3 *(72.1)* | -4.2 *(-7.6)* | sqw0788 |
| Unknown Tributary (RB) | 19.2 | 17.3 *(63.1)* | 22.3 *(72.1)* | -5.0 *(-9.0)* | sqw0861 |
| Side-Channel (LB) | 19.2 | 14.9 *(58.8)* | 24.4 *(75.9)* | -9.5 *(-17.1)* | sqw0863 |
| Indian Ford Creek (RB) | 19.5 | 26.1 *(79.0)* | 24.3 *(75.7)* | 1.8 *(3.2)* | sqw0868 |
| Unknown Tributary (LB) | 20.0 | 16.6 *(61.9)* | 22.4 *(72.3)* | -5.8 *(-10.4)* | sqw0886 |
| Dam outflow (RB) | 21.2 | 16.8 *(62.2)* | 21.9 *(71.4)* | -5.1 *(-9.2)* | sqw0936 |
| Unknown Tributary (LB) | 22.0 | 17.4 *(63.3)* | 18.3 *(64.9)* | -0.9 *(-1.6)* | sqw0978 |
| Spring (RB) | 22.8 | 12.9 *(55.2)* | 15.1 *(59.2)* | -2.2 *(-4.0)* | sqw1014 |
| Side-Channel (LB) | 23.4 | 14.8 *(58.6)* | 15.0 *(59.0)* | -0.2 *(-0.4)* | sqw1052 |
| Spring (RB) | 30.1 | 5.5 *(41.9)* | 12.0 *(53.6)* | -6.5 *(-11.7)* | sqw1311 |
| Spring (RB) | 30.3 | 8.4 *(47.1)* | 11.8 *(53.2)* | -3.4 *(-6.1)* | sqw1322 |
| Spring (RB) | 30.4 | 7.7 *(45.9)* | 12.7 *(54.9)* | -5.0 *(-9.0)* | sqw1326 |
| Spring (LB) | 30.8 | 8.1 *(46.6)* | 12.5 *(54.5)* | -4.4 *(-7.9)* | sqw1342 |
| Spring (RB) | 30.9 | 8.7 *(47.7)* | 12.7 *(54.9)* | -4.0 *(-7.2)* | sqw1344 |
| Snow Creek (LB) | 31.3 | 10.3 *(50.5)* | 12.5 *(54.5)* | -2.2 *(-4.0)* | sqw1364 |
| Side-Channel (RB) | 31.8 | 12.9 *(55.2)* | 12.6 *(54.7)* | 0.3 *(0.5)* | sqw1390 |
| North Fork Squaw Cr. (RB) | 34.1 | 13.6 *(56.5)* | 10.9 *(51.6)* | 2.7 *(4.9)* | sqw1488 |
| Unknown Tributary (LB) | 34.6 | 7.4 *(45.3)* | 10.3 *(50.5)* | -2.9 *(-5.2)* | sqw1513 |
| South Fork Squaw Cr. (RB) | 35.2 | 9.1 *(48.4)* | 10.9 *(51.6)* | -1.8 *(-3.2)* | sqw1540 |
| Park Creek (RB) | 35.6 | 10.1 *(50.2)* | 10.6 *(51.1)* | -0.5 *(-0.9)* | sqw1561 |

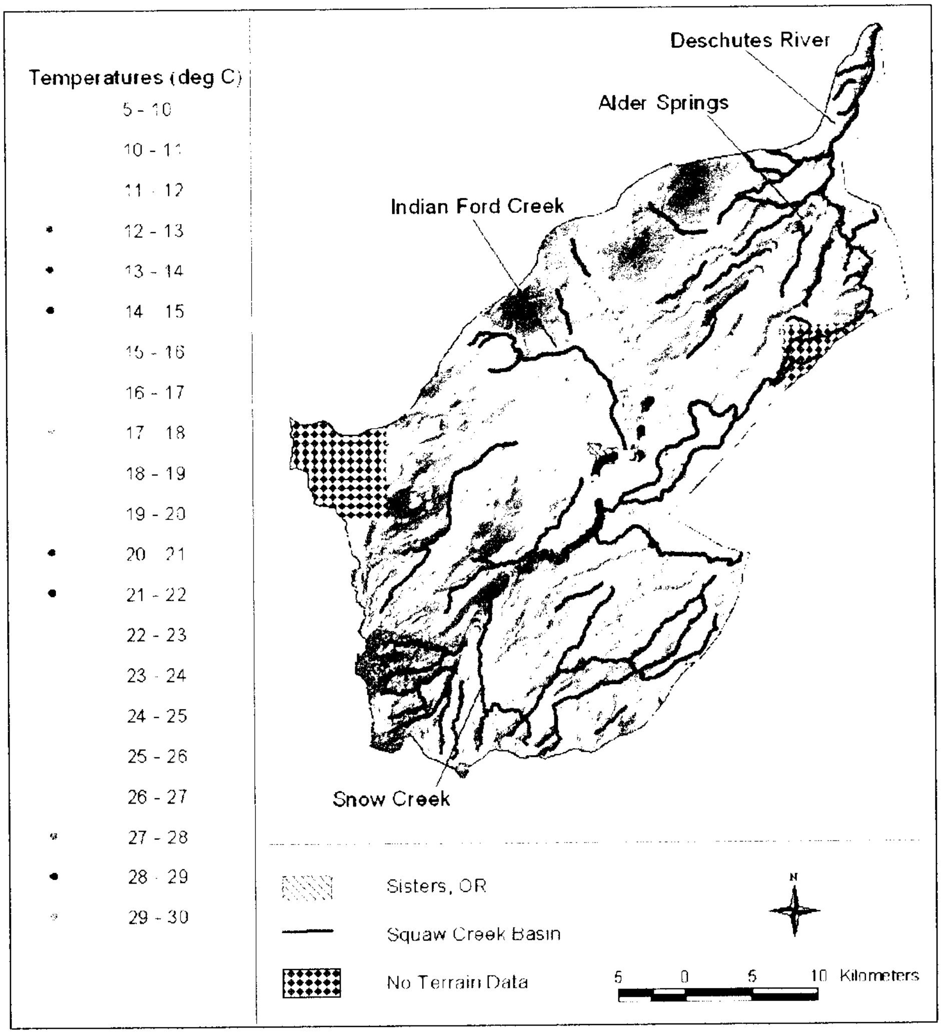


Figure 9 – Point pattern map of Squaw Creek temperatures plotted over a shaded terrain relief map.

A small (0.2°C – 0.5°C) net temperature increase was observed between rm 21.5 and rm 17.5[2]. Local thermal variability was observed throughout this reach with a 4.5°C range of stream temperatures of (*20.4°C to 24.9°C*). A local maximum was reached near the inflow of Indian Ford Creek, which contributed warmer water to Squaw Creek. However, Squaw Creek temperatures had already reached this maximum prior to the Indian Ford Creek inflow. The imagery suggests that volumetric flow from Indian Ford Creek is small relative to Squaw Creek and that direct thermal influence is strictly local. A dam outflow (Figure 10) at rm 21.2 and four surface inputs all contributed cooler water in this reach. The surface input at rm 19.2 (Figure 11) appears to be an upwelling of cooler water that originated in the stream and is flowing sub-surface through the floodplain[3]. The source of the other surface inputs could not be positively determined from the imagery.

[2] Reach includes the town of Sisters.
[3] This is also known as hyporheic flow.

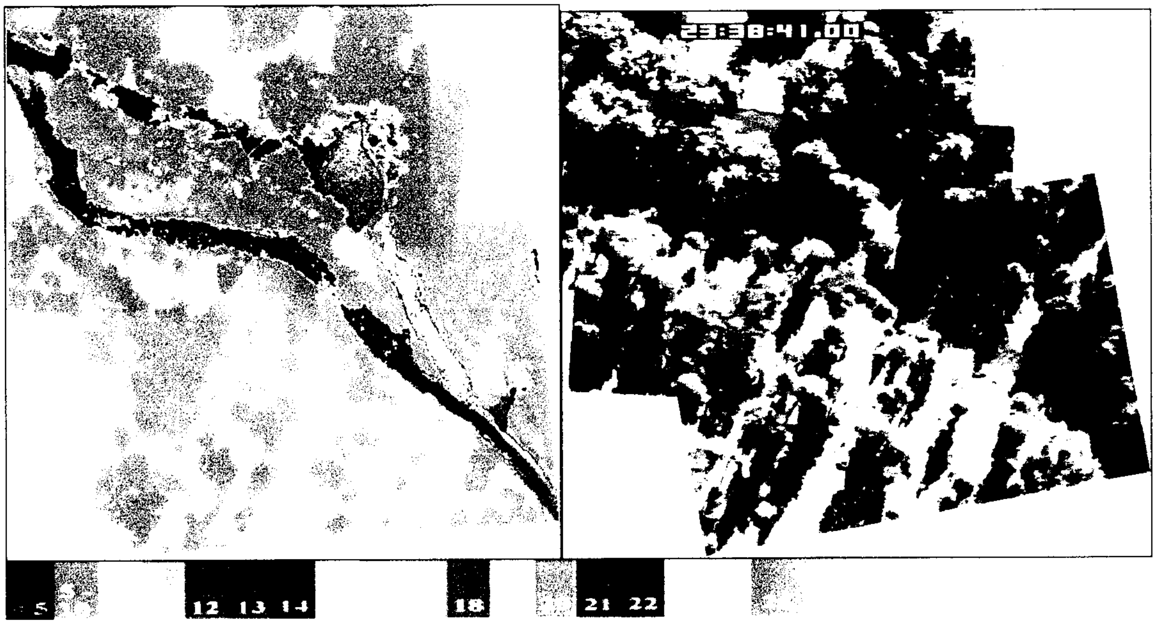


Figure 10 – FLIR/Color Video showing the outflow of a dam at river mile 21.2 (mosaic of frames: sqw936 to sqw939) contributing cooler water (16.8°C) to Squaw Creek (21.9°C). Stream flow is from the top to the bottom of the image.

A spring inflow (Figure 12) at river miles 17.4 and 17.3 results in a dramatic 8.0°C decrease in stream temperature. These springs were not identified on the USGS 7.5' Topographic Maps and occur approximately 1 mile upstream of the mapped location of Camp Polk Springs. From river miles 17.4 to 13.7, stream temperatures increase in the downstream direction at an average rate of 2.4°C/mile (*9.0°C over 3.7 miles*). A series of three springs were detected around Camp Polk Springs. These springs contribute cooler water, but do not alter the overall longitudinal heating trend in this reach. Stream temperatures continue to increase over the next 12.2 river miles with only local variability. No surface inputs were detected over this reach and stream temperatures approached the observed daily maximum air temperatures of 28°C.

A series of 5 spring inflows were detected between river mile 1.2 and 1.5, which included the mapped location of Alder Springs (Figure 13). The springs collectively lower the temperature of Squaw Creek by approximately 8.6°C. A second set of springs (Figure 14) were detected at river mile 0.5 to 0.4, which were not identified on the USGS 7.5' Topographic Maps. These springs further lower the temperature of Squaw Creek by 1.0°C. Due to the spring inflows in the lower 1.5 miles, Squaw Creek was ultimately a cooling source to the Deschutes River.

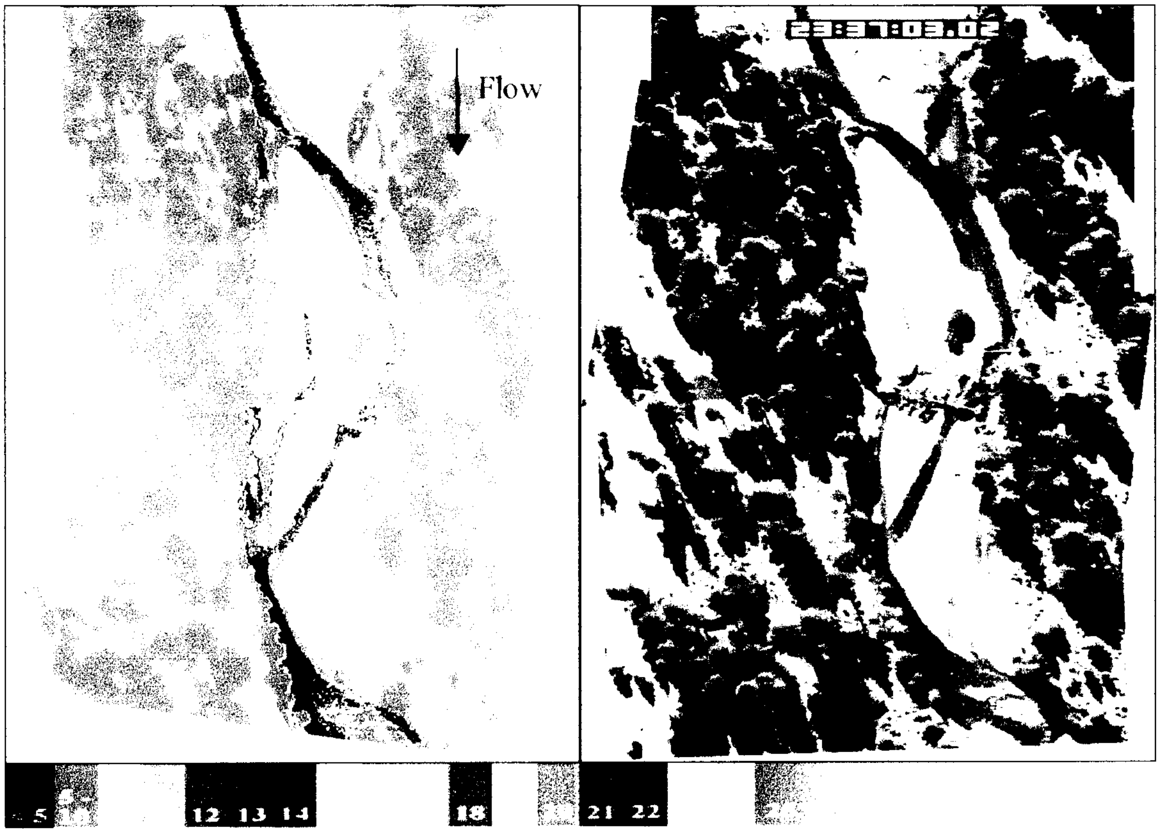


Figure 11 – Upwelling of cooler water at rm 19.2 that originated in the stream and flows through the flood plain (mosaic frames: sqw862-864).

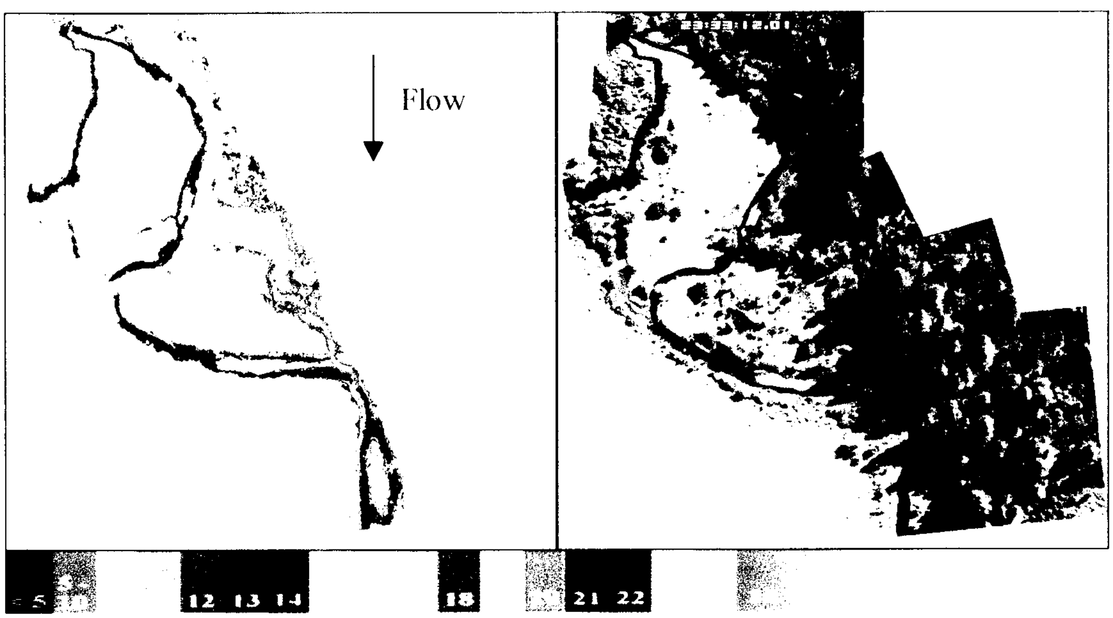


Figure 12 – Apparent spring detected at rm 17.3 that drops the temperature of Squaw Creek by 8°C (mosaic: frames sqw767_7773).

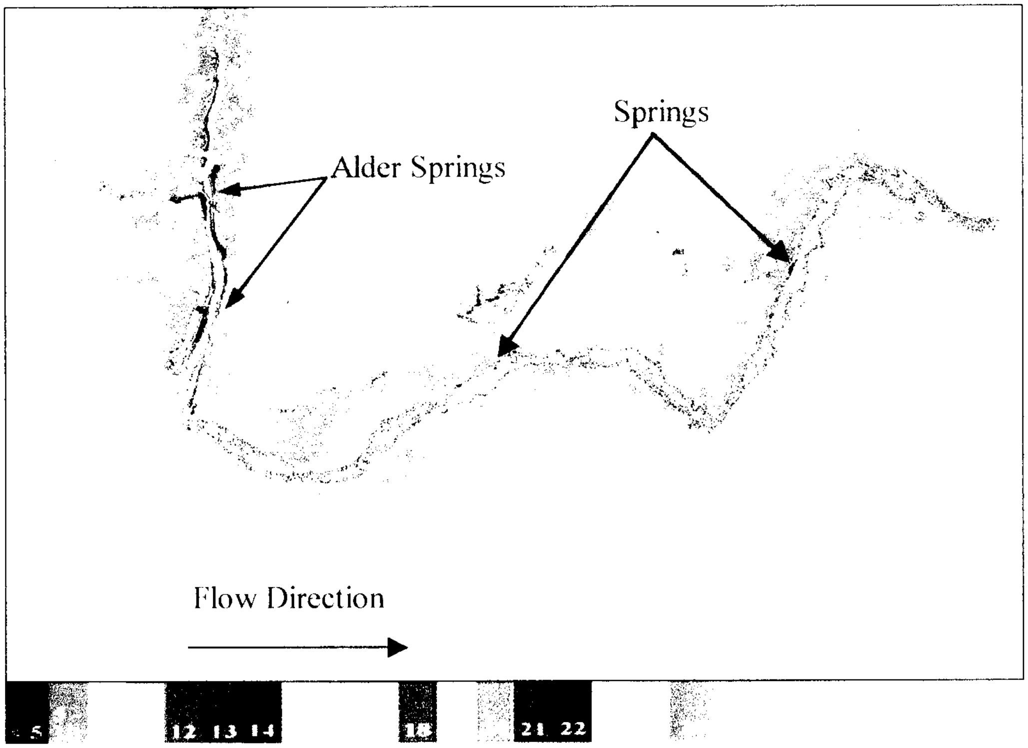


Figure 13 – FLIR images (mosaic frames: sqw0056_67) showing a series of spring inflows at Alder Springs (rm 1.2 to rm 1.5).

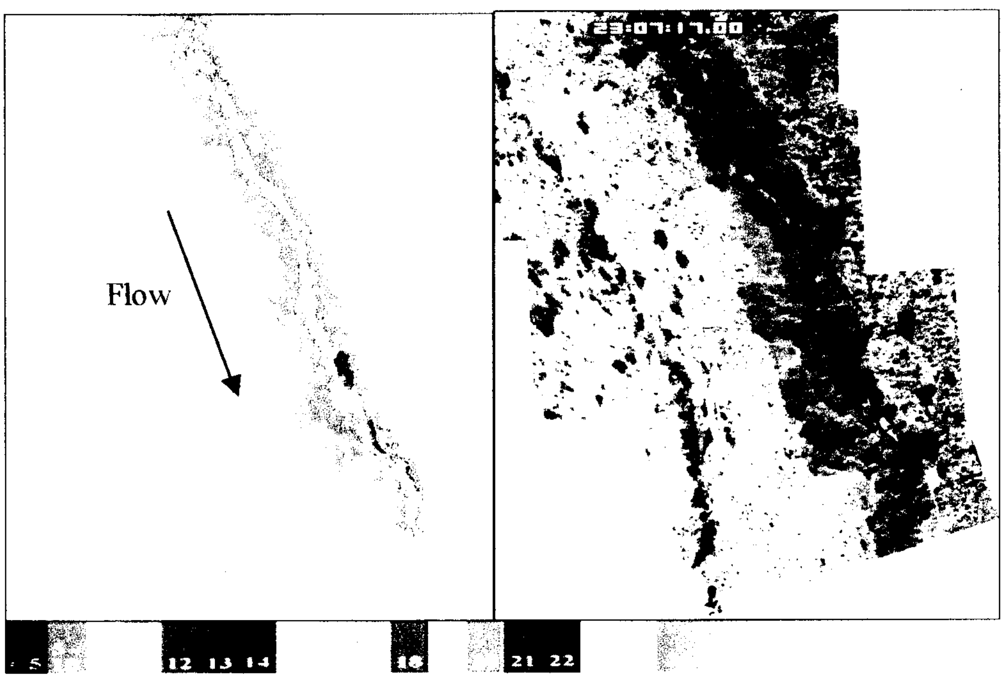


Figure 14 – FLIR image (mosaic frames: sqw30 to sqw34) showing a set of spring inflows at river mile 0.5.

# Indian Ford Creek

A longitudinal temperature profile was developed for Indian Ford Creek from the confluence of Squaw Creek to the headwater springs (Figure 15). Near the headwaters, Indian Ford Creek divides into three branches that originate from two springs. The FLIR survey covered each of these branches in order to help understand the temperature regime in the headwater areas. The right and middle branches originate from Paulina Springs with the right branch flowing through a series of ponds. The left most branch originates from a separate spring. Indian Ford Creek had several reaches where no surface water was visible in the FLIR imagery. In these cases the survey followed cooler vegetation and willows. Temperatures were only sampled where surface water was visible and continuous. Figure 16 shows a point pattern map of Indian Ford Creek temperatures plotted over a shaded terrain relief map. This map provides an additional spatial context for longitudinal temperature profile along with reaches that could not be accurately sampled.

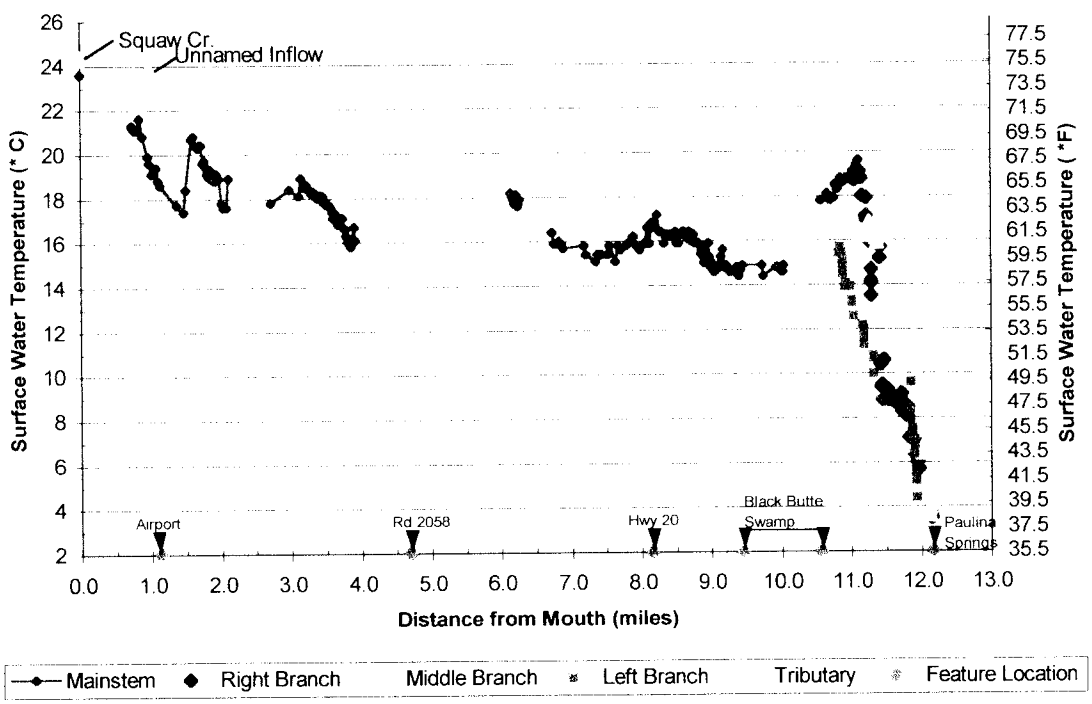


Figure 15 - Median stream temperatures versus river mile for Indian Ford Creek. Segments in the profile that do not have temperature data represent areas that could not be reliably be sampled due to little or no detectable surface water.

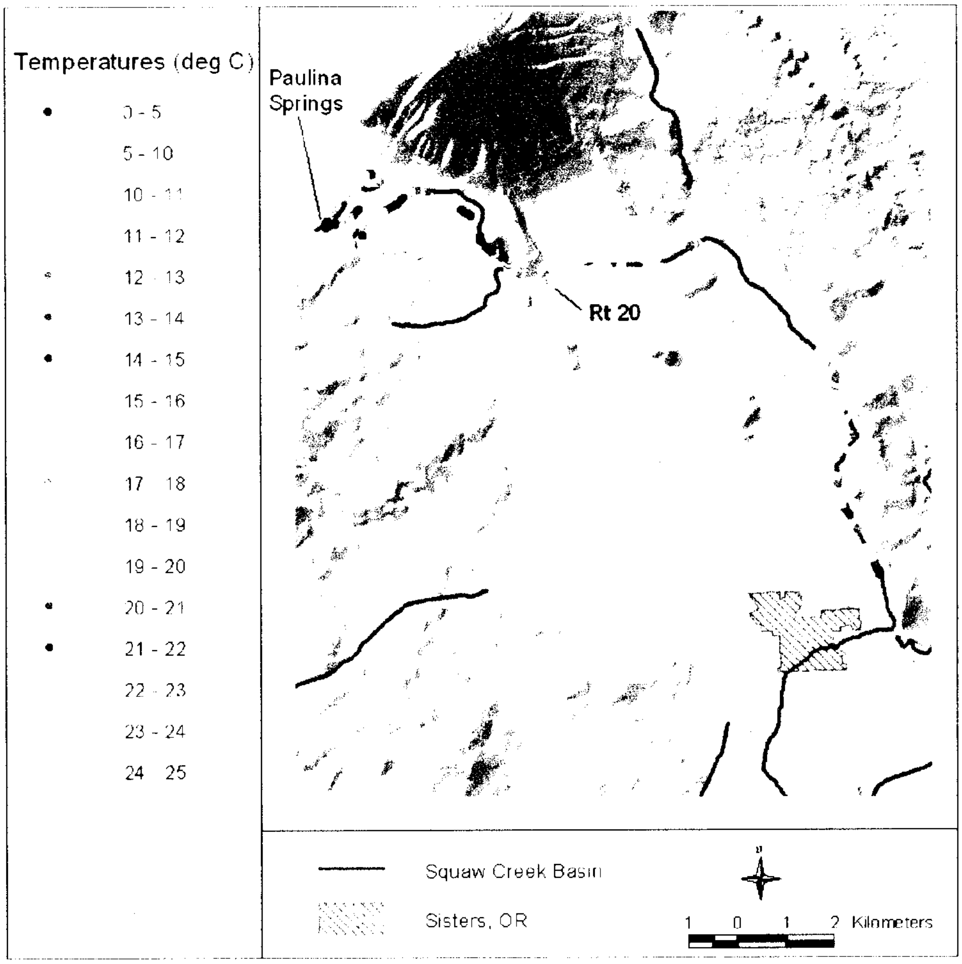


Figure 16 – Point pattern map of Indian Ford Creek temperatures plotted over a shaded relief map. The map also shows reaches that could not be accurately sampled.

The headwater springs in Black Butte Meadow showed the coldest temperatures measured in the basin (approximately 4°C). From the headwaters, stream temperatures increased by approximately 11°C over the first mile. There was no defined channel through Black Butte Swamp (rm 10.5) and there was little surface water detected. The longest continuous section of surface water in the stream was observed downstream of the swamp from rm 10.0 to rm 6.7. Temperatures in this reach showed local variability with an overall net increase of approximately 1.5°C. The stream from mile 6.7 to mile 3.9 had few areas in which water temperatures could be reliably sampled in the imagery. Multiple small channels were often obscured by streamside willows and other vegetation making it difficult to detect surface water in these sections. Cooler vegetation along the stream corridor suggested shallow sub-surface flow where surface water was not detected. The lower 4 miles of Indian Ford Creek were characterized by intermittent surface flow.

## Discussion

FLIR imagery was collected on Squaw Creek, Indian Ford Creek, and a 6-mile section of the Deschutes River. Analysis of the Squaw Creek flight in relation to the daily stream temperature cycle indicates that the timing of the Squaw Creek survey was consistent with maximum daily stream temperatures for July 28, 2000. The Indian Ford Creek survey occurred approximately 1 hour prior to recorded maximum daily temperatures. Longitudinal stream temperature patterns were developed for each survey stream and include the median temperature and location of surface water inflows. WS, LLC FLIR surveys over the past 4 years have shown that, while absolute temperatures change, the longitudinal patterns of warming and cooling remain consistent from year to year.

The 4.5°C temperature difference between headwaters and mouth of Squaw Creek is not indicative of the large course scale variability observed in the longitudinal temperature profile. Of the 33 point source inflows detected during the survey, 30 contributed water cooler then the Squaw Creek mainstem. The point source inflows included three spring complexes (river miles 30.1-30.4, 16.0-17.4, and 1.2-1.5) that dramatically lowered stream temperatures and altered the longitudinal temperature pattern. The USGS 7.5' Topographic maps identified springs around Camp Polk that were detected in the FLIR imagery. However, these springs appeared to have a relatively small influence on mainstem temperatures compared to another spring located approximately 1 mile upstream of Camp Polk, which was not identified on the USGS topographic maps. A 4th spring complex was observed between river miles 30.1 and 30.9, which also caused local decrease in mainstem temperatures.

In addition to point source inputs, there were several distinct shifts in longitudinal heating rates. Figure 17 shows the longitudinal temperature patterns in relation to terrain elevation and location of physical features along Squaw Creek. The terrain elevation was derived from a 10-meter digital elevation model of the watershed and provides a general measure of stream gradient. The highest rate of longitudinal heating was observed between river miles 26.3 and 21.5. Two features are evident in this reach. First, stream gradient begins to decrease around river mile 26. This indicates a possible geomorphic shift and alteration of one or more of the parameters that that influence longitudinal heating rates including velocity (travel time), channel characteristics, and/or riparian community structure and composition. The second and more prominent feature is the diversion for the Squaw Creek Canal (Figure 18). While flow levels were not measured as part of the aerial survey, the longitudinal temperature profile suggests that flow reduction may play a significant role in the observed increase in stream heating rates.

Stream temperatures in Squaw Creek exceeded 20°C through two different sections. The stream section between rm 17.7 and rm 21.5 showed local thermal variability, but generally did not increase in temperature. The stream section between rm 15.0 and rm 1.5 showed a gradual increase in stream temperatures. Cool water seeps were detected in both of these sections (Figure 11 and Figure 19), which contribute fine-scale thermal heterogeneity.

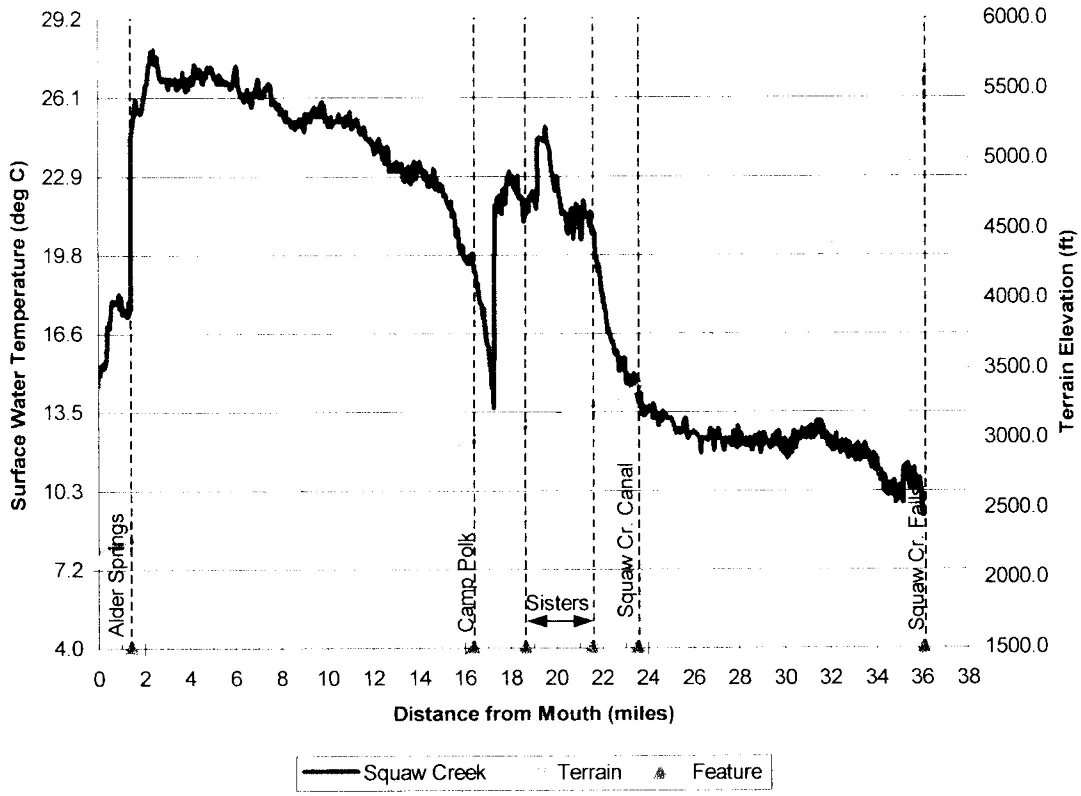


Figure 17 – Median stream temperature and terrain elevation versus river mile for Squaw Creek. The plot also shows feature locations along the stream.

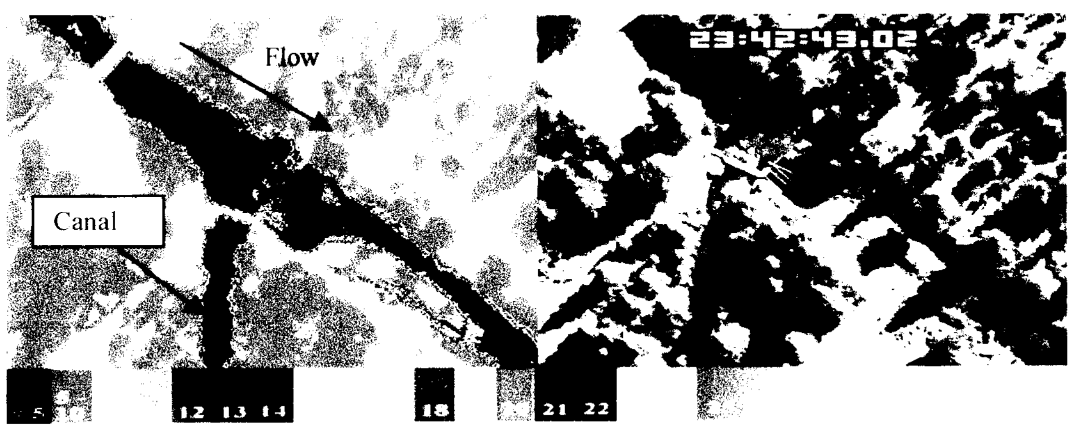


Figure 18 – FLIR/Color video image pair showing Squaw Creek Canal Diversion Squaw Creek (14.2°C) flows from the top left to bottom right of the image (frame: sqw1059).

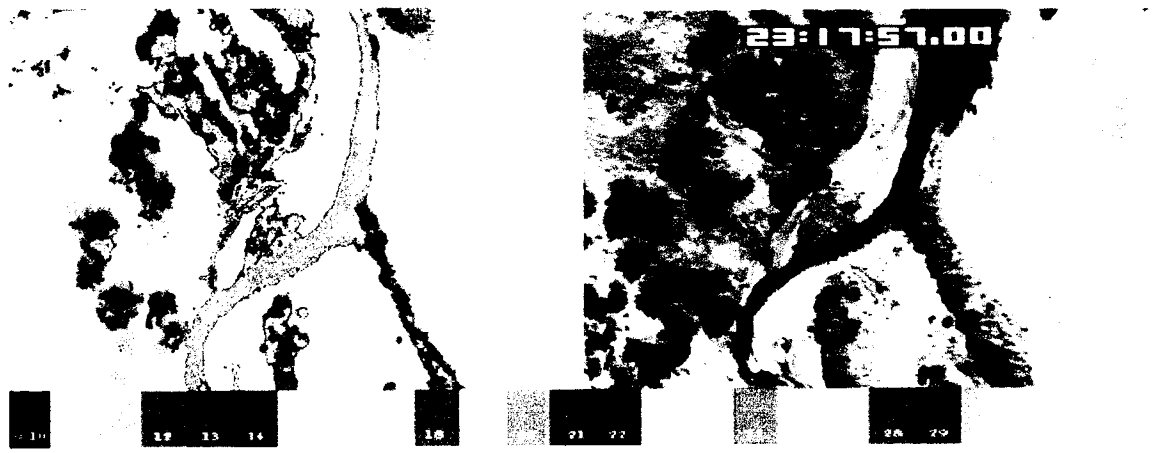


Figure 19 – FLIR/color video image showing upwelling of cooler water through the flood plain at river mile 8.5 (frame: sqw0354).

Indian Ford Creek was characterized by a series of connected wetlands. Due to intermittent visibility in the imagery, there is little continuity in the longitudinal temperature profile. Like Squaw Creek, flow regulation is part of the current hydrology of Indian Fork Creek. There are irrigation canals and several man-made ponds (Figure 20) along its length. Sub-surface flow through the stream channel and wetlands also influence the stream's temperature patterns. For example, a stream temperature of 18°C was observed at the downstream end of Black Butte Meadow. However, the stream fans out in Black Butte swamp and emerges at approximately 15.0°C. While it was generally not possible to sample water temperatures from the imagery in the wetland areas, image mosaics of the swamp (Figure 21) showed multiple small channels and cooler vegetation.

Indian Ford Creek had relatively little flow at the confluence of Squaw Creek. Further analysis of the thermal regime of Indian Ford Creek should examine current in-stream flows in relation to historic flow patterns.

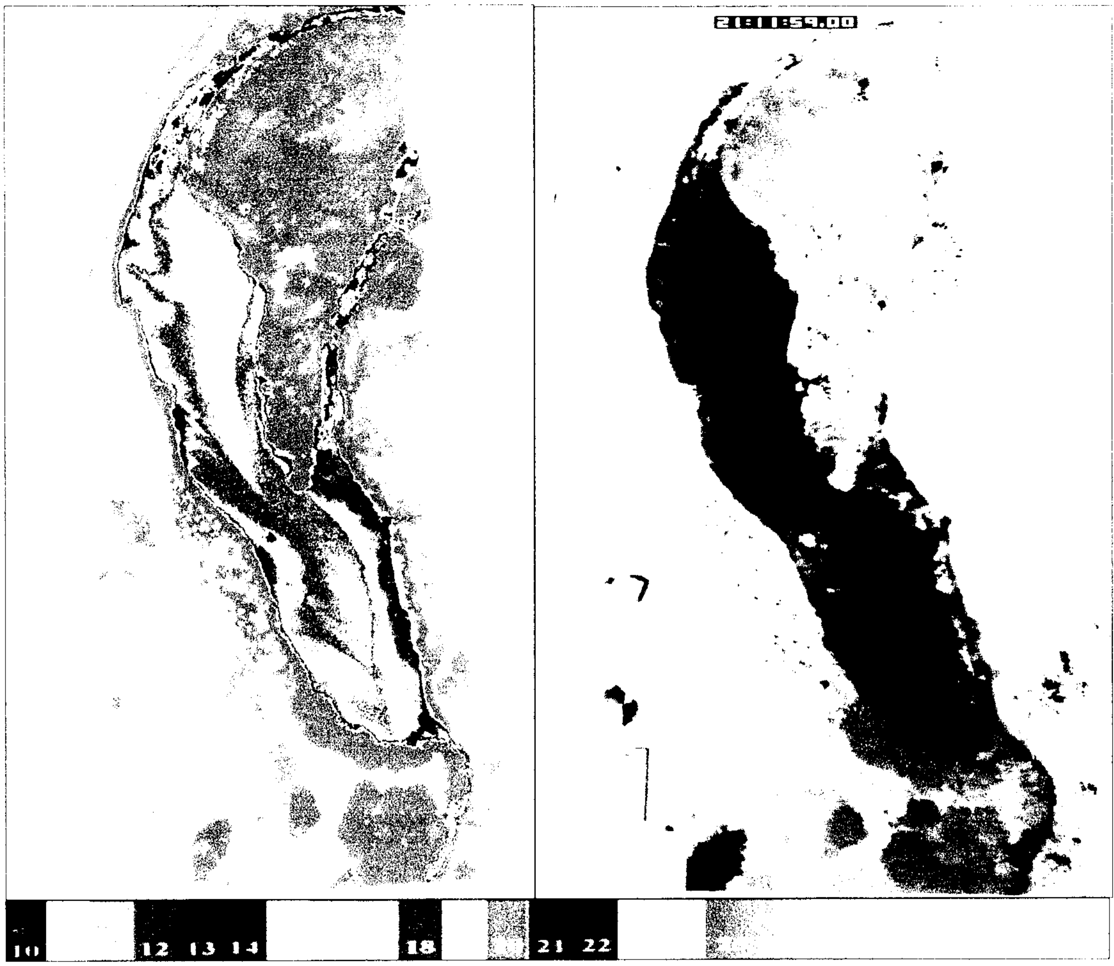


Figure 20 – FLIR/color video Image showing a pond in Indian Ford Creek (rm 2.1). Vegetation is visible on the water surface upstream of the pond. This was typical of several areas along Indian Ford Creek and precluded accurate temperature sampling from the image. The thermal patterns on the pond suggest thermal stratification in the downstream end of the pond (mosaic: frame if276- if278).

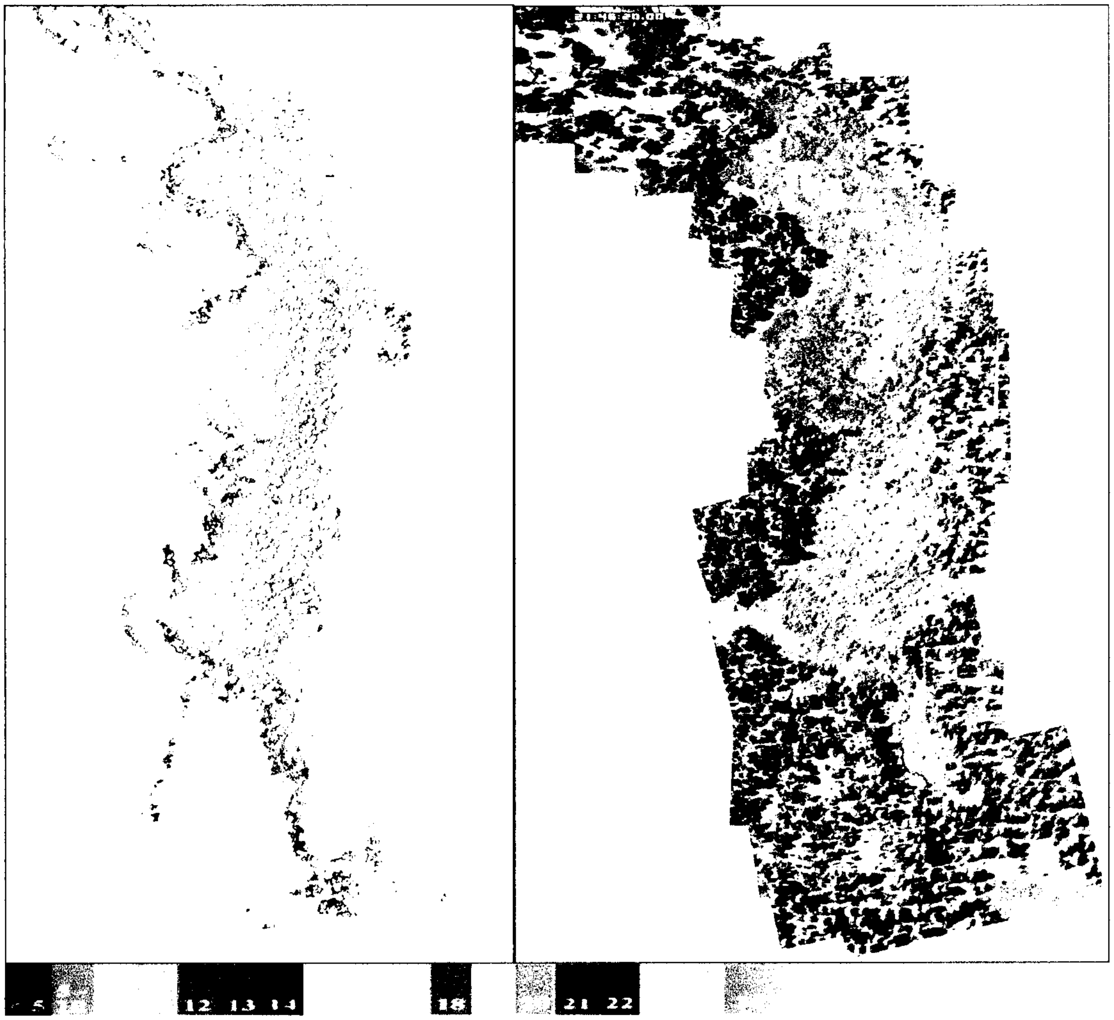


Figure 21 – FLIR/color video image mosaic (frames: vifl850 to vifl888) showing Indian Ford Creek through Black Butte Swamp. The imagery was collected at an altitude of 2000 ft above ground level in order to capture the approximate width of the swamp. The FLIR image mosaic shows generally cooler vegetation through the swamp. However, only a small section of surface water was detected in either image.

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# Appendix C

# Squaw Creek Monitoring

# Sisters Schools Monitoring Report

# SQUAW CREEK EDUCATION AND RESTORATION PROJECT

A Cooperative Project Between:

Deschutes National Forest, Sisters Ranger District
Sisters School District
St. Francis School, Bend
Bend Community School

With funding provided by:

Governor's Watershed Enhancement Board
USDA Forest Service
Sisters School District
Deschutes Watershed Council
Deschutes Soil and Water Conservation District
Oregon Department of Fish and Wildlife
Oregon Water Resources Department
Central Oregon Flyfishers
and
Squaw Creek Watershed Residents


Many thanks to the participants
Barbara Lee
Kathy Kemper
David Hewett
Glen Herron
Colleen Lynch
Jens Lovhang

Michelle Elpi
Class of 2001

Megan McGuire
Class of 1997

Amber Leis
Class of 1998

# Sisters High School "Stream Team"

Besse Ward
Class of 2001

Anton Rius
Class of 2001

Carolyn Franks
Class of 1999

Matt Adams
Class of 2000

## Introduction

The waters of Squaw Creek have played an important role in the settlement and development of the Sisters area. Water has been diverted from the creek since the late 1800's for agricultural and domestic use. The high demand for water has modified the natural flows of Squaw Creek, which in turn have resulted in higher summer water temperatures. Squaw Creek has been listed by the Oregon Department of Environmental Quality (ODEQ) as water quality limited, due to high summer temperatures and flow modification.

Peak flow (when the water is highest) in Squaw Creek is usually in June, when snow melt is coming off of the mountains. The lowest natural flows occur in winter, when most water is locked up in snow or ice. Currently, the lowest flows now occur during the late summer and early fall primarily due to water being diverted out of the normal channel.

Squaw Creek supports populations of native rainbow trout, suckers, dace, and sculpin, as well as non-native brook trout and brown trout. Prior to construction of the Pelton -Round Butte Dam complex Squaw Creek played an important role in the spawning and rearing of steelhead trout and chinook salmon. Efforts are now underway to possibly reintroduce these species of fish to the Deschutes River system. Squaw Creek could play an important role in their successful re-establishment.

The Why-chus Watershed Analysis was published in 1998 by the Sisters Ranger District. Squaw Creek is the largest watershed within the analysis area. The analysis states that water issues, especially those regarding flows are the most critical to restoring a healthy watershed. The goals outlined by the analysis include:

- Restore stream flows sufficient to provide connectivity of aquatic habitat to the Deschutes River.
- Recover water quality sufficient to meet state water quality standards and support fish and other aquatic species.
- Restore riparian habitat on public and private lands to enhance stream stability, reduce water temperatures, and provide habitat.

- Reduce conflicts between irrigation needs and aquatic systems and species.
- Encourage development that is compatible with functioning aquatic systems and that does not limit future restoration efforts.

The Squaw Creek Education and Restoration Project was designed to fulfill three goals: 1) to educate students and the community about the importance of healthy streams and watersheds; 2) to monitor Squaw Creek's current condition; and 3) to begin restoration efforts of Squaw Creek. The objective for the first year of the project was to collect data for one calendar year and establish a baseline for further efforts.

The Squaw Creek Education and Restoration Project will begin the effort to achieve these goals. The only way change can occur is if the community supports the change. The monitoring described in this project is aimed at building that support.

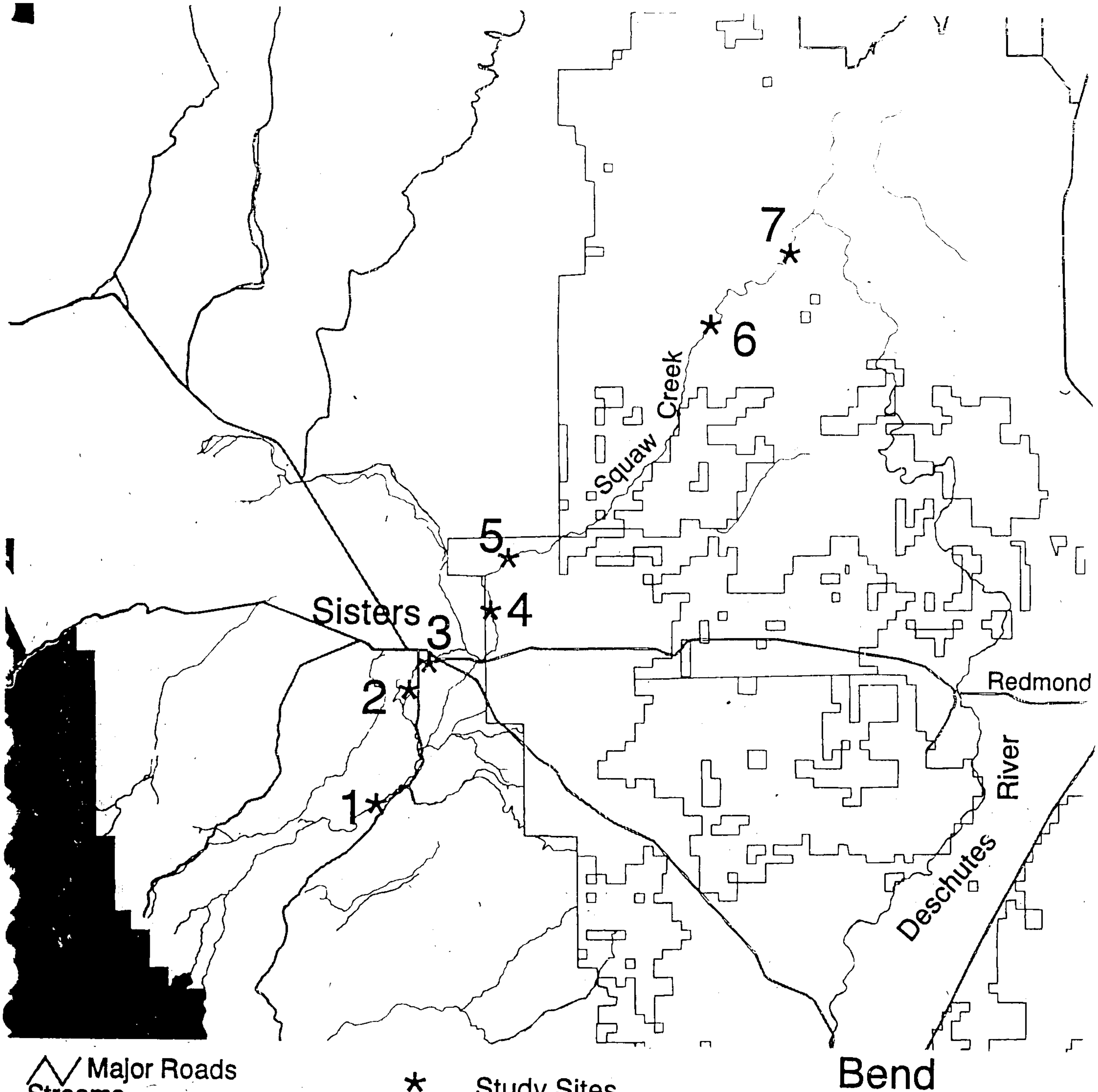
## Study Sites

Seven sites were selected along the length of Squaw Creek, each representing a particular reach of Squaw Creek. The location of these sites is presented in Figure 1.

- Site 1 is located above all major diversions on Squaw Creek, near the USGS gauging station approximately four miles upstream of Sisters, Oregon. It is the best representation of the natural state of the creek.
- Site 2 is located approximately 2 miles upstream of Sisters, at the FS road 4606 footbridge. This site is below the Squaw Creek Irrigation District (SCID) diversion, the major diversion on Squaw Creek.
- Site 3 is located at the Sisters City Park. This site represents the stretch of Squaw Creek with the lowest flow. This stretch is typically de-watered during the height of the irrigation season.
- Site 4 is located upstream of the Camp Polk Road bridge, about 3 miles downstream of Sisters. Springs enter Squaw Creek upstream of this site, and add approximately 5 cubic feet per second (cfs) to the stream. This site is in an area with good riparian vegetation cover and bank stability.
- Site 5 is located downstream of the Camp Polk bridge. This section of stream was channeled and trenched after the floods of 1964, and is the most affectedsite in terms of bank erosion and lack of riparian vegetation.
- Site 6 is approximately 12 miles downstream from Sisters, down in Squaw Creek Canyon, on the Crooked River Grasslands. This site is below all major diversions and represents a fairly undisturbed reach of the creek, but with low flow.
- Site 7 is located just downstream of Alder Springs, a large spring complex about 2.5 miles above Squaw Creek's confluence with the Deschutes River.

Each site (except sites 6 and 7) was assigned to one particular teacher and their class (table 1). Due to difficulty of access to sites 6 and 7, data was collected by USFS personnel. Each class took field trips to their sites to collect data, assisted by a Forest Service biologist. Parents and high school volunteers also helped out with the field trips.

# Squaw Creek Education Project
# Study Sites




Major Roads

Streams

Ditch

Perennial

Wilderness

Deschutes NF

BLM

* Study Sites

Site 1 - USGS Station

Site 2 - 4606 Footbridge

Site 3 - Sisters City Park

Site 4 - Upper Camp Polk

Site 5 - Lower Camp Polk

Site 6 - Grasslands

Site 7 - Alder Springs

1:250000

N

W E

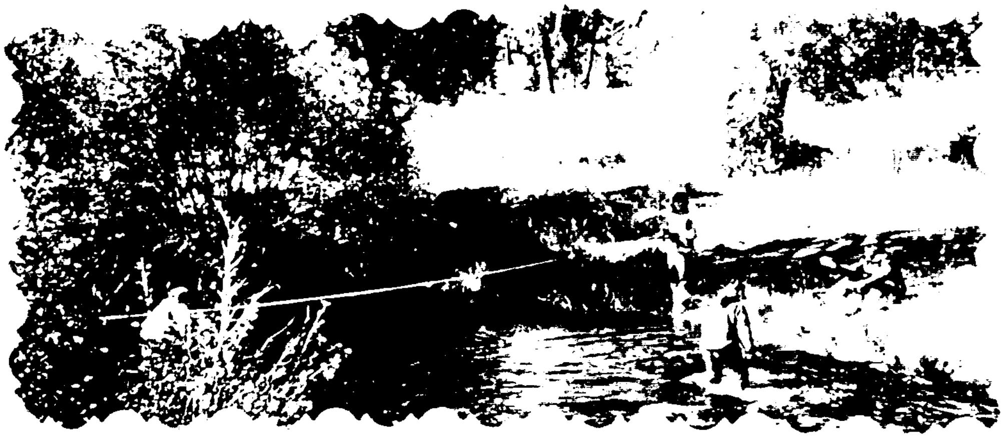
S

# Site 1

# Site 2


80

# Site 4



# Site 5

Site 6

Site 7

Indian Ford

Site 8

## Executive Summary

**From 1998 through 1999, a cooperative monitoring and restoration project was initiated on Squaw Creek** by the Upper Deschutes Watershed Council (UDWC), Sisters School District, Bend Community School, St. Francis School, Oregon Department of Fish and Wildlife (ODFW), Oregon State University (OSU), Portland General Electric (PGE) and the Deschutes National Forest (DNF). For two years, middle and high school students monitored water quality in the field four times each year and planted willows once each year. Teachers, high school student leaders, and biologists from the DNF and PGE instructed the students in field techniques for dissolved oxygen, pH, flow, stream temperature, stream bank stability and riparian plant typing. Biologists and volunteers sampled fish populations in 1999 and linked fish habitat surveys to valley bottom vegetation.

Using flow data collected by the students, we found a strong relationship between summer stream flow and high summer stream temperatures. Using this relationship, **an estimated 27 cubic feet per second would be needed to maintain summer stream temperatures** below the state criteria. Squaw Creek is listed as a 303(d) water quality limited stream by Oregon Department of Environmental Quality because of high water temperatures. As a result of irrigation diversions, instream summer flow is now limited to 2 cubic feet per second downstream of the town of Sisters. Additional flow may be needed to improve redband trout habitat. A critical period of low flow and high water temperatures also occurred in April, during the spawning season of redband trout.

Other water quality concerns raised by student monitoring included low dissolved oxygen during April and in August. Stream bank stability was low in stream reaches where summer flows were low. Willow and cottonwood were planted in May of 1999 but were washed away by a flood in November 1999. Good redband and steelhead trout habitat was linked to low floodplain areas with cottonwood-lined flood channels that spread floodwater and reduce stream bank erosion. Water withdrawals reduce trout habitat by decreasing water depth. Fish surveys found fewer adult and young redband trout in the diverted reach near Sisters than in other reaches sampled.

# Conclusions

As Squaw Creek flows downstream out of the wilderness, water quality is high. Water temperature at **site 1** is cold due to its sources in the mountain snow and cold water springs such as Pole Creek. This cool temperature may limit the diversity of macroinverebrates and fish. Flows supplied by snowmelt remain high into August buffering the effect of the August sun. Shade from forest vegetation helps to maintain the cool water temperature and high dissolved oxygen.

As water is removed for irrigation downstream, the wetted channel becomes shallow. Shallow water in **site 2** is more exposed to the air and sun, warming the water as it flows to Sisters. Stream banks become less stable because of the reduced riparian vegetation.

The confinement of the floodplain increases in Sisters at **site 3** and instability increases. Bridges and development have squeezed the stream, causing deposition and channel instability immediately downstream. Water depth is shallow due to low flows, making much of the stream too shallow for trout. Water temperatures in Sisters can exceed that suitable for trout in some years.

Below site 3 Indian Ford Creek's nutrient rich, warm water combines with the spring water of the Camp Polk area. At the Camp Polk **site 4**, a healthy riparian floodplain functions to spread floodwaters. The macroinvertebrate community is diverse and abundant, possibly benefiting from stable spring flow, the moderate temperatures and organic matter inputs from the riparian vegetation and Indian Ford Creek. Trout are drawn to the spring water, the moderated temperatures and abundant invertebrates. **Site 5** below Camp Polk Road has similar water quality and productivity but fish habitat is limited because of the narrow, confined channel left after channelization.

The Crooked River National Grassland **site 6** has stable flow and good habitat but is limited by low flow, high water temperatures and low dissolved oxygen. Flow, temperature and oxygen are recovered by coldwater inputs from Alder Springs at **site 7**. Diversity of macroinvertebrates and fish are high. Connectivity to the Deschutes River and the increase in water quality allows bull trout to move from the Deschutes River into Squaw Creek to rear.

The above description of conditions is based on the results of this and past monitoring efforts. Our measurements indicate that we need to work to improve the water quality, stream bank stability and fish habitat in Squaw Creek. Even during high water years, Squaw Creek does not meet state water quality standards for temperature during trout spawning/incubation or rearing seasons. There is a strong correlation between the low summer stream flow and the water temperature. Our estimate of 27 cfs should be considered a low estimate for flow restoration because of the data used from the high water year of 1999. Using a stream temperature model Houslet (1998) estimated that nearly 40 cfs would be needed in Sisters to maintain favorable August water temperatures in Squaw Creek.

Two periods of water temperature violations were found, one in April/May when natural flow is low and irrigation begins, and the other in August. Low flows and high temperatures in April were thought to be the cause of a fish kill in the area of Sisters in 1990 (Riehle 1990). The April high temperatures could possibly be avoided by timing early season withdrawals to avoid the brief natural low-flow periods.

More flow is needed to increase the average water depth than is needed to maintain favorable water temperature. Sufficient water depth is needed for fish to use stream bank cover. Lower flows leave the channel dry along the stream bank, reducing riparian vegetation. Added flow will support riparian vegetation, leading in time to more stable stream banks. More measurements are needed to pinpoint what flow is needed for the best depth and fish habitat quality

For the years we studied, dissolved oxygen was mostly above the ODEQ standards, other than site 3 and 4 in springtime and site 6 in August. *E. coli* bacteria counts from Squaw Creek met standards for contact recreation, although Indian Ford Creek is a source of bacteria to Squaw Creek. The pH measures showed no signs of major algae blooms. However, these results could be affected by the high water during 1999.

Riparian vegetation was more abundant along stream banks that are connected to low floodplains, which allows floods to spread and reduce the stress on stream banks. Fish habitat quality was linked to more stable, vegetated stream banks. Development has already reduced the ability of the stream to spread floodwaters in many reaches and stream banks have eroded as a result. Therefore, floodplain planning and management is of great importance to reduce erosion and maintain fish habitat.

Redband trout are found throughout the stream, both above and below the diversions. With more work, a better relationship could be drawn between snorkeling and electrofishing that would allow monitoring of fish populations by snorkeling. For the first time, fish have been documented in Squaw Creek in the town of Sisters in a reach which was previously dry during the summer. The 2 cfs secured for instream flow helped sustain redband trout in Sisters through the entire year—the first step to the recovery of aquatic connectivity in Squaw Creek. The Sisters site had a low percentage of young and adult fish compared to the other sites with more reliable flows, suggesting that there is more flow restoration needed to sustain a fishery.

## Recommendations

Restoration opportunities include: 1) secure summer instream flow to meet state water temperature and dissolved oxygen standards throughout the stream, 2) secure instream flow to maintain trout habitat requirements throughout the stream, 3) prevent floodplain encroachment to allow floodwaters to spread, 4) sustain summer flow to support riparian vegetation, especially from the main diversion to Camp Polk Rd, 5) reconnect flood plain channels to the stream where possible to allow flood water spreading to reduce bank erosion, 6) plant riparian vegetation along stream banks where adequate floodplain channels provide stable areas for planting, 7) coordinate early season water withdrawals to avoid the low flow periods in the springtime to protect redband spawning habitat.

Future monitoring recommendations: 1) Continue stream temperature and fish population monitoring to follow the results of restoration efforts and confirm the results of this study during normal water years, 2) assess the required flow to support fish habitat and, 3) gage stream flow at the Sisters city park, 4) provide better floodplain delineation for floodplain management.

The Squaw Creek Education and Restoration Project began as a way to involve local students in watershed assessment and restoration. The project grew and came to be more than an outdoor classroom. The monitoring conducted has provided useful information that has increased our understanding beyond that of the 1998 USFS Watershed Analysis. The insights gained can be used to guide future restoration projects. This monitoring can also serve to measure the benefits from the restoration projects already implemented.

# Media Coverage

THE Nugget

SISTERS, OREGON

*Wednesday, July 23, 1997*

# Sisters students collect data on Squaw Creek

*By Jim Cornelius*

Sisters High School students will apply their science studies to a real-life project beginning this fall as they monitor Squaw Creek.

The students will play a [illegible] role in the [illegible] $[illegible]26 grant administered by the [illegible] Deschutes County [illegible] Watershed Council and the Soil and Conservation District.

According to watershed resources coordinator Barbara Lee, the students and volunteers will collect data on 20 miles of Squaw Creek [illegible] information ranging from [illegible] temperature [illegible]

See CREEK [illegible]

**CREEK** *from page 1*

acidity or alkalinity and aquatic insects.

The data the students collect will be analyzed in an effort to get a complete picture of the riparian conditions along the creek. That information, according to Lee, will help the Sisters community make informed decisions about the creek and its uses.

"We're hoping to involve the community in a collaborative approach to using the resources in the watershed," Lee said.

The funding cycle of the grant is two years, but, Lee said, "the project may well extend beyond that."

Lee said the grant administrators are currently working on guidelines for when and how data is collected.

The grant came from the Governor's Watershed Enhancement Board.

COMMUNITY

Photo by Cindy Glick

David Glick led Sisters students in watershed restoration work on Squaw Creek.

# Students restore Squaw Creek

Miss Packard's sixth grade class spent Thursday morning, March 19, planting willows along the banks of Squaw Creek in the Sisters City Park.

The effort was part of a watershed educational program presented by David Glick from the Deschutes National Forest. The willows should help stabilize the banks, provide shelter for birds and small mammals, keep water temperatures low and provide a nice snack for the local deer herd.

Miss Butler's science class [illegible]

The middle school class is working with the Sisters Range District on an ongoing

> *Miss Butler's science class cut willows on Friday and will plant these sticks along Squaw Creek.*

stream monitoring project. The [illegible]

and stream width and flow. All the information will be used by the Sisters Ranger District to assist in a watershed analysis of Squaw Creek.

A Watershed Festival is set for June 27 at the Sisters City Park. Students are encouraged to make posters which show watersheds and their importance.

These posters will be displayed at the festival and prizes will be awarded. Many other activities are planned.

For more information con- [illegible]

# Kids go afield for science

## Sisters students making a real-world difference

By Jan Volz
The Bulletin

Bulletin/Jan Volz

USFS biologist Jens Lovtang helps sixth-grader Matt Fegette.

SISTERS — With forest-green hip waders strapped over their shoulders, Wes Estvold's students wade into the knee-deep waters of Squaw Creek.

Lines are strung across the creek to help the middle schoolers balance against the current while checking stream depth, width and velocity.

On the bank, some students calculate the water's temperature, dissolved oxygen and pH level; others sort and identify aquatic insects.

These sixth-graders take their work seriously, perhaps because they know their efforts will have a real-world impact.

The information gathered by these students won't just go into their notebooks or be memorized for a test and then forgotten. The data will be used to determine future water quality and habitat enhancement projects.

The Sisters School District has teamed up with the U.S. Forest Service and the non-profit Deschutes County Watershed Council to study Squaw Creek. A two-year, $24,000 grant from the Governor's Watershed Enhancement Board is being used to purchase equipment and supplies as well as provide transportation and grant coordination.

Last year, about 250 students in grades 5, 6, 7 and 10 made baseline measurements on the stream. This year, their counterparts are following up to see if the recent return of irrigation water rights to the creek is making a difference.

For the students, it's a chance to participate in hands-on science as well as gain an understanding of environmental issues appearing in the news almost daily.

When experts discuss the temperature and oxygen needs of fish or the impacts of grazing and logging, students from Sisters schools know exactly what they're talking about.

Similar measurements taken by students three years ago persuaded the Forest Service to eliminate cattle grazing along a stretch of Indian Ford Creek.

On Squaw Creek, students are studying several facets of stream health, including the effect of irrigation withdrawals.

"Students really get to see a difference," said Jens Lovtang, fisheries biologist with the Sisters Ranger District. He oversees quality control for the data.

"In September, the water flow is very low, about 15 cubic feet per second (cfs)," he said. "But in October, it's about 50 cfs."

See KIDS, Page A2

# Kids: Project helps monitor stream health

Continued from Page A1

[illegible]

[illegible]

Student involvement won't stop at education and information gathering, science teacher Cheryl Butler said. Next spring, students will [illegible]

# Students complete creek project

Local students will soon complete a two-year project studying Squaw Creek water issues.

Students from the Sisters School District participated in a monitoring project to establish baseline information about the quality and quantity of water in Squaw Creek.

"The students have had a fun-filled experience applying classroom science knowledge to a real-world field situation," explained Sisters teacher Cheryl Butler. "All grades have used a curriculum that meets state standards for science education while contributing to the success of a community watershed project."

In the project, students learned about watersheds, water monitoring methods and natural resource stewardship.

Upper Deschutes Watershed Council coordinator Barbara Lee said the students' efforts will contribute to future conservation programs.

"The students' field work has helped provide essential information for implementing effective community stewardship activities within the watershed," said Lee. "Project information will help measure the success of water and land conservation activities."

According to project coordinators, long-term efforts will protect beneficial uses of water, secure funding for management activities and improve fish populations within the Squaw Creek watershed.

The final field days for student participation will occur May 25-27.

The monitoring project is a joint effort among the Upper Deschutes Watershed Council, the Council's Squaw Creek Stewardship Committee and the Deschutes National Forest, Sisters Ranger District.

SISTERS, OREGON
*Wednesday, October 13, 1999*

THE Nugget

# Project offers hope for Squaw Creek

*By Jim Cornelius*

Steelhead and Chinook salmon may swim in Squaw Creek again — and not too long from now.

According to Forest Service fish biologist Mike Riehle, experiments will be conducted this winter to introduce fish above Pelton and Round Butte dams to see how well they swim through the reservoir.

A two-year stream monitoring program with the help of Sisters students has been integral to creating a restoration plan for the Squaw Creek watershed, which includes Indian Ford Creek.

Students monitored the health of the streams and their work was good enough to be used as evidence in a restoration plan being drafted by the Forest Service and watershed stewardship groups.

*See* **CREEK** *on page 34*

**CREEK** *from page 1*

"We found a lot of exciting things out," Riehle said the Sisters School Board Monday, October [illegible] "We probably couldn't ha[illegible] done it without the school."

Barbara [illegible] of the stewardship or[illegible]ation Upper Deschute[illegible]ershed Council noted th[illegible] [illegible]24,000 Governor's Wa[illegible] [illegible] Enhancement Grant be[illegible] [illegible]vailable for the project [illegible] [illegible] the students were d[illegible] [illegible]eir time and efforts [illegible] [illegible]ject.

Scien[illegible] [illegible]er [illegible] [illegible] led [illegible] [illegible], where elementary [illegible] [illegible]dle school students [illegible] [illegible] from the stream [illegible] [illegible]

[illegible] the younger students in their efforts.

Sisters High School student Matt Adams noted that the project had some real and immediate impacts on how Indian Ford creek is treated.

"We were able to change some of the grazing (regulations) that had an impact on the creek," he told the board.

Bessy Ward started with the project as a 7th grader and became a project leader.

"It was the most valuable experience I've ever received because it applied [illegible]erything I've been learning in school," from leadership to math and science, she said.

According to [illegible] [illegible] teacher in Bend, and [illegible] [illegible]

# Thanks Sisters School Kids!

The Upper Deschutes Watershed Council wishes to thank you for your participation in the Squaw Creek Monitoring Project!

MRS. KEMPER'S 5TH GRADE CLASS 1998-1999

[illegible]

10TH GRADE BIOLOGY TEACHER SCOTT HERRON, THE HIGH SCHOOL STREAM TEAM WHO ASSISTED 5TH, 6TH, 7TH AND 10TH GRADE TEACHERS

[illegible]

MS. BUTLER'S CLASSES 7TH GRADE STUDENTS THE ENTIRE CLASS 1997-1998

[illegible]

MRS. KEMPER'S 5TH GRADE CLASS 1997-1998

[illegible]

6TH GRADES CLASSES OF MR. WES ESTVOLD, MISS CAROL PACKARD AND MRS. HEIDI SMITH FOR 1998-1999

[illegible]

MR. HEWETT'S 5TH GRADE CLASS 1998-1999

[illegible]

MR. HEWETT'S 5TH GRADE CLASS 1997-1998

[illegible]

MS. BUTLER'S 7TH GRADE CLASS 1998-1999

[illegible]

# Appendix D

## Squaw Creek Monitoring

## Bend Community School Watershed Report

# Indian Ford Creek Watershed Study

Fall 1998

Bend Community School

Introduction
By Karen Tonsfeldt

**Project:** A group of students from the Bend Community School (BCS) are participating in a watershed ecology class taught by Julie Robertson. The class has eleven people ranging from sixth to ninth grade. They are joining schools in Sisters for the remainder of the year to work on a project called The Squaw Creek Watershed Assessment. This is a cooperative effort between USFS - Sisters Ranger District, Sisters High, Sisters Middle School, BCS and the Deschutes Watershed Counsel. This is the second year the project has been going on, but the first year BCS has participated in it. BCS is conducting a series of tests for pH, dissolved oxygen, and other water information from Indian Ford Creek, a creek that runs into Squaw Creek .

**Purpose:** Local residents and fish management agencies have identified Squaw Creek as needing restoration work. Also, there is a need to improve riparian habitat. Squaw Creek's stream bed was accidentally damaged in the 1960's by flood control operations. Data collected by this project will provide information to stabilize the stream bank and to restore Squaw Creek irrigation ditch. One of the goals is to reconnect the upper and lower sections of Squaw Creek and to improve the habitat of anadromous fish and rainbow trout. Because Indian Ford Creek (the creek that BCS will be testing) runs into Squaw Creek, it is important that we test there to get a broader picture of the Squaw Creek watershed.

**Data Collection:** BCS will be doing the following tests for the Sisters Ranger District: water temperature, dissolved oxygen, depth, flow rate and pH. These tests will be taken four times during the school year. They will be conducted twice during the fall (September and October) and twice in the spring. Besides collecting data, we will be learning much about collecting and identifying microinvertebrates that live in the water.

Karen Tonsfeldt
Water Ecology
December 11, 1998

## Collection of Data

Our watershed ecology class collected the following data from Indian Ford Creek: information about flow, temperature, dissolved oxygen, pH (part Hydrogen), and macroinvertebrates. The Forest Service also collects this information. Data will be collected five times a year.

**Flow:**

Flow measures the amount of water flowing in the creek in cubic feet per second. We measured flow by measuring the width of the stream with a tape measure then separating the stream into even cells. In each cell we measured the depth, width and velocity. The area times the velocity equals the flow (F=VxA). To measure the velocity, we used a digital MarshMcBirney FLO-MATE and a depth staff. The peak flow is supposed to be in June when the snow melt is leaving the mountains. The lowest flow is in late summer or fall.

**Temperature:**

We obtained the temperature by putting a thermometer in the center of the creek for two minutes. The most important times to take temperatures of the water are in the months between April and August. These are the hottest months of the year, so temperature is most likely to affect the fish and other creatures living in the stream during these months.

**Dissolved Oxygen:**

We measured Dissolved Oxygen by taking a 300 ml bottle and holding it in the center of the stream for two minutes. Then we added chemicals and shook the container for three minutes. We matched the color of the liquid on a color wheel to see how much $O_2$ is in the water.

**Part Hydrogen:**

We calculated the pH by putting two 5-ml bottles in the center of the stream. In one we put a chemical, and in the other we didn't add anything. Then we put the two in a color wheel and compared them. The chemical color needs to match the natural color under a color slide.

**Macroinvertebrates:**

To collect macroinvertebrates, we put a net into the water while we kicked up sand and dirt around it. We then lifted up the net and emptied the collection of dirt into a tray. We took the tray, and separated the insects with eyedroppers and tweezers. Then we counted the species and individuals.

# How To Get to the Location Where B.C.S Did Their Studies

By: Michael Forte

Indian Ford Creek is a watershed of Squaw Creek which is a watershed of the Deschutes River. Indian Ford Creek travels across a portion of land owned by Deschutes Basin Land Trust which is near Sisters off of Hwy 20. This is the site in which we did our studies. If you are on Hwy 20 going West from Bend, Oregon, take a right hand turn (North) at Camp Polk Road just as you enter Sisters. Travel two miles to a point where road makes a 90 degree bend and crosses Indian Ford Creek. There should be a large meadow on left. This location is near the Indian Ford Ranch subdivision. Turn left (West) on the paved road that parallels the meadow and fence line, and go about 1/4 mile to where the fence is crossable near the creek. Walk about 500 ft in a meadow to opening in the trees (mostly Willow trees) and the creek should be right there. The meadow land is owned by Deschutes Basin Land Trust.

The place where we are doing our testing on the creek runs through a bunch of Willows. The creek has lots of grass in the water (Picture #2) and in the meadow around the creek (Picture #1) . There are a few rodents but we did not see any animals while we were there. There are probably fish in the creek because they are known to live in the creek. The creek is about thigh deep (to a child) and has lots of algae.

DESCHUTES COUNTY
1"=200'

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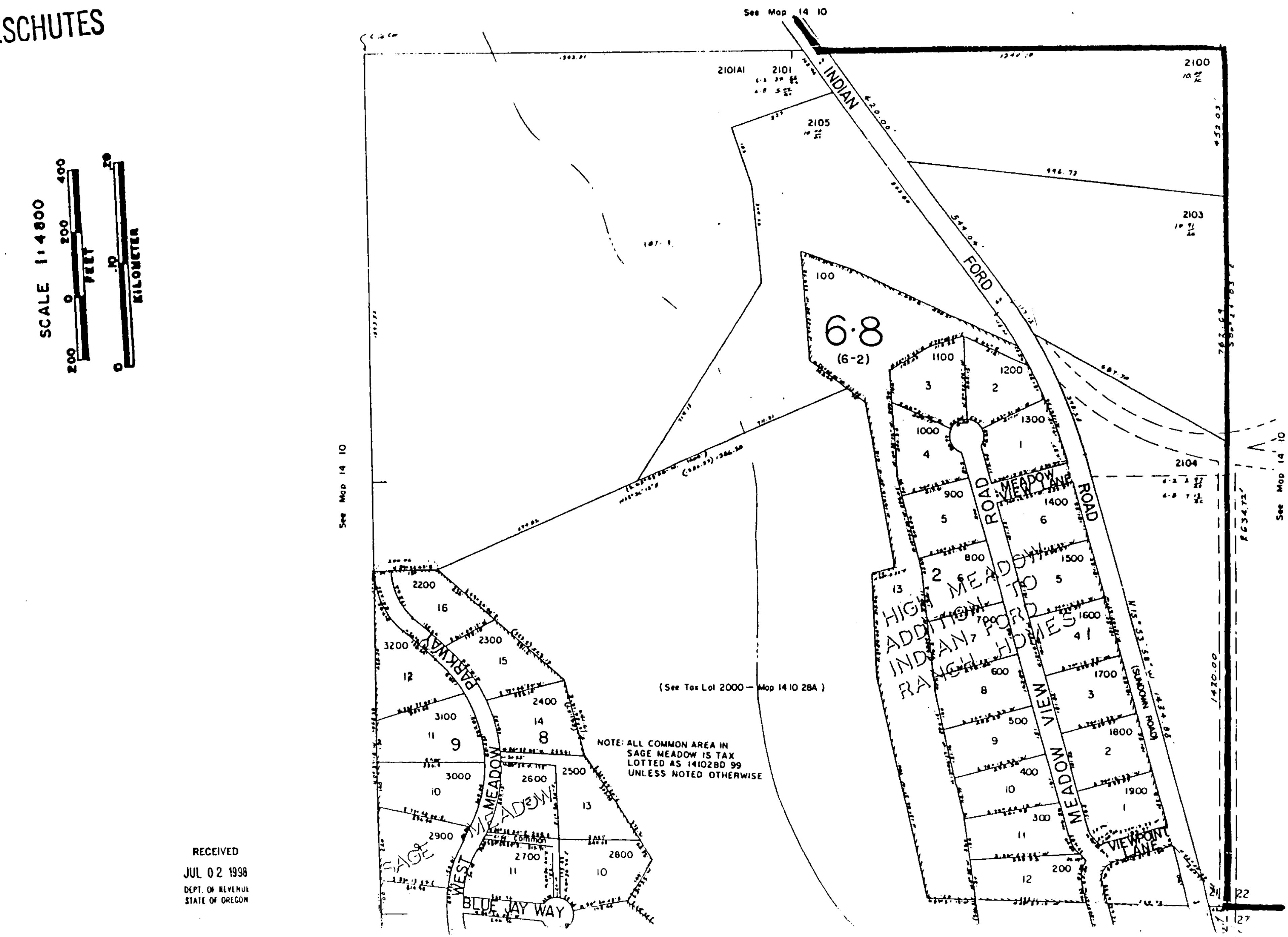
JUL 0 7 1998

DESCHUTES

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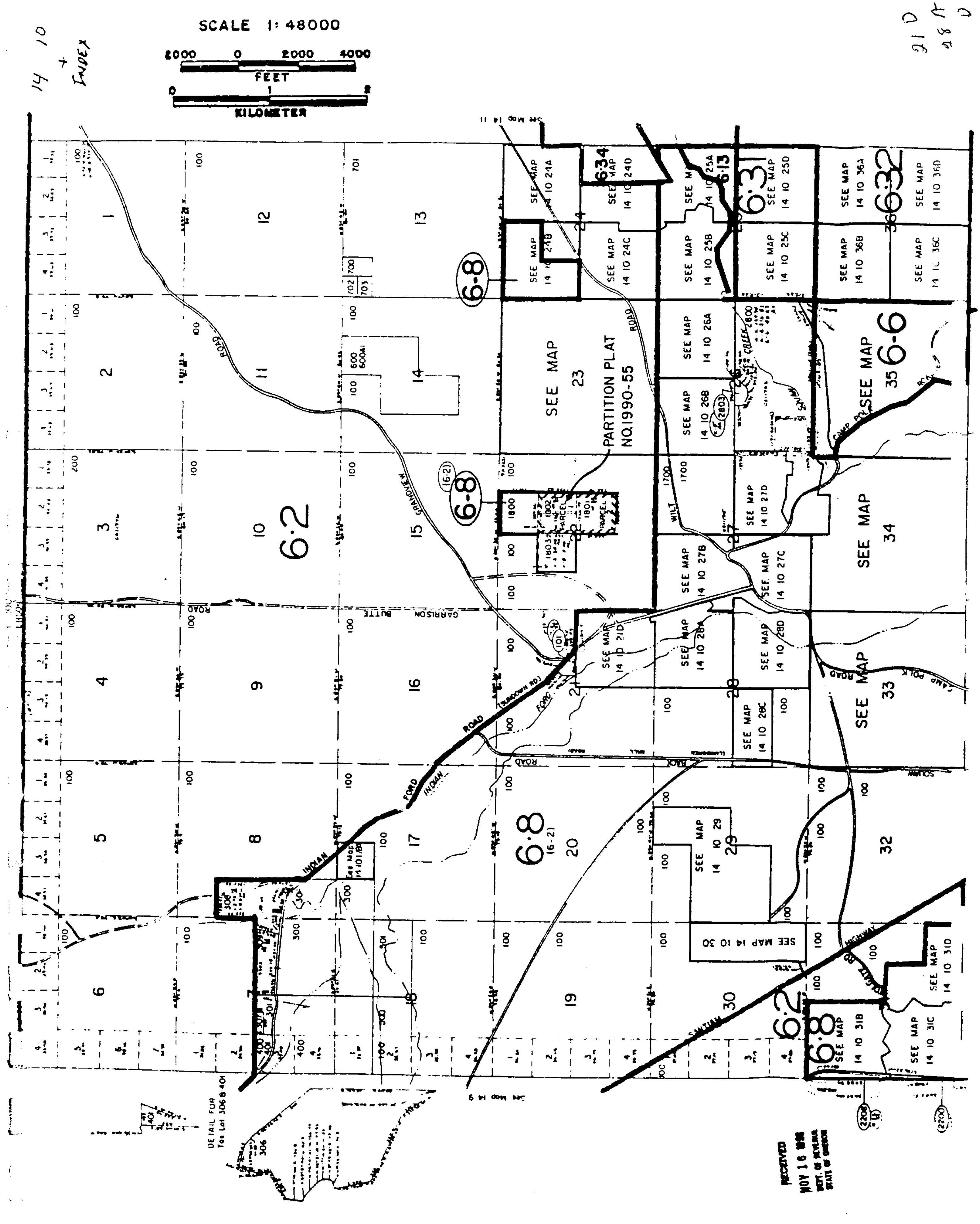

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PARTITION PLAT NO.1990-55
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SEE MAP 14 10 31C
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SEE MAP 14 10 36A
SEE MAP 14 10 36B
SEE MAP 14 10 36C
SEE MAP 14 10 36D
SEE MAP 33
SEE MAP 34
SEE MAP 35
GRANDVIEW ROAD
GARRISON BUTTE ROAD
INDIAN FORD ROAD
CAMP POLK ROAD
SQUAW CREEK
SANTIAM HIGHWAY
DETAIL FOR Tax Lot 306 & 401
RECEIVED NOV 16 1998 DEPT. OF REVENUE STATE OF OREGON

# Analysis and Conclusion of Data Collected

## Analysis:

This analysis isn't going to be very accurate due to lack of data. There are only two different sets of data that have been collected at this point in time. These two sets of data were taken on September 25, 1998 and one on October 23, 1998. The flow rate nearly doubled in that time span. This could be because the season was changing or because of the change in allocated water in the irrigation canals because the people stop irrigating. Another possible reason is because of an increase in rainfall. Also, the dissolved oxygen (DO) went up 2.3, which is quite a considerable amount. Perhaps this was because of the flow rate rising.

Testing was also done on the macroinvertebrates each time. The difference between the two sets of data was that the second time there were fewer aquatic insects the drop was 185 less insects. Again, this is may be due to the change in the season, but more likely due to less effort by the students during the second test. The temperature of the water dropped ten degrees probably because of the weather. The pH (parts hydrogen) stayed about the same, one test result said the pH was 7.5 and the other said it was 7.5. The Wetted Area ($ft^2$) went up slightly, but not too much.

## Conclusion:

Again, any conclusions may not be true due to the lack of data at this point in our study. It would seem the living conditions for a better salmon population at sites four and five were helped by the inflow of Indian Ford Creek upstream. This might be said because at Site 3, the last one above Indian Ford Creek, the temperature there is about 4 -10 degrees higher than sites 4 and 5, the two sites immediately following the tributary of Indian Ford Creek. Also, the pH levels of sites 4 and 5 are more suitable to a salmon habitat. To have a more accurate conclusion there needs to be more data collected and analyzed.

## Squaw Creek Data Sheet

1998

| | | | | |
|---|---|---|---|---|
| Site Number | IF | | Date | 9/25/98 |
| Station Number | 1 | | Teacher | Robertson |

## Water Quality Worksheet

| | | | | | |
|---|---|---|---|---|---|
| Water Temperature ($^{o}$F) | 55 | Hach pH | 7 | DO (ppm) | 12 |
| E. coli sample taken (y/n): | n | PhotoPoint (y/n): | y | D.O. method: | HACH |

## Flow Worksheet

| | | | | | | |
|---|---|---|---|---|---|---|
| Stream Width (ft) | | 10 | Measured Flow (CFS | | 2 | |
| # | Distance on tape (ft) | Cell Width (ft) | Depth (ft) | velocity (1 | area (sq ft) | discharge |
| Bank | 2 | | 0 | | | |
| 1 | 2.5 | 1 | 0.5 | 0 | 0.5 | 0.00 |
| 2 | 3.5 | 1 | 0.7 | 0.1 | 0.7 | 0.07 |
| 3 | 4.5 | 1 | 1 | 0 | 1 | 0.00 |
| 4 | 5.5 | 1 | 1.3 | 0.1 | 1.3 | 0.13 |
| 5 | 6.5 | 1 | 1.4 | 0.5 | 1.4 | 0.70 |
| 6 | 7.5 | 1 | 1.5 | 0.5 | 1.5 | 0.75 |
| 7 | 8.5 | 1 | 1.5 | 0.1 | 1.5 | 0.15 |
| 8 | 9.5 | 1 | 1.4 | 0.03 | 1.4 | 0.04 |
| 9 | 10.5 | 1 | 1.3 | 0.01 | 1.3 | 0.01 |
| 10 | 11.5 | 1 | 0 | 0.01 | 0 | 0.00 |
| Bank | 0 | | 0 | | | |

## *MacroInvertebrate Field Datasheet*

| | | | |
|---|---|---|---|
| Site # : | IF | Teacher Name | 1 |
| Station #: | 1 | Field Date | September 25, 1998 |

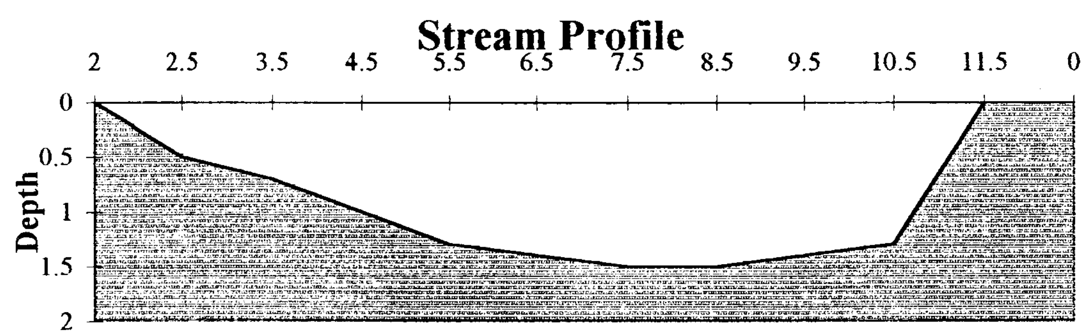
| Name of Macroinvertebrate Order | Number of different kinds | Number of Individuals |
|---|---|---|
| Mayflies | 2 | 110 |
| Stoneflies | 0 | 0 |
| Caddisflies | 2 | 5 |
| Waterboatman | 1 | 1 |
| Riffle Beetles | 1 | 2 |
| Damselflies | 1 | 2 |
| Freshwater Clams | 1 | 75 |
| Snails | 1 | 100 |
| Watermites | 1 | 1 |
| Krill | 1 | 1 |

## *Total*

| *Measure* | *How to calculate* | *Enter Answer* |
|---|---|---|
| *Mayfly Richness* | Count number of diferent kinds of Mayflies | 2 |
| *Stonefly Richness* | Count number of diferent kinds of Stoneflies | 0 |
| *Caddisfly Richness* | Count number of different kinds of Caddisflies | 2 |
| *Mayfly/Stonefly/Caddisfly Richness* | Add number of different kinds of Mayflies/ Caddisflies/ Stoneflies | 4 |
| *Taxa Richness* | Count number of different kinds of macroinvertebrates | 11 |
| *Macroinvertebrate Abundance* | Count number of individual macroinvertebrates of all kinds | 297 |

## *Squaw Creek Education Project*
## *Field Station Summary Sheet*

| | | |
|---|---|---|
| *Site # :* | IF | September 25, 1998 |
| *Station # :* | 1 | IF |
| | | **Water Quality Data** |
| *Water Temperature:* | 55°F | HACH |
| *Hach pH* | 7 | 12 |
| | | **Water Flow Data** |
| *Flow (cfs):* | 2 | 10 |
| *Average Stream Depth (ft) :* | 1.06 | 9.43 |
| *Wetted Area (cu ft)* | 10.6 | |




### *Macroinvertebrates*

| | *Total Answer* |
|---|---|
| *Mayfly Richness* | 2 |
| *Stonefly Richness* | 0 |
| *Caddisfly Richness* | 2 |
| *Mayfly / Stonefly / Caddisfly Richness* | 4 |
| *Taxa Richness* | 11 |
| *Macroinvertebrate Abundance.* | 197 |

## Squaw Creek Data Sheet

1998

| | | | | |
|---|---|---|---|---|
| Site Number | IF #2 | | Date | 9/25/98 |
| Station Number | 2 | | Teacher | Robertson |

## Water Quality Worksheet

| | | | | | | |
|---|---|---|---|---|---|---|
| Water Temperature (°F) | 48 | Hach pH | 7.5 | | DO (ppm) | 9 |
| E. coli sample taken (y/n): | n | PhotoPoint (y/n): | | y | D.O. method: | HACH |

## Flow Worksheet

| | | | | | | |
|---|---|---|---|---|---|---|
| Stream Width (ft) | | 10 | Measured Flow (CFS) | | 3 | |
| # | Distance on tape (ft) | Cell Width (ft) | Depth (ft) | velocity (f | area (sq ft) | discharge |
| Bank | 2 | | 0 | | | |
| 1 | 2.5 | 1 | 0.6 | 0 | 0.6 | 0.00 |
| 2 | 3.5 | 1 | 0.8 | 0 | 0.8 | 0.00 |
| 3 | 4.5 | 1 | 1 | 0.2 | 1 | 0.20 |
| 4 | 5.5 | 1 | 1.3 | 0.5 | 1.3 | 0.65 |
| 5 | 6.5 | 1 | 1.5 | 0.8 | 1.5 | 1.20 |
| 6 | 7.5 | 1 | 1.5 | 0.5 | 1.5 | 0.75 |
| 7 | 8.5 | 1 | 1 | 0 | 1 | 0.00 |
| 8 | 9.5 | 1 | 1.5 | 0 | 1.5 | 0.00 |
| 9 | 10.5 | 1 | 1.2 | 0 | 1.2 | 0.00 |
| 10 | 11.5 | 1 | 0.7 | 0 | 0.7 | 0.00 |
| Bank | 12 | | 0 | | | |

## *MacroInvertebrate Field Datasheet*

| | | | |
|---|---|---|---|
| Site # : | IF #2 | Teacher Name | 2 |
| Station #: | 2 | Field Date | September 25, 1998 |

***Pools, Side channels. Stream Bank Habitats***

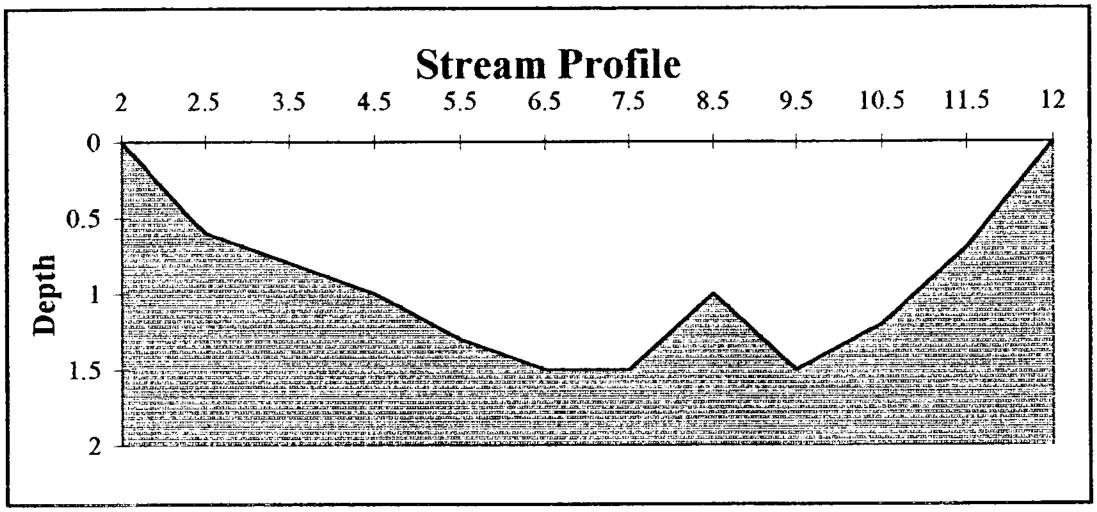
| Name of Macroinvertebrate Order | Number of different kinds | Number of Individuals |
|---|---|---|
| Mayflies | 2 | 136 |
| Stoneflies | 0 | 0 |
| Caddisflies | 2 | 4 |
| Leaches | 1 | 4 |
| Waterboatman | 1 | 5 |
| Backswimmers | 1 | 1 |
| Scud | 1 | 2 |
| Damselfly | 2 | 5 |
| Snails | 3 | 8 |
| Worms | 3 | 3 |
| Coleptera | 1 | 1 |

## ***Total***

| ***Measure*** | ***How to calculate*** | ***Enter Answer*** |
|---|---|---|
| *Mayfly Richness* | Count number of diferent kinds of Mayflies | 2 |
| *Stonefly Richness* | Count number of diferent kinds of Stoneflies | 0 |
| *Caddisfly Richness* | Count number of different kinds of Caddisflies | 2 |
| *Mayfly/Stonefly/Caddisfly Richness* | Add number of different kinds of Mayflies/ Caddisflies/ Stoneflies | 4 |
| *Taxa Richness* | Count number of different kinds of macroinvertebrates | 17 |
| *Macroinvertebrate Abundance* | Count number of individual macroinvertebrates of all kinds | 169 |

## *Squaw Creek Education Project*
## *Field Station Summary Sheet*

| | | |
|---|---|---|
| *Site # :* | IF #2 | September 25, 1998 |
| *Station # :* | 2 | IF #2 |
| | | ***Water Quality Data*** |
| *Water Temperature:* | 48°F | HACH |
| *Hach pH* | 7.5 | 9 |
| | | ***Water Flow Data*** |
| *Flow (cfs):* | 3 | 10 |
| *Average Stream Depth (ft) :* | 1.11 | 9.01 |
| *Wetted Area (cu ft)* | 11.1 | |




## ***Macroinvertebrates***

| | *Total* |
|---|---|
| *Mayfly Richness* | 2 |
| *Stonefly Richness* | 0 |
| *Caddisfly Richness* | 2 |
| *Mayfly / Stonefly / Caddisfly Richness* | 4 |
| *Taxa Richness* | 17 |
| *Macroinvertebrate Abundance.* | 169 |

## Squaw Creek Data Sheet

1998

| | | | | |
|---|---|---|---|---|
| Site Number | IF | | Date | 10/23/98 |
| Station Number | 1 | | Teacher | Robertson |

## Water Quality Worksheet

| | | | | | | |
|---|---|---|---|---|---|---|
| Water Temperature ($^{o}$F) | 38 | Hach pH | 7.5 | | DO (ppm) | 9 |
| E. coli sample taken (y/n): | n | PhotoPoint (y/n): | | y | D.O. method: | HACH |

## Flow Worksheet

| Stream Width (ft) | | 10 | Measured Flow (CFS | | 3 | |
|---|---|---|---|---|---|---|
| # | Distance on tape (ft) | Cell Width (ft) | Depth (ft) | velocity (f | area (sq ft) | discharge |
| Bank | 2 | | 0 | | | |
| 1 | 2.5 | 1 | 0.9 | 0 | 0.9 | 0.00 |
| 2 | 3.5 | 1 | 1.1 | 0 | 1.1 | 0.00 |
| 3 | 4.5 | 1 | 1.35 | 0.5 | 1.35 | 0.68 |
| 4 | 5.5 | 1 | 1.5 | 0.5 | 1.5 | 0.75 |
| 5 | 6.5 | 1 | 1.7 | 0.5 | 1.7 | 0.85 |
| 6 | 75 | 1 | 1.7 | 0.5 | 1.7 | 0.85 |
| 7 | 8.5 | 1 | 1.7 | 0 | 1.7 | 0.00 |
| 8 | 9.5 | 1 | 1.5 | 0.02 | 1.5 | 0.03 |
| 9 | 10.5 | 1 | 1 | 0.02 | 1 | 0.02 |
| 10 | 11.5 | 1 | 0.9 | 0.01 | 0.9 | 0.01 |
| Bank | 12 | | 0 | | | |

## *MacroInvertebrate Field Datasheet*

| | | | |
|---|---|---|---|
| Site # : | IF | Teacher Name | 1 |
| Station #: | 1 | Field Date | October 23, 1998 |

***Pools, Side channels. Stream Bank Habitats***

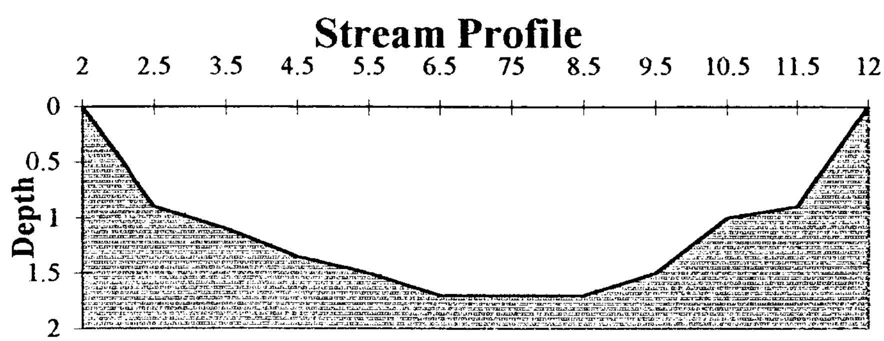
| Name of Macroinvertebrate Order | Number of different kinds | Number of Individuals |
|---|---|---|
| Mayflies | 3 | 20 |
| Stoneflies | 0 | 0 |
| Caddisflies | 1 | 5 |
| Krill | 1 | 5 |
| Leaches | 1 | 5 |
| Boatman | 1 | 1 |
| Watermite | 1 | 3 |
| snails | 2 | 5 |
| diptera | 1 | 1 |
| | | |
| | | |

## ***Total***

| ***Measure*** | ***How to calculate*** | ***Enter Answer*** |
|---|---|---|
| *Mayfly Richness* | Count number of diferent kinds of Mayflies | 3 |
| *Stonefly Richness* | Count number of diferent kinds of Stoneflies | 0 |
| *Caddisfly Richness* | Count number of different kinds of Caddisflies | 1 |
| | | |
| *Mayfly/Stonefly/Caddisfly Richness* | Add number of different kinds of Mayflies/ Caddisflies/ Stoneflies | 4 |
| | | |
| *Taxa Richness* | Count number of different kinds of macroinvertebrates | 11 |
| | | |
| *Macroinvertebrate Abundance* | Count number of individual macroinvertebrates of all kinds | 44 |

## *Squaw Creek Education Project*
## *Field Station Summary Sheet*

| | | |
|---|---|---|
| *Site # :* | IF | October 23, 1998 |
| *Station # :* | 1 | IF |
| | | **Water Quality Data** |
| *Water Temperature:* | 38°F | HACH |
| *Hach pH* | 7.5 | 9 |
| | | **Water Flow Data** |
| *Flow (cfs):* | 3 | 10 |
| *Average Stream Depth (ft) :* | 1.34 | 7.49 |
| *Wetted Area (cu ft)* | 13.35 | |




## ***Macroinvertebrates***

| | *Total* |
|---|---|
| *Mayfly Richness* | 3 |
| *Stonefly Richness* | 0 |
| *Caddisfly Richness* | 1 |
| *Mayfly / Stonefly / Caddisfly Richness* | 4 |
| *Taxa Richness* | 11 |
| *Macroinvertebrate Abundance.* | 44 |

## Squaw Creek Data Sheet

1998

| | | | | |
|---|---|---|---|---|
| Site Number | IF #2 | | Date | 10/.23/98 |
| Station Number | 2 | | Teacher | Robertson |

## Water Quality Worksheet

| | | | | | |
|---|---|---|---|---|---|
| Water Temperature (°F) | 38 | Hach pH | 7 | DO (ppm) | 10 |
| E. coli sample taken (y/n): | n | PhotoPoint (y/n): | y | D.O. method: | HACH |

## Flow Worksheet

| Stream Width (ft) | | 10 | Measured Flow (CFS | | 3 | |
|---|---|---|---|---|---|---|
| # | Distance on tape (ft) | Cell Width (ft) | Depth (ft) | velocity (f | area (sq ft) | discharge |
| Bank | 2 | | 0 | | | |
| 1 | 2.5 | 1 | 0.9 | 0 | 0.9 | 0.00 |
| 2 | 3.5 | 1 | 1.1 | 0 | 1.1 | 0.00 |
| 3 | 4.5 | 1 | 1.4 | 0.2 | 1.4 | 0.28 |
| 4 | 5.5 | 1 | 1.6 | 0.5 | 1.6 | 0.80 |
| 5 | 6.5 | 1 | 1.7 | 0.8 | 1.7 | 1.36 |
| 6 | 7.5 | 1 | 1.7 | 0.5 | 1.7 | 0.85 |
| 7 | 8.5 | 1 | 1.7 | 0 | 1.7 | 0.00 |
| 8 | 9.5 | 1 | 1.5 | 0 | 1.5 | 0.00 |
| 9 | 10.5 | 1 | 1 | 0 | 1 | 0.00 |
| 10 | 11.5 | 1 | 0.9 | 0 | 0.9 | 0.00 |
| Bank | 12 | | 0 | | | |

## *MacroInvertebrate Field Datasheet*

| | | | |
|---|---|---|---|
| Site # : | IF #2 | Teacher Name | 2 |
| Station #: | 2 | Field Date | 10/.23/98 |

***Pools, Side channels. Stream Bank Habitats***

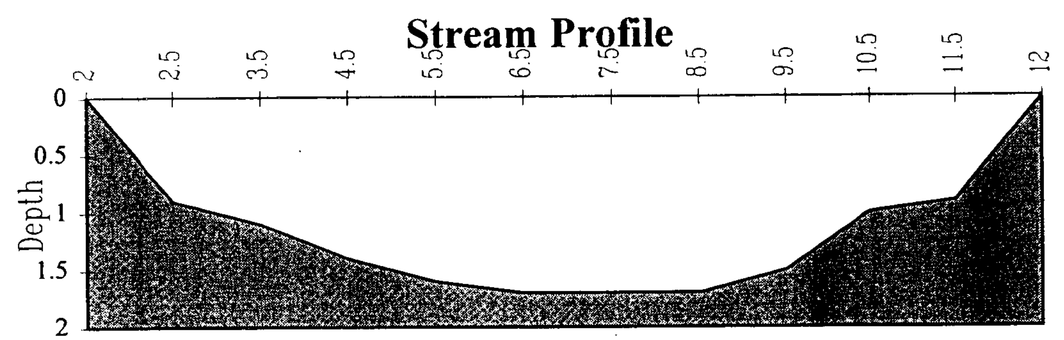
| Name of Macroinvertebrate Order | Number of different kinds | Number of Individuals |
|---|---|---|
| Mayflies | 3 | 6 |
| Stoneflies | 0 | 0 |
| Caddisflies | 2 | 4 |
| Leaches | 1 | 8 |
| Freshwater Krill | 1 | 2 |
| Stoneflies | 1 | 1 |
| Snails | 2 | 30 |
| Mite | 1 | 1 |
| | | |
| | | |

## ***Total***

| *Measure* | *How to calculate* | *Enter Answer* |
|---|---|---|
| *Mayfly Richness* | Count number of diferent kinds of Mayflies | 2 |
| *Stonefly Richness* | Count number of diferent kinds of Stoneflies | 0 |
| *Caddisfly Richness* | Count number of different kinds of Caddisflies | 2 |
| | | |
| *Mayfly/Stonefly/Caddisfly Richness* | Add number of different kinds of Mayflies/ Caddisflies/ Stoneflies | 5 |
| | | |
| *Taxa Richness* | Count number of different kinds of macroinvertebrates | 11 |
| | | |
| *Macroinvertebrate Abundance* | Count number of individual macroinvertebrates of all kinds | 52 |

## *Squaw Creek Education Project*
## *Field Station Summary Sheet*

| | | |
|---|---|---|
| *Site # :* | IF #2 | 10/.23/98 |
| *Station # :* | 2 | IF #2 |
| | ***Water Quality Data*** | |
| *Water Temperature:* | 38°F | HACH |
| *Hach pH* | 7 | 10 |
| | ***Water Flow Data*** | |
| *Flow (cfs):* | 3 | 10 |
| *Average Stream Depth (ft) :* | 1.35 | 7.41 |
| *Wetted Area (cu ft)* | 13.5 | |




### ***Macroinvertebrates***

| | *Total* |
|---|---|
| *Mayfly Richness* | 2 |
| *Stonefly Richness* | 0 |
| *Caddisfly Richness* | 2 |
| *Mayfly / Stonefly / Caddisfly Richness* | 5 |
| *Taxa Richness* | 11 |
| *Macroinvertebrate Abundance.* | 52 |

# Analysis and Conclusion of Data Collected

## Analysis:

This analysis isn't going to be very accurate due to lack of data. There are only two different sets of data that have been collected at this point in time. These two sets of data were taken on September 25, 1998 and the other on October 23, 1998. The flow rate nearly doubled in that time span. This could be because the season was changing or because of the change in allocated water in the irrigation canals when people stop irrigating. Another possible reason is because of an increase in rainfall. Also, the dissolved oxygen (DO) went up 2.3 $_{PPM}$, which is quite a considerable amount. Perhaps this was because of the flow rate rising.

Testing was also done on the macroinvertebrates each time. The difference between the two sets of data was that the second time there were 185 fewer aquatic insects. Again, this may be due to the change in the season, but more likely due to less effort by the students during the second test. The temperature of the water dropped ten degrees probably because of the weather. The pH (parts hydrogen) stayed about the same. One test result had a pH result of 7.5 and the other had a result of 7.5. The Wetted Area ($ft^2$) went up slightly, but not too much.

## Conclusion:

Again, any conclusions may not be valid due to the lack of data at this point in our study. It would seem the living conditions for a better salmon population at sites four and five were helped by the inflow of Indian Ford Creek upstream. This might be said because at Site 3, the last one above Indian Ford Creek, the temperature there is about 4 -10 degrees higher than sites 4 and 5, the two sites immediately dowstream of the tributary of Indian Ford Creek. Also, the pH levels at sites 4 and 5 are more suitable to a salmon habitat. To have a more accurate conclusion, there needs to be more data collected and analyzed.

1)

2)

# Appendix E

## Squaw Creek Monitoring

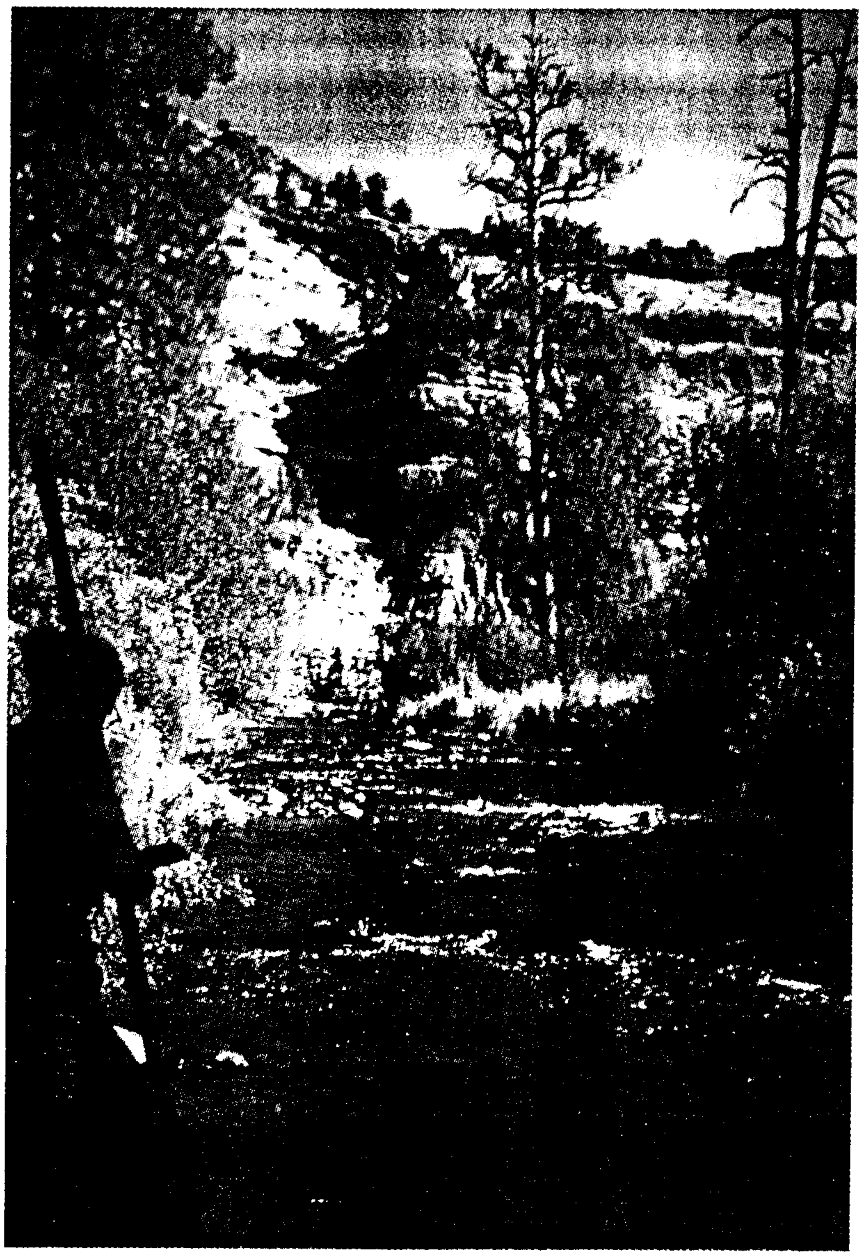
## Stream Habitat Survey Summary

USFS and ODFW Reports

# SQUAW CREEK STREAM SURVEY HABITAT SUMMARY

## DESCHUTES NATIONAL FOREST
## AND
## OREGON DEPARTMENT OF FISH AND WILDLIFE

1997



# Squaw Creek Stream Survey Habitat Summary

Nathaniel S. Dachtler
Fishery Biologist

USDA Forest Service
Deschutes National Forest
Bend, OR 97701

Jennifer L. Burke
Experimental Biology Aide

Oregon Department of Fish and Wildlife
Aquatic Inventories Project
Bend, OR 97702

January 23, 1998

## Basin Overview

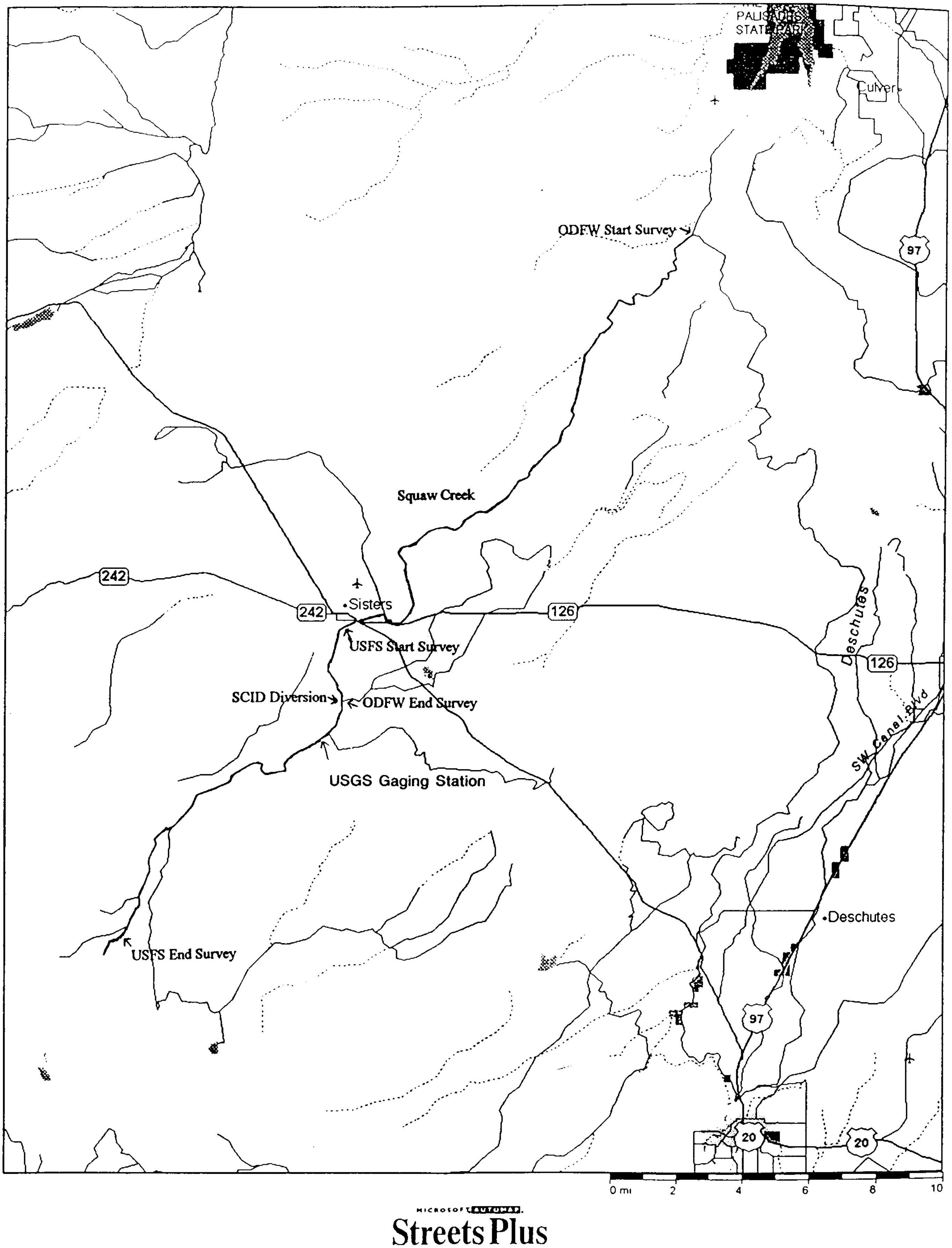
In the summer of 1997, the United States Forest Service (USFS) and Oregon Department of Fish and Wildlife (ODFW) surveyed aquatic habitat on Squaw Creek. ODFW was responsible for the lower portion extending from the confluence with the Deschutes River to the Squaw Creek Irrigation District (SCID) diversion located approximately 1.7 kilometers west of Sisters. USFS continued the survey from the irrigation diversion to Squaw Creek Falls. In order to compare the two types of survey methods used by each agency, a section of overlap between the two surveys was conducted (Figure 1).

Squaw Creek basin encompasses three land use management areas; Crooked River Grasslands (USFS), private property, and Deschutes National Forest. Habitat can be examined according to these three management areas. The sections in the Crooked River Grasslands and Forest Service lands above the SCID diversion contain potentially good spawning and rearing habitat. The private portions and the USFS section below the SCID Diversion have been altered and are in need of restoration. Overall, in-channel large wood volume is very low in the Crooked River Grassland, private property, and the lower portion of the USFS survey. From the USGS gaging station (# 14075000) to Squaw Creek Falls, adequate wood is present and the habitat is primarily intact.

Below the SCID Diversion, flow and temperature are an issue. From the mouth to Alder Springs, heavy spring inflow helps maintain a steady water flow, however temperatures may be limiting. From Alder Springs to the SCID diversion, temperature and water flow were the main limiting factors for fish. The section between SCID Diversion and the USGS gaging may be limited by water temperature. Above the USGS gaging station, water flow and temperature were in satisfactory condition with the exception of Pole Creek, a tributary that was entirely diverted before it entered Squaw Creek.

Both agencies conducted single pass fish surveys using a combination of electrofishing and snorkeling techniques. Redband trout were found throughout the survey except in the last unit just below Squaw Creek Falls. Brook Trout were only observed on the private property just above the Crooked River Grasslands and near Squaw Creek Falls. They may be present at low densities throughout the system. Brown trout were found from the mouth of Squaw Creek up to the lower sections of private property. Sculpin (species including Paiute sculpin) were observed in the Crooked River Grasslands and extended above the USGS gaging station (Reach 3, USFS). Longnose dace were found from the Crooked River Grasslands to below the SCID diversion. Whitefish were found at the mouth of Squaw Creek (Reach 1, ODFW). Trout fry were observed from the Crooked River Grasslands (Reach 2, ODFW) to below Forest Service road 1514 (Reach 4, USFS). In the Grasslands, fry were found in close association to the springs, particularly Alder Springs. Suckers, including bridgelip sucker, were found in the Crooked River Grasslands and the lower portion of private property.

# Figure 1. Habitat Survey Map of Squaw Creek.



**ODFW Survey Summary**

Crooked River Grasslands

The Crooked River Grasslands encompasses the lower 11.3 kilometers of Squaw Creek and its tributaries. This coincides with reaches 1 and 2 of the ODFW survey. Recreation was the primary land use. Grazing in the area was discontinued approximately 11 years ago and an old partial-cut timber area was present in reach 2. The channel was constrained, primarily by bedrock, in a steep valley. No fish barriers or diversions existed in this section. In reach 1 stream flow was constantly fed by numerous springs extending from the Alder Springs area to the mouth of Squaw Creek. The springs maintained a steady temperature input of 12°C. Above Alder Springs, spring inflow diminished such that stream flow decreased dramatically. Consequently, temperatures approached 23°C at 1.7 km above Alder Springs and 26°C in reach 2. The riparian consisted of alder, ponderosa pine, juniper, grasses and shrubs. Several sections of the riparian had been scoured from floods in previous year but it was generally intact and stabilizing.

The average gradient was 1.7% in reach 1 and 1.0% in reach 2. The dominant habitat unit for both reaches was riffles (59%). Gravel and cobble were the dominate substrate types. Percent silt was low (6% and 7%). Several instances of full channel bedrock were present where the channel was constrained by bedrock. Percent bedrock was 18% and 12%. Residual pool depth ranged from 0.74 meters in reach 1 to 0.61 meters in reach 2. Woody debris cover was lacking with low wood volume (1.8 and 4.3 $m^3$/km). Bank stability was very good at 99% of the habitat units had either non-erodible, vegetative, or boulder-cobble stabilized banks. Habitat diversity in reaches 1 and 2 contributed quality spawning and rearing habitat.

Private Property

Above Crooked River Grasslands, Squaw Creek flowed through private property for 24.8 kilometers including Sisters State Park and a portion of Deschutes National Forest. Reaches 3 through 12 address this section. Reaches 4, 6, 8, and 10 were unsurveyed due to no access. Two reaches, 7 and 9, were less than 1 kilometer in length. The channel is largely unconstrained in a broad valley. Land use consisted of light grazing in reaches 3 and 5, agriculture in reaches 5 and 7, and residential in reaches 7 through 11. Reach 12 consisted primarily of large timber. The average gradient was between 0.8 and 1.5%.

In past years, Squaw Creek typically goes dry below the town of Sisters. Water flow was present throughout the survey, however this was due to an above normal snow pack in the headwaters of Squaw Creek. The only named tributary, Indian Ford Creek, contributed approximately 30% flow in reach 9, however, above the confluence flow was limiting in reaches 9 and 11. Stream temperatures ranged from 12°C to 19.5°C. Indian Ford Creek's temperature was higher (21°C) than that of Squaw Creek (19°C above confluence). Five small springs or unnamed tributaries contributed from 1 to 5% flow at 15°C throughout the private property section. Five diversions were noted, one of which was screened.

Riffles were the dominant habitat types in all reaches. With the exception of Reach 11, riffles accounted for more than 60% of the percent area in all reaches. Scour pools were the secondary habitat type found most frequently, with the greatest percentage in reaches 11 and 12 (31-24%). Reach 11 had 14.4 pools/km, the most of all the reaches. Reach 12 had the second highest number of pools/km (9.8). Gravel and cobble were the dominant substrate type. Silt remained below 8% throughout the survey. Very little bedrock was present with the highest percentage in reach 12 at 5%. Residual pool depth ranged from 0.53 to 0.75 m. The width to depth ratio increased as the survey continued upstream. This was largely due to dewatering. Wood volume continued to be low throughout this section.

ODFW rated bank stability as a percentage of the reach length based on a ranking of each habitat units bank as either stable or actively eroding. In reaches 3 and 5, bank stability was from 61% and 66%. Reach 7 had 90% bank stability. In reaches 9 and 11, bank stability fell slightly to 76% and 73%, and then down to 31% in reach 12. After the flood of 1964, the Army Corps of Engineers dredged, straightened, and channelized (cobble levees) reaches 9 through 12. Bank instability and lack of undercut banks were due to continual migration of the stream in an effort to reestablish its channel to its former sinuosity. Sections of channelization were found in the form of boulder rip rap and fill.

**USFS Survey Summary**

The U.S. Forest Service surveyed six reaches from the road 16 crossing in the town of Sisters to Squaw Creek Falls (river mile 20.6 to 34.4).

Reach one was effected by five irrigation withdraws. This resulted in higher temperature and fluctuations in available habitat. A maximum temperature of 19.3 °C was recorded by a Hobo temperature data logger during the month of August. This section was surveyed once in April at 29 cfs and again in August at 7 cfs (IFIM) at Sisters State Park. Both main and off channel habitats shrank at lower flows. The reach had 16 pools/kilometer at 29 cfs which was much higher than any of the other reaches. Low numbers of medium and large sized wood (8 pieces/ kilometer) was probably a result of wood removal to protect diversion and bridge structures. Wood may have been removed during the channel straightening done after the 1964 flood by the Army Corps. Recent flood events had caused banks to erode thus recruiting several new trees into the stream. The highest percent of unstable banks (13%) was found in this reach. Rip rap covered 4% of the banks mainly around Sisters and diversion structures. Gravel berms from channel straightening existed along 14% of the streams banks.

Reach two shows sign of past management practices. Two diversions exist in the reach and a few bermed areas still existed from the Army Corps channelization project after the 1964 flood. The reach had 6.7% unstable banks and this was only higher than reach one. Riffle habitat dominated (90%) and the reach was lacking in large woody debris (7 pieces/kilometer). Wood deficiencies may be partly due to the earlier channel straightening efforts. Parts of this reach and the first three quarters mile of reach three was burned by a wildfire in 1959. The burn was salvaged, in some cases right down to the stream, leaving few trees for future recruitment. A hobo temperature data logger recorded a maximum temperature of 14.8 °C during the month of August.

Reach three was incised in a canyon and bedrock has helped to form many of the pools. Habitat was dominated by riffles (94%) but boulders and bedrock provide pocket water refuge. This reach had the highest number of boulders greater than one meter in diameter (214 per kilometer). Suitable spawning areas were available in some of the pool tail-outs. A falls (2.1 meters high) created by large boulders and wood may be a potential fish migration barrier. The surrounding forest was primarily intact but plantations and recent cutting could be seen on the ridge tops above the canyon. Sufficient levels of medium and large wood (19 pieces/kilometer) were found in the reach with the majority (44%) of these pieces located in debris jams (>4 pieces). Single pieces of wood dominated all other reaches, except reach four.

Reach four had a lower gradient than reach three and was dominated by riffles (89%). It had the highest amount of off channel pools which are important fry rearing areas. Good potential spawning sites were available in this reach. Suitable numbers of large and medium sized wood (30 pieces/kilometer) were found in this reach. Wood accumulations(2-4 pieces) were the dominate configuration type (45%). The surrounding forest was intact but signs of past harvesting could be seen. In one location old stumps and dirt were sloughing off into the stream. This helped contribute to the reaches relatively high amount of unstable banks (5.9%). A Hobo temperature data logger recorded temperatures from April to July. The maximum temperature for this period was 11.3 °C in July.

Reaches five and six were in good condition. Riffles dominated the habitat (97% and 91%) and medium and large size woody debris (23 and 29 pieces/kilometer) were sufficient. There was a lack of suitable spawning habitat because in several locations sheets of bedrock substrate covered the entire stream bottom for several hundred meters. Trout were seen holding in pocket pools situated in these bedrock riffles. Reach six ended at Squaw Creek falls which is approximately 16-17 meters high. This fall was definitely a fish barrier. At this point the stream was reduced to about 32% of its original flow.

Several tributaries entered in this section. These included Pole Creek (reach 3), Snow Creek (reach 4) and North Fork Squaw Creek (reach 5) and South Fork Squaw Creek (reach 6). Ten other smaller unnamed tributaries ranging from a trickle to a few cfs were found. Snow Creek and North Fork Squaw Creek may have had some potential spawning areas for redband trout and steelhead. Pole Creek had a 2.4 meter falls at the confluence that may only be passable at high flows. The lower half kilometer of Pole Creek was almost entirely diverted during the summer months.

## Summary of the Reach Comparison between ODFW and USFS Surveys

Reach 12 (plus a portion of reach 11) in the ODFW survey and reach 1 in the USFS survey are the same reach used for comparison of the two surveys methods. The reach extends from Forest Service road 16 crossing to the SCID diversion dam, approximately 4.5 kilometers. The reach is a mixture of both private and Forest Service property.

There are four diversion dams, all of which are potential fish barriers. The lower two had secondary channels which may permit passage at high flows. The second of these two had a temporary cobble dam at the top which may be impassable during irrigation withdraw. Another potential barrier was an old diversion/bridge structure (1.7 meters high) approximately 80 meters below the SCID diversion dam. No alternate passage was provided. The SCID diversion dam was also a potential barrier (1.2 meters high). A fish ladder was present on the east side of the dam but it was lacking water flow in the upper portion.

Flow estimates at SCID diversion were provided by the Oregon Department of Water Resources at the time of the surveys. The Forest Service survey was conducted on August 26 and 28, with flows at 20.8 and 16.8 cfs. The ODFW survey was done on September 8 and 9, with flows at 10.8 and 9.8 cfs. This difference may have accounted for slight discrepancies in the data. Modification of the data for the purpose of comparison was necessary and was noted (Appendix A).

### Aquatic Habitat

The reach length and total number of main channel habitat units was slightly greater for the USFS survey than ODFW survey (Table 1). Temperatures found by ODFW were two degrees higher and might be attributed to reduced flows during their survey. Percent area of main channel pools was larger for ODFW possibly due to the larger grouping of pool habitats based on the fewer number of individual pools. ODFW estimated 52 more boulders (greater than 0.5m in diameter) than the USFS. Percent undercut banks were estimated to be slightly greater by ODFW (Table 2).

TABLE 1. Comparison of habitat surveys.

| Agency | Survey Dates | # of Main Channel Units | Reach Length in meters | Maximum Temps. °C |
|---|---|---|---|---|
| ODFW | 9/8 and 9/9 | 112 | 4277 | 15.5 |
| USFS | 8/26 and 8/28 | 125 | 4588 | 12.5 |

TABLE 2. Comparison of habitat attributes.

| Agency | % Area of Main Channel Pools | % Area of Main Channel Riffles | # of Boulders >0.5 meters | % Undercut Banks |
|---|---|---|---|---|
| ODFW | 35.8 | 61.4 | 610 | 10 |
| USFS | 27.4 | 72.4 | 558 | 7 |

## Habitat Characteristics

Habitat characteristics such as the number of pools greater than 1 meter depth, residual pool depth, average wetted width, and average bankfull width (active channel) were found to be close in comparison to one another (Figure 2).

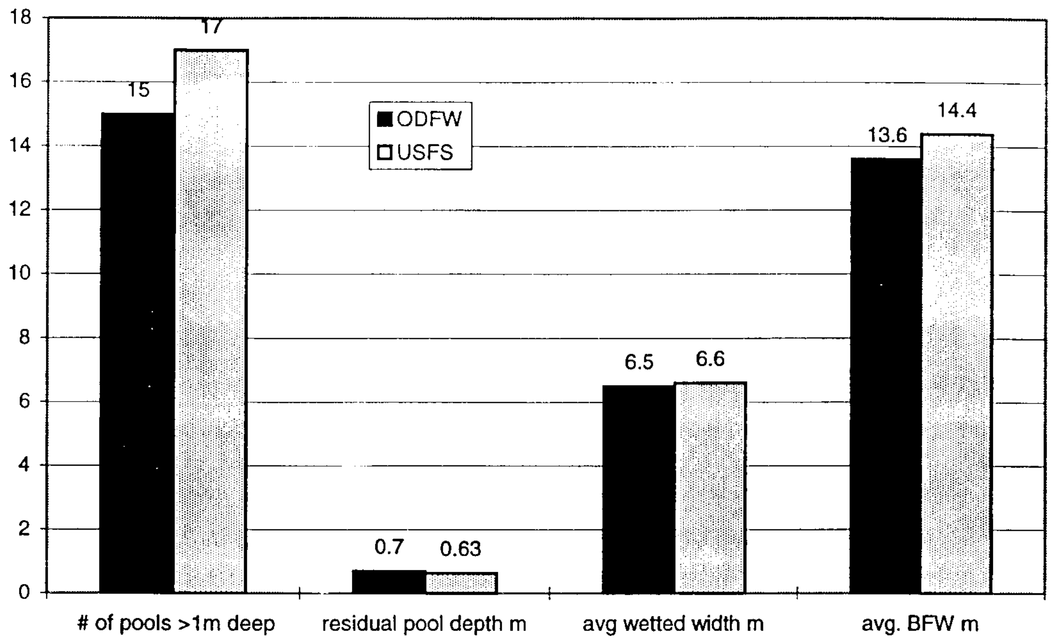



Figure 2. Comparison of pool and riffle characteristics.

## Woody Debris

All woody debris counted was consistent in comparison in that ODFW accounted for slightly more pieces of wood than USFS (Figure 3). This may be due to differences in estimation of wood size and method of determining where the diameter is estimated. In addition, different methods are utilized for accountable wood. Modification of ODFW data was necessary in order to compare the wood classes.

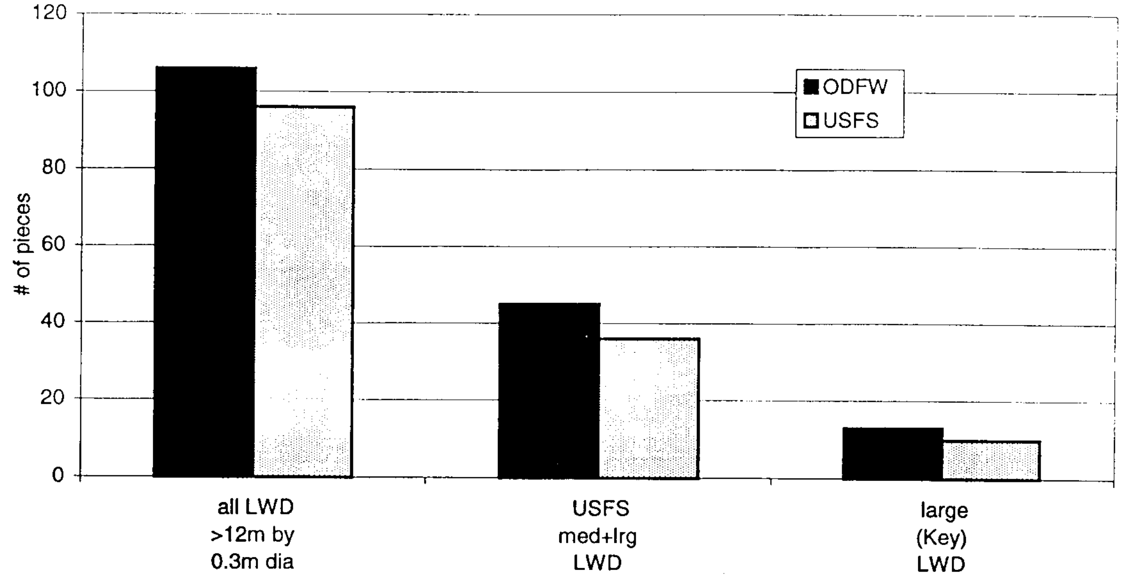



Figure 3. Comparison of different sized woody debris.

## Substrate

USFS duplicated this reach survey first in April, and then again in late August. Both of the USFS surveys were conducted by the same observer and the substrate estimates were within 2% of each other. ODFW estimated higher amounts of sand and smaller material, as well as boulder and bedrock. USFS estimated higher percentages of gravel and cobble. Both agencies found gravel and cobble to be the dominant substrate sizes, followed by sand (Figure 4).

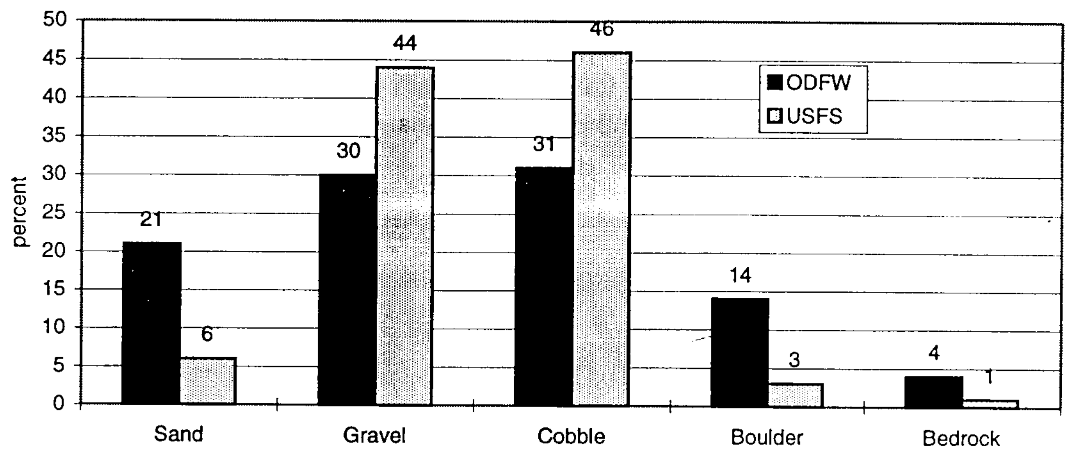



Figure 4. Comparison of estimated substrate.

APPENDIX A: COMPARISON OF ODFW AND USFS 1997 SURVEY METHODS

| | ODFW | USFS |
|---|---|---|
| | Active channel width | Bankfull width |
| Area % pools | % pool + glides | % pools |
| Area % riffles | % fast waster units less secondary channels | % riffles |
| Sand | Sand, silt, and organic material | Sand |
| Pieces of wood | Excluded root wads and 3m length class | All measured pieces of wood |
| Medium and large wood | Wood in 0.6m dbh and 12m length class | Medium and large wood size class |
| % undercut | % undercut | % undercut |
| Bank stability | % of reach length based on ranking the total length of each habitat units bank. | % of reach length |

# Squaw Creek

## Modified Level II Stream Inventory

### Deschutes National Forest - Sisters Ranger District
**Funding Provided in Part by Portland General Electric**

**1997**

| | |
|---|---|
| Dates surveyed: | Apr. 3-8 (reach 1), Aug. 26-Sept. 8 (reach 1), and Sept. 15th-Oct. 9 (reaches 2-6) |
| Observer: | Nate Dachtler |
| Recorder(s): | Brad Houslet (reach 1) and Jens Lovtang (reaches 2-6) |
| Report Prepared By: | Nate Dachtler |
| NFS Watershed Code: | 17, 07, 03, 01, NFS, 93, B |
| Mouth Location: | T13S R12E SO7 NE1/4 |
| USGS Quadrangles: | Sisters, Three Cr. Butte, Trout Cr. Butte, Broken Top, South Sister, and North Sister |
| Tributary To: | Deschutes River |
| County and State: | Deschutes, OR |
| Stream Length (map): | 40 miles |
| Distance Surveyed (map): | 16.3 miles, River Mile 20.6 to 34.4 |
| Actual Distance Surveyed: | 18.7 miles (reach 1 surveyed twice) |
| Watershed Area (surveyed area): | 48,310 acres |

| | Reach 1 #1 | Reach 2 | Reach 3 | Reach 4 | Reach 5 | Reach 6 |
|---|---|---|---|---|---|---|
| Rosgen Classification: | C | C | B | C | B | B |
| Average Riffle Width: | 30 ft | 42 ft | 32 ft | 35 ft | 33 ft | 30 ft |
| Width to Depth Ratio: | 21.9 | 26.3 | 18.3 | 21.4 | 16.7 | 12.7 |
| Entrenchment Ratio: | 1.6 | 1.4 | 1.4 | 1.3 | 1.3 | 1.3 |
| Sinuosity (map): | 1.1 | 1.0 | 1.2 | 1.1 | 1.0 | 1.1 |
| Percent Gradient (map): | 0.9 | 0.7 | 3.0 | 1.8 | 3.1 | 3.8 |

| | |
|---|---|
| Stream Order: | $4^{th}$ |
| Stream Class: | I |
| Game Fish: | redband trout *(Oncorhynchus mykiss gairdneri)*<br>brook trout*(Salvelinus fontinalis)* |
| Non Game Fish: | sculpin *(Cottus sp.)*<br>longnose dace *(Rhinicthys cataractae)* |
| Amphibians Observed: | cascade frog *(Rana cascadae)* |

## Executive Summary


An aquatic habitat survey was conducted this summer on Squaw Creek using United States Forest Service (USFS) level II protocol with some additions. The surveyed section extended from the town of Sisters to the first major falls within the Three Sisters Wilderness boundary. It was divided into six reaches based on geomorphic and geographic differences. The stream was surveyed to determine the condition of the aquatic habitat and the distribution of fish species present. Squaw Creek was last surveyed in 1990 (Riehle) and some comparisons between the two surveys are included in this report. Oregon Department of Fish and Wildlife (ODFW) surveyed the section from the mouth to the Squaw Creek Irrigation District (SCID) diversion. This included a portion of overlap with the USFS survey. Data from the overlap portion was compared in a cooperative summary report.

Squaw Creek is designated a wild and scenic river from the McAllister ditch (R.M. 25) to its headwaters (R.M. 39.4). The last spawning summer steelhead was documented in 1964 - 1965 (Nehlson). The stream currently supports a population of native redband trout. These fish were mainly <10 inches in length. Brook trout were also present in small numbers.

The stream was dominated by riffle habitat with mostly cobble and gravel substrate. Bedrock was prevalent in reaches 3, 5 and 6. Boulders (>3.3 feet dia.) were most abundant in reach 3. Only 109 main channel pools were found in 18.6 miles of stream, nearly half of these were located in reach 1. Large wood was limited in reaches 1 and 2 due to wood removal, channelization and poor recruitment potential in the Squaw Creek burn area. Reaches 3-6 had >30 pieces of large wood/mile. Temperatures in reach 1 exceeded the 17.8 °C requirement for adult salmonids for ten days during the summer (DEQ 1996).

Reach 1 has been altered by channelization projects and irrigation withdraws. As a result 12-13% of the banks were unstable and eroding, 14% of the banks were bermed and 4% were rip-rapped. Reach 1 was surveyed at two different flows in order to document habitat changes. At moderate flow (29 cfs) it had 15% less main channel pool habitat but 65% more off channel pools. At low flow (7 cfs), riffle area decreased 34% and total main channel habitat area decreased 25%. Reach 2 has two diversions and Pole Creek is diverted before its confluence in reach 3.

Annual peak flows occur during spring melt off from May to July. The highest flow on record was 2,000 cfs on December 25, 1980. Squaw Creek has experienced three events in the last 30 years near the 100 year flood stage. Carver Lake a glacial lake in the upper watershed, could create a potential flood of up to 9,800 cfs if its moraine dam washes out.

If summer steelhead are to be reintroduced, it seems crucial that sufficient instream flow be established below Sisters to maintain lower water temperatures, improve spawning success and provide upstream passage. Additional flow would also greatly benefit the redband trout population below the SCID diversion.

## Watershed Issues

The primary watershed issues lie in reaches 1 and 2. Reach 1 has five irrigation diversions that can completely dewater the stream during the summer. Only the Sokel diversion is reportedly screened for fish. The SCID diversion is entitled to take up to 181 cfs if the flow in the stream permits, while still providing water for the other ditches. The stream is water quality limited below the SCID diversion due to temperature increases and low levels of dissolved oxygen. Reach two has three diversions that are not screened for fish.

Other issues in reach 1 and parts of reach 2 were the result of channelization by the Army Corps of Engineers. They bulldozed and constructed gravel berms along eleven miles of the stream in several areas after the 1964 flood (Army Corps 1978). Boulder rip-rap along the stream bank was common around the major diversions and near the town of Sisters. Recent flood events have caused the stream to work towards regaining its old flood plain. This has resulted in several of the berms being breached. The stream banks are being downcut in several areas causing active bank erosion and delivering sediments to the stream. The accelerated bank erosion caused several large Ponderosa pines and cottonwoods to fall in and around the channel increasing large wood recruitment. Private landowners along the lower end of the reach periodically clean wood from the channel on their land in order to protect bridges and diversion structures. The riparian zone in reach 1 was unable to fully establish itself because of reduced summer flows and high winter flows. Pole Creek, in reach 3, may have helped cool Squaw Creek before the diversion was put in place. Currently it is almost entirely diverted during the summer.

## Management Recommendations

1. Work with irrigators to reduce water loss in their ditches and consider the possibility of buying back water rights in order to restore some flow through the town of Sisters.
2. Work with irrigators to install fish screens on the diversion ditches, possibly using challenge cost shares funds to accomplish this.
3. Restore the stream in the channelized areas of reach 1 so that it is functioning properly. This will first require regaining a more stable flow regime throughout the summer.
4. Monitor dispersed camping along the stream in reaches 1 and 2. Consider closing some of the riparian roads, particularly those that ford the stream.

## Protocol

Current USFS 1997 level II stream survey protocol was used. All main channel habitat dimensions were measured. Side channel and off channel pool habitat was estimated. Our survey was linked with the survey completed this year by ODFW on lower Squaw Creek. Boulders >3.3 feet diameter were counted for each reach and boulders >1.6 feet diameter were counted in reach 1. Percentage of undercut banks was recorded for each habitat unit. Percentage of rip-rapped and bermed banks was estimated in reach 1. Some ODFW wood protocol was incorporated into our survey. Wood counted within the active flood channel was done using ODFW protocol. This allowed us to count wood suspended over the bankfull channel and asses wood by its location, debris type, and configuration. Hobo temperature data loggers were installed in 1997 at three locations along the stream. Temperatures were also taken approximately every hour with a calibrated hand held thermometer. In order to observe habitat changes at different flows reach one was surveyed at 29 and 7 cfs.

Fish sampling was completed using a combination of single pass electrofishing and daytime snorkeling techniques. Every tenth pool and fifteenth riffle habitat was sampled (Figures 3-5). Reach 1 was fish sampled twice because of the repeated habitat survey. When water clarity permitted snorkeling was more effective for larger trout. Electrofishing captured smaller trout and non-game species but was ineffective in the large pools due to low water conductivity. One pool was sampled twice on consecutive days using alternate methods. It yielded one small redband trout and a few sculpins from the shallows while electrofishing. Three larger 4-8 inch redband trout were observed snorkeling the same pool.

## Basin Overview

Squaw Creek has four major gradient changes that were used to differentiate the reaches. The stream within the surveyed section rose in elevation from approximately 3,200 feet to approximately 5,000 feet in 13.8 miles (Figure 1). The headwaters of Squaw Creek begin at the glaciers located on the eastern flanks of the Three Sisters and Broken Top. The major tributaries within the upper watershed are; North Fork Squaw Creek, South Fork Squaw Creek, Snow Creek, and Pole Creek (Figure 2). Several smaller unnamed tributaries also enter the system. The majority of Pole Creek is diverted during the summer. Southwest of Sisters eight diversions dewater Squaw Creek during the summer. About four miles downstream at Camp Polk springs add approximately six cfs. Indian Ford Creek enters below Sisters but much of its water is seasonally diverted. Squaw Creek then flows for several miles through a deep canyon located on both private land and the Crooked River National Grasslands. Approximately 70 cfs is contributed by Alder Springs, located about 1.5 miles above the confluence with the Deschutes River.

## Reach Descriptions

Reach 1: Sisters at Road 16 to Squaw Creek Canal, R.M. 20.6 to R.M. 23.1 (Figure 3)

Reach one started at the town of Sisters, had a low gradient and was dominated by cobble and gravel. It had a very wide floodplain in several areas. The riparian zone in this reach was generally sparse with mountain alder *Alnus incana*, black cottonwood *Populus trichocarpa* and willows *Salix sp.* being the dominant species. The outer forest was dominated by Ponderosa pine *Pinus ponderosa* with a few western junipers *Juniperus occidentalis*, Douglas firs *Pseudosuga menziesii*, and lodgepole pine *Pinus contorta*. The understory is mostly bitterbrush *Purshia tridentata*.

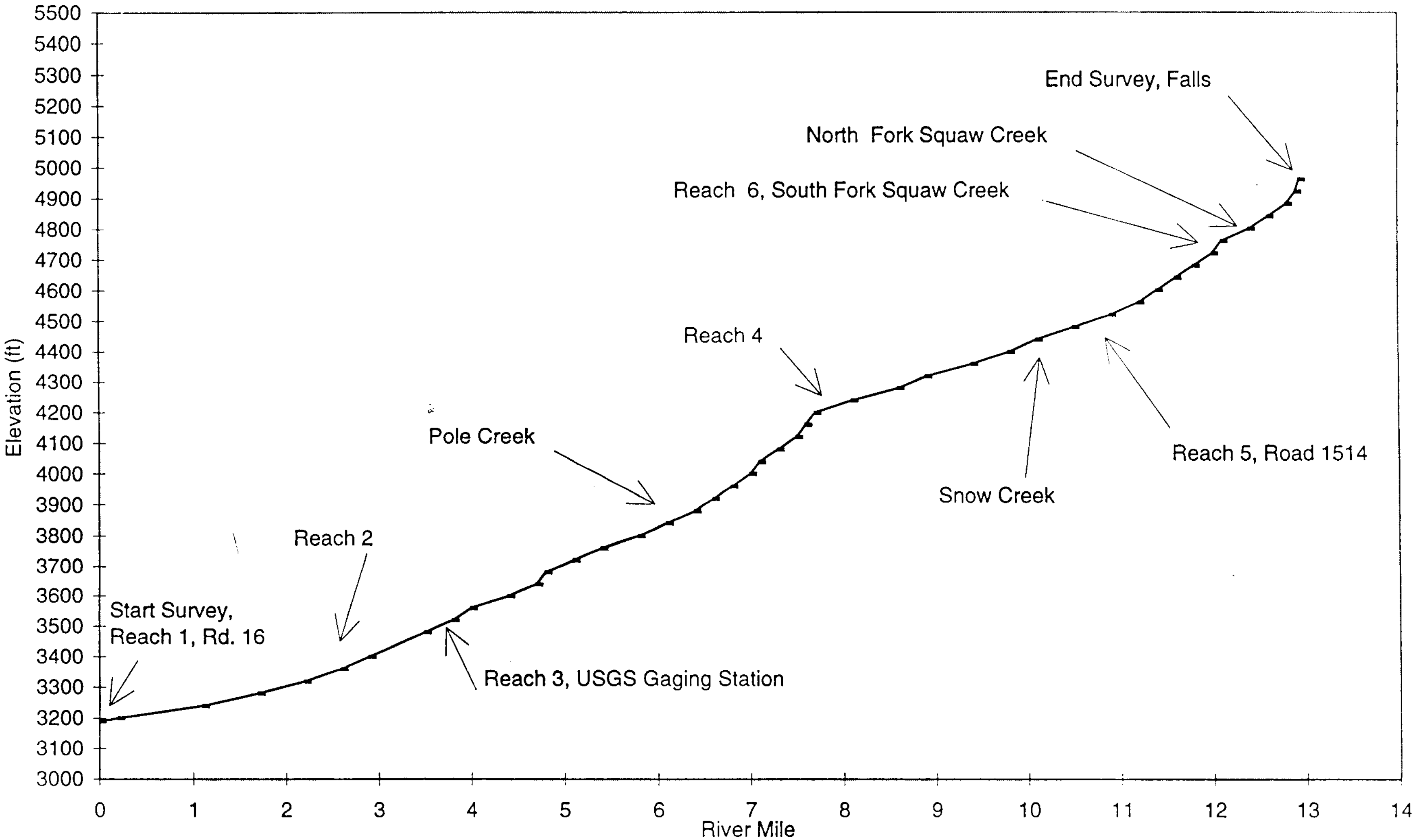
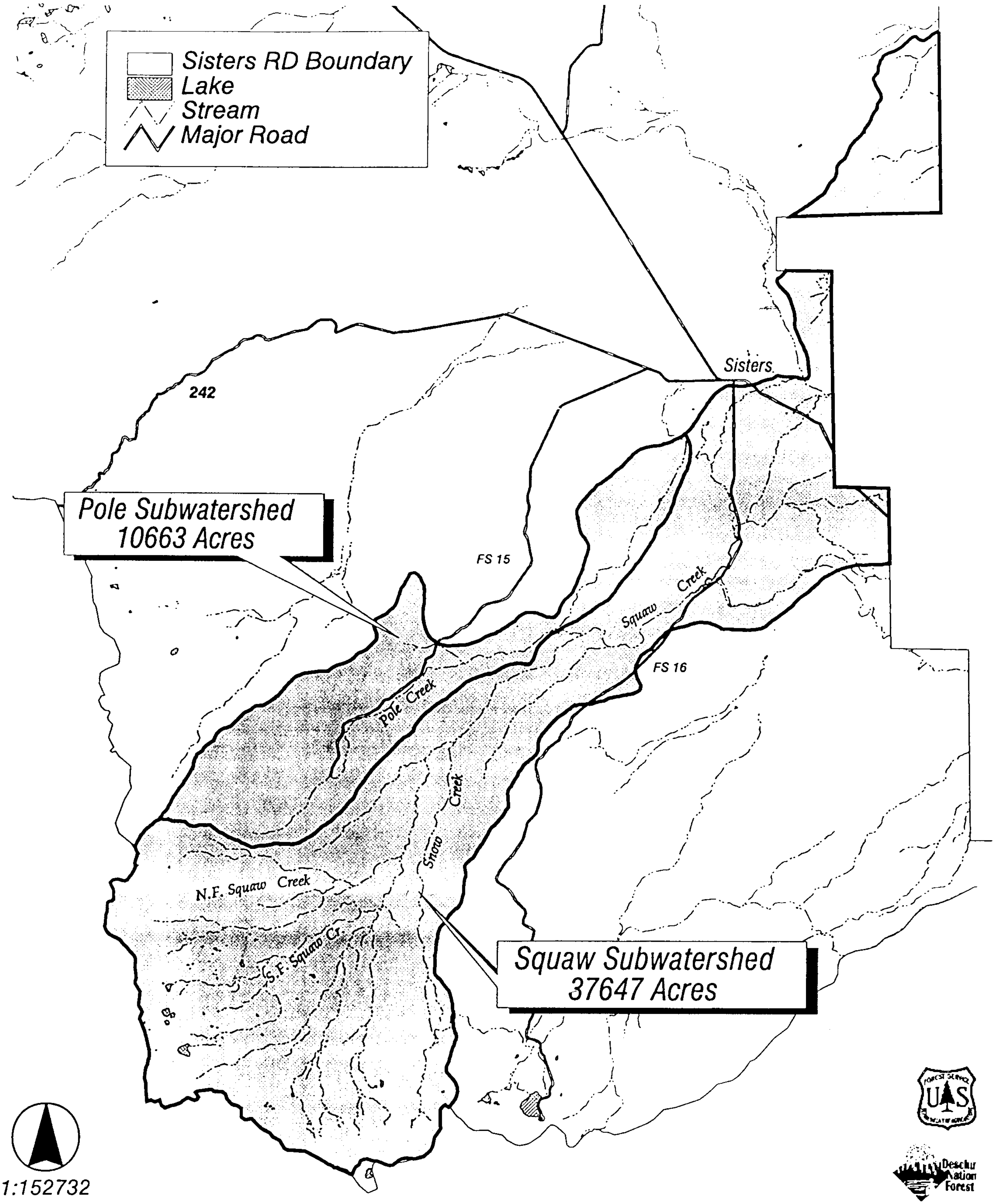



FIGURE 1. Elevational profile of Squaw Creek, Reaches 1-6

FIGURE 2

# Squaw and Pole Creek Subwatersheds



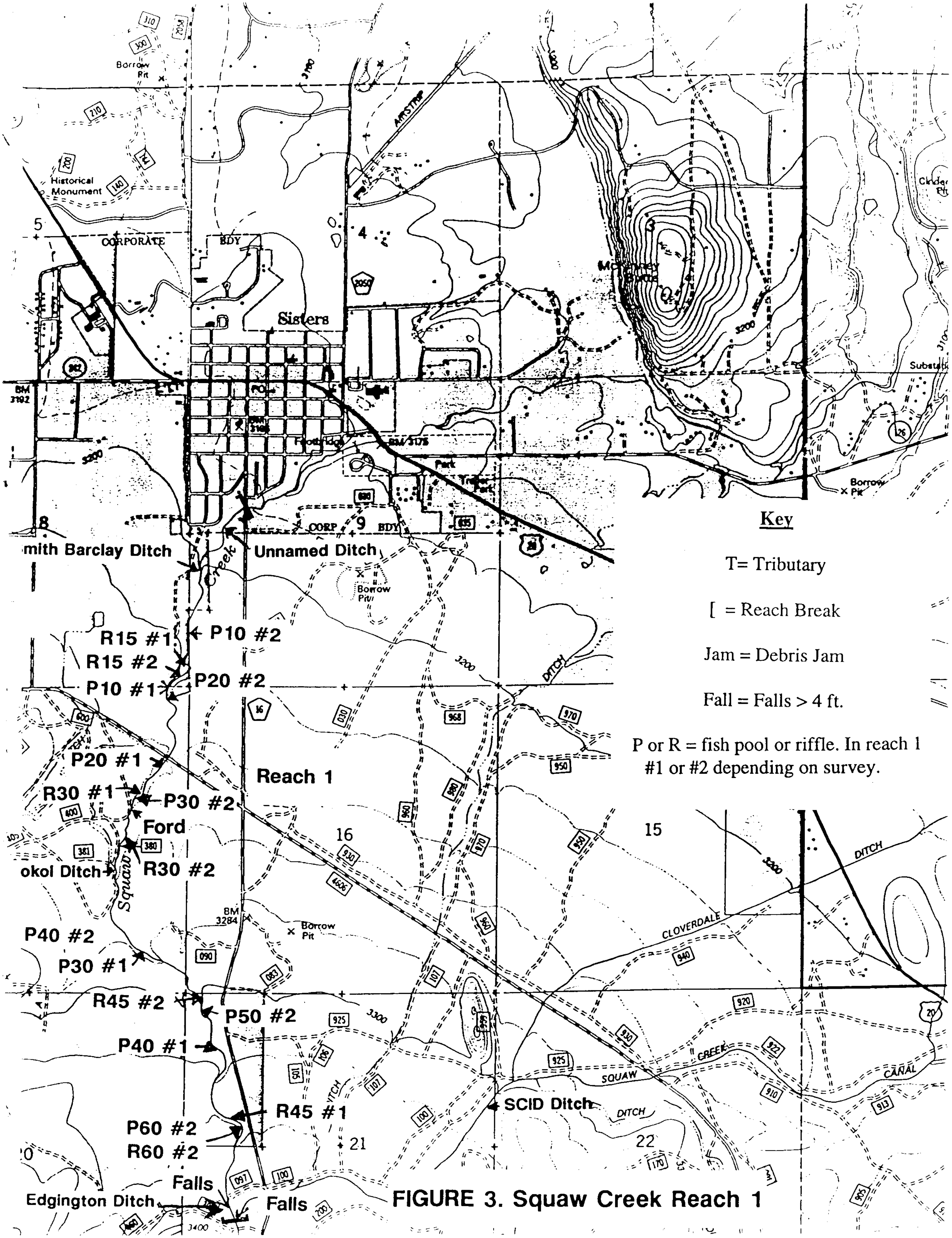



FIGURE 3. Squaw Creek Reach 1

This reach has a long history of disturbances starting in 1912 with the dewatering for irrigation. The current names of the diversion ditches are; Smith-Barclay, Sokol, Edgington, Cloverdale (SCID), and one is unnamed. After the 1964 flood the Army Corps of Engineers channelized this section for irrigation and flood control purposes. Recent flood events have caused the thalweg side of several bends to become highly eroded. Active sloughing of soils could be seen throughout this reach (Photo 1). The lack of older large wood was apparent but many new pieces of wood have been added during recent flood events. On the private land several logs had been removed from the stream and signs of fresh bulldozer tracks were observed during the survey. Pools formed around this new wood will probably disappear in the next few flood events now that the wood is absent. A Prescribed fire along the bank had burned up to the water edge resulting in damage to the riparian zone. Several four wheel drive roads and dispersed camps were found along the stream. Two of these roads forded the stream.

Reach 2: SCID diversion dam to USGS gaging station, R.M. 23.1 to R.M. 24.7 (Figure 4)

Reach two began at the SCID diversion, which is the largest diversion on Squaw creek, and can take the majority of the available water. The stream flows through a wide flood plain. Entrenchment was low, and it displayed features of deposition, active meandering, with in channel gravel bars, depositional terraces, and cut banks. The substrate was gravel and cobble dominated. Gradient was low at less than one percent. Riparian vegetation was primarily composed of a Ponderosa pine overstory, and a mountain alder understory. Besides, the SCID diversion, Lazy Z, Plainview and McAllister ditches divert water from the reach. Reach 2 ended at United States Geological Survey (USGS) gaging station number 14075000. Above this the stream becomes confined in a steep canyon.

Reach 3: USGS gaging station to end of confined channel, R.M. 24.7 to R.M. 29.3 (Figure 4)

Reach three begins where the stream exits a steep walled canyon. The most defining features were high entrenchment and the presence of bedrock. There was a high occurrence of boulders, ranging from a meter wide to large house-sized (Photo 2). Some of the riffles had high amounts of bedrock substrate, with many of the pools being formed by bedrock (Photo 3). Valley width was narrow throughout the reach, in only a few places the canyon was wide enough to allow formation of depositional terraces. Several log jams and debris accumulations were present. Gradient was moderately steep, mapped at an average of 3.0% and measured during the survey as high as 8.5%. Pole creek entered as an eight foot waterfall on the right bank about half way up the reach. Only a trickle was flowing in it during the survey because of an upstream diversion. Riparian vegetation was similar to reach 2. Ponderosa pine, white fir *Abies concolor* and Douglas fir dominated the overstory and mountain alder dominated the understory.

Reach 4: End of confined channel to Rd. 1514, R.M. 29.3 to R.M. 31.4 (Figure 5).

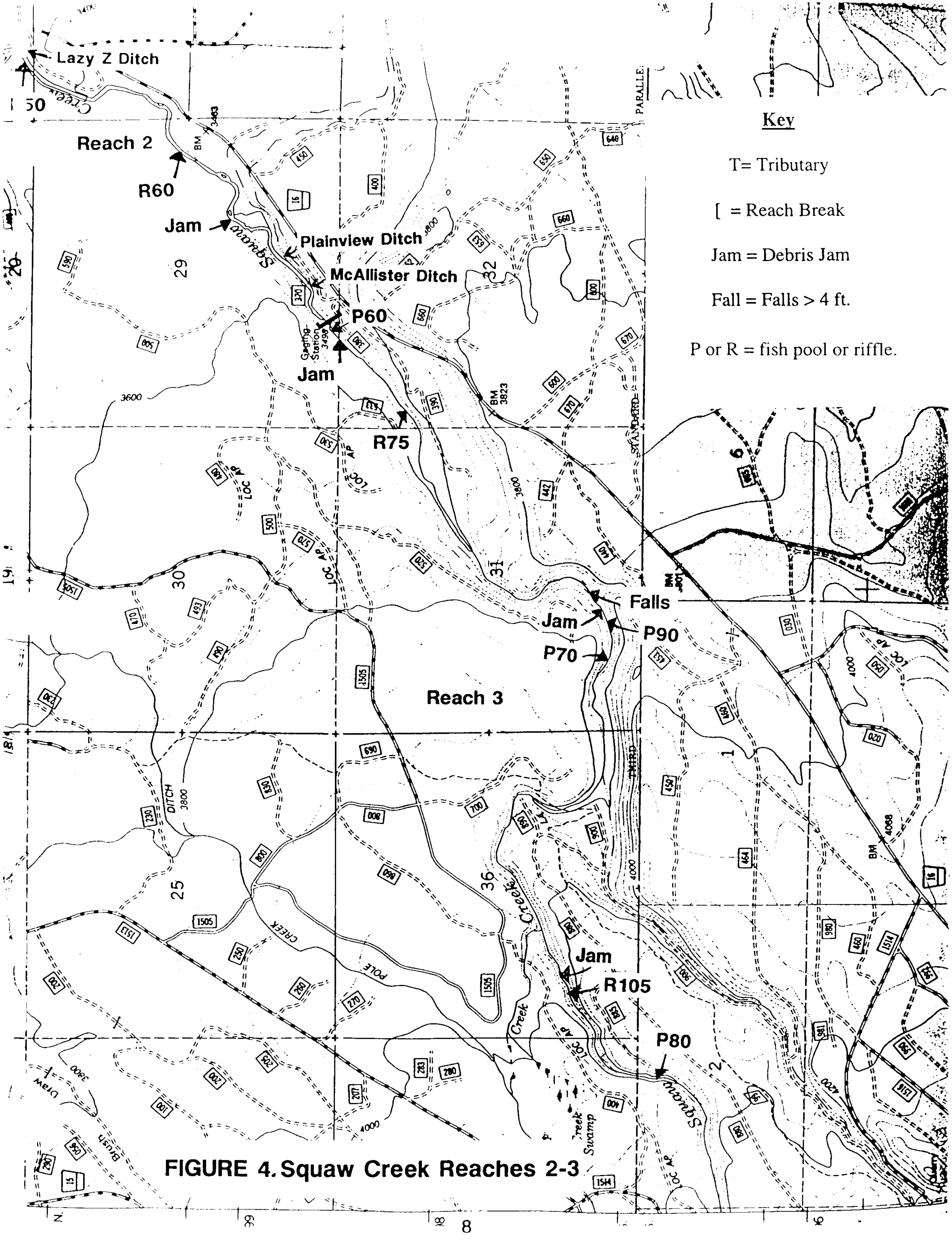



FIGURE 4. Squaw Creek Reaches 2-3

In this reach Squaw Creek flowed through a wide valley with a broad flood plain. The reach began where the stream leaves the canyon of reach 3. A small spring fed tributary entered on the west bank at the beginning of the reach. The most definitive characteristic of reach four was active meandering, with new gravel bar formation, recent wood recruitment, and some bank erosion. Entrenchment and gradient were both moderate. Several tributaries entered Squaw Creek in the reach, the largest of which was Snow Creek. Below the confluence of Snow Creek, the stream flowed against a canyon wall and some 60 feet high eroding cut banks were present. Above Snow Creek, the stream flowed through the middle of the valley. The valley floor was flat through much of the reach, with the highest terrace approximately six to ten feet above the water surface. In several locations, the stream had flowed over its banks at high water and spilled into the surrounding forest. A dry overflow channel exited on the west bank, and flowed for approximately 300 feet before disappearing. Side channels and small braided sections were present in this reach (Photo 4). Even though the gradient was lower (1.8%) than reach 3 main channel pools were uncommon.

Riparian vegetation was composed of overstory mature Ponderosa pine and understory alders. Engelmann spruce *Picea engelmannii* was the most common instream wood species, and lodgepole pine was present in the forest canopy. A few groves of aspen *Populus tremuloides* and cottonwoods were scattered within the flood plain.

Reach 5: Road 1514 to North Fork Squaw Creek, R.M. 31.4 to R.M. 33.1 (Figure 5)

Reach 5 increased to a gradient of 3.1% and was entrenched by bedrock walls in several locations. Riffles were the dominant habitat type within the reach. Roads were located several hundred feet upslope of the stream. A few dispersed campsites were located on the east bank near the 1514 road. Bedrock substrate began to dominate about halfway up the reach. Several long riffles flowed over 100% bedrock substrate (Photo 5). Riparian vegetation was composed of overstory lodgepole and Ponderosa pine with alder and Engelmann spruce along the stream banks. This reach ended at the junction with North Fork Squaw Creek at the Three Sisters Wilderness boundary. A flood in 1970 on North Fork Squaw Creek was caused by a 200 acre foot moraine lake failure. This was evidenced by large bouldery debris piles and dead submerged trees at its confluence with Squaw Creek (Laenan et al. 1987).

Reach 6: North Fork Squaw Creek to first major falls, R.M. 33.1 to R.M. 34.4 (Figure 5)

The most definitive feature was bedrock substrate in the lower part of this reach. Several bedrock sheets over 1,000 feet long were found within this section. Few pools have formed in the sections containing these bedrock sheets. The stream is entrenched between the bedrock canyon walls. A log jam midway up the reach backed up the stream, causing it to braid into the surrounding forest. Several pockets of good spawning habitat had been deposited above this log jam. South Fork Squaw Creek entered three fourths of the way up the reach and supplied about 60% of the flow. The canyon above this was still narrow with cobble, gravel, and boulder substrate. Riparian vegetation included

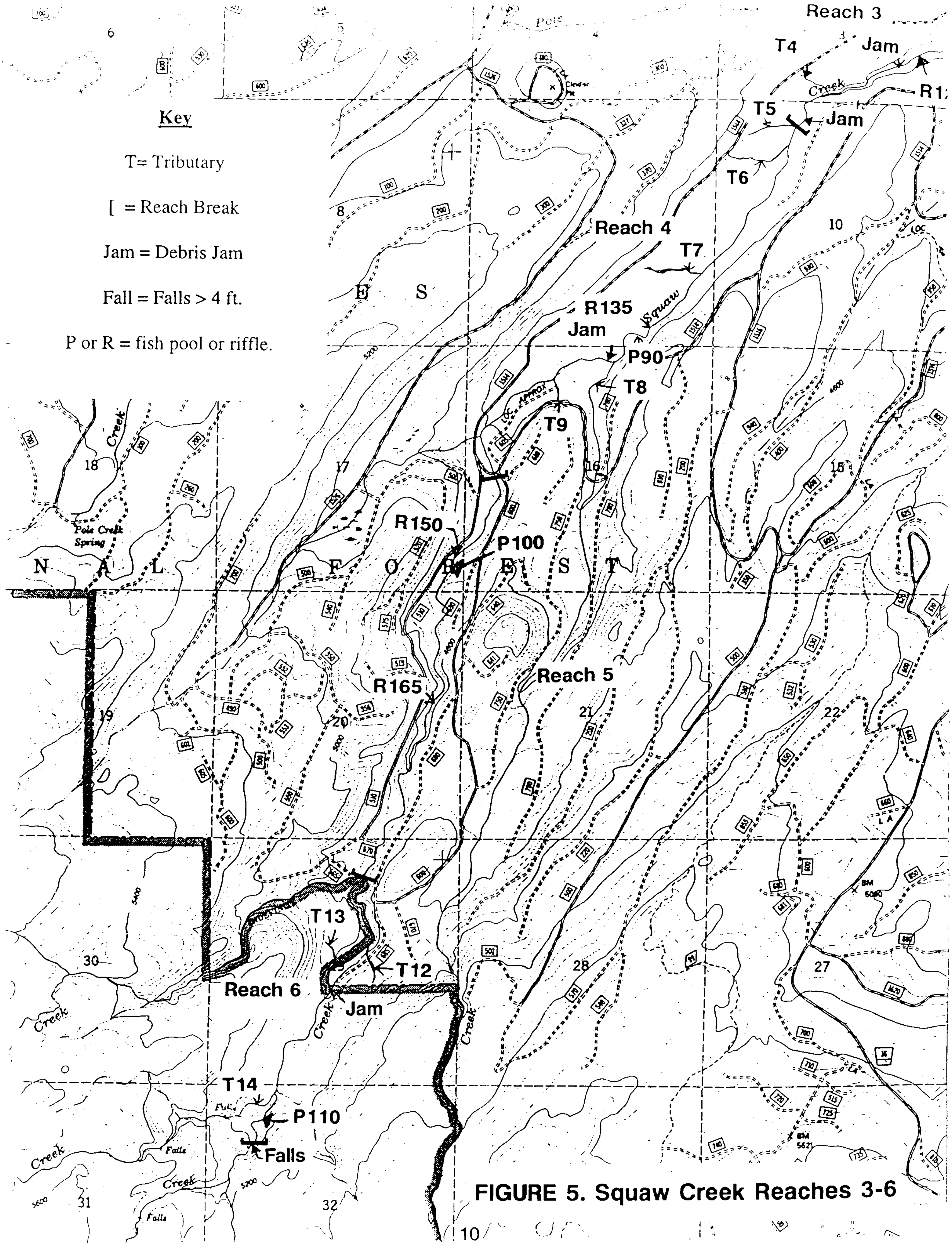



FIGURE 5. Squaw Creek Reaches 3-6

Ponderosa pine, lodgepole pine, white fir, mountain alder and Engelmann spruce (Photo 6). This reach ended at Squaw Creek Falls, which was approximately 45 - 55 feet high and a complete upstream migration barrier for fish.

## Available Aquatic Habitat

Riffle habitat accounted for more than eighty percent of the main channel habitat in reaches 2-6. Reach 1 had the highest percentage of pools and pools/mile (Table 1). A total of 109 main channel pools were found in the surveyed section. A little less than half were located in reach 1. An average of six pools/mile (>3 feet deep) were found in the surveyed stretch. Reach 1 by itself had ten pools/mile (>3 feet deep). Reach 4 had the highest amount of off-channel pool area. These serve as important fry rearing habitats. Off channel pool habitat was dominated by alcove pools in reaches 1, 3, and 6, and backwater pools in reaches 2 and 4. Isolated pools were most abundant in reaches 4 and 5 (Figure 6 ). The number of pools/mile decreased since the 1990 survey with the exception of reach 1 (Riehle 1990).

During the repeat survey of reach 1, at 7 cfs the number of pools/mile and percent pools increased. The average pool depth decreased by three tenths of a foot at low flow. Pool area increased by 15% and was partly the result of a diversion dam backing up water and creating a pool over 400 feet long. An additional 15 pools were measured during low flow because habitats previously called riffles exhibited pool characteristics. Area of off channel pools in reach 1 decreased 65% at low flow. The average riffle width decreased by six feet and riffle area decreased 34% during the second survey.

Despite a long history of channel modifications reach 1 could offer some of the best available habitat in the surveyed section. If flows can be somewhat stabilized during the summer it could provide a valued fishery and a connection between redband trout populations in lower and upper Squaw Creek.

TABLE 1. Aquatic habitat comparisons between the 1990 (Riehle) and 1997 surveys.

| Reach | Pools/mile | | % Pools | | % Riffles | | % Side Channels | |
|---|---|---|---|---|---|---|---|---|
| | 1990 | 1997 | 1990 | 1997 | 1990 | 1997 | 1990 | 1997 |
| 1 (29 cfs) | 19 | 16 | 23 | 17 | 56 | 80 | 1 | 1 |
| 1 (7 cfs) | - | 22 | - | 27 | - | 72 | - | 0 |
| 2 | 7 | 5 | 9 | 5 | 83 | 90 | 7 | 5 |
| 3 | 10 | 5 | 14 | 6 | 86 | 94 | 0 | 0 |
| 4 | 8 | 4 | 9 | 4 | 73 | 89 | 13 | 7 |
| 5 | 10 | 4 | 12 | 3 | 84 | 97 | 2 | 0 |
| 6 | 11 | 3 | 13 | 4 | 86 | 91 | 0 | 2 |

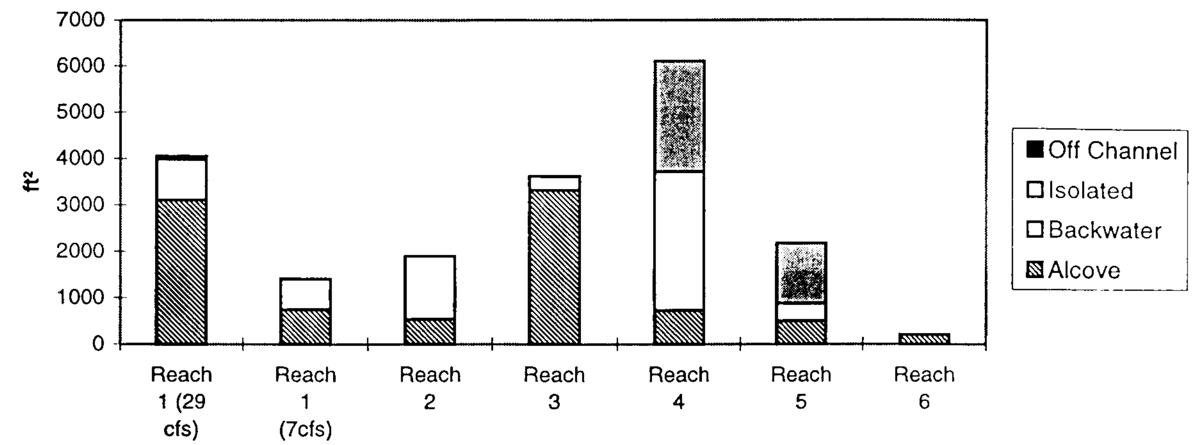



FIGURE 6. Area of off - channel pool types for reaches 1-6.

## Woody Material

Wood decreased throughout the stream between the 1990 (Riehle) and 1997 surveys, with the exception of reach 1 (Table 2). This was due to freshly fallen ponderosas and cottonwoods from recent flood events. All reaches except reach 1 and 2 exceeded the minimum guideline of 20 pieces/mile of large wood set forth by the PACFISH document in 1994 (Table 2). Lack of wood in these reaches was probably a result of removal to protect diversion and bridge structures. The wildfire of 1959 in the lower end of reach 3 was salvage logged up to the stream edge and no longer provided wood recruitment. The numbers of wood pieces found in reach 1 at 7 cfs was similar to what ODFW found in their survey. Configuration of the wood counted within the active flood channel indicated that single pieces dominated in reaches 1, 2 and 6; debris jams dominated in reach 3; and accumulations dominated in reach 4 (Figure 7). Wood located within the active flood channel was dominated by whole trees with root wads in reach 1, as a result of the bank erosion. All other reaches were dominated by naturally broken off trees (Figure 8). Additional pieces of wood suspended over the channel and above bankfull increased wood/mile numbers in reaches 3-6 by 1.3 to 5.3 pieces/mile (Table 2).

TABLE 2. Pieces of wood per mile found during 1990 (Riehle) and 1997 surveys. Additional 1997 large pieces suspended over and above the bankfull channel.

| Reach | All LWD/Mile | | Large LWD/Mile | | Large Class/Mile | | Med. Class/Mile | | Small Class/Mile | | Large LWD/ Mile Abo' Bankfull |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1990 | 1997 | 1990 | 1997 | 1990 | 1997 | 1990 | 1997 | 1990 | 1997 | 1997 |
| 1 @ 29 cfs | 28.7 | 48.0 | 11.7 | 19.5 | 1.8 | 6.4 | 9.9 | 13.1 | 16.9 | 28.5 | 0.0 |
| 1 @ 7 cfs | - | 33.3 | - | 12.5 | - | 3.5 | - | 9.0 | - | 20.8 | 0.0. |
| 2 | 57.9 | 20.4 | 33.0 | 11.3 | 10.8 | 2.2 | 22.2 | 9.1 | 24.9 | 9.1 | 0.0 |
| 3 | 100.0 | 61.5 | 54.1 | 30.7 | 16.8 | 13.4 | 37.3 | 17.2 | 45.9 | 30.9 | 3.4 |
| 4 | 130.6 | 81.0 | 53.7 | 48.1 | 11.4 | 15.2 | 42.3 | 32.9 | 77.0 | 56.6 | 1.3 |
| 5 | 161.0 | 77.0 | 87.4 | 37.2 | 25.3 | 17.4 | 62.1 | 19.9 | 73.6 | 39.7 | 4.5 |
| 6 | 133.1 | 105.6 | 68.4 | 46.5 | 15.2 | 19.4 | 53.2 | 27.1 | 64.6 | 58.1 | 5.2 |

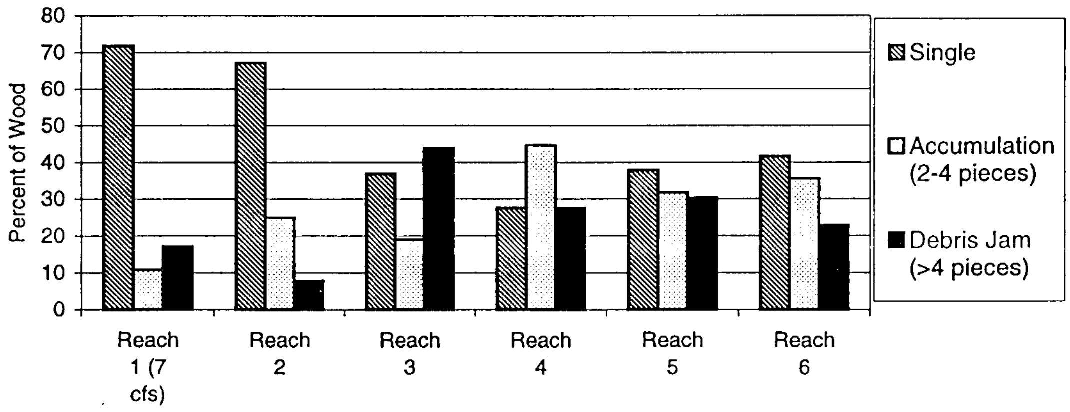



FIGURE 7. Configuration of wood pieces within the active flood channel using ODFW size classes.

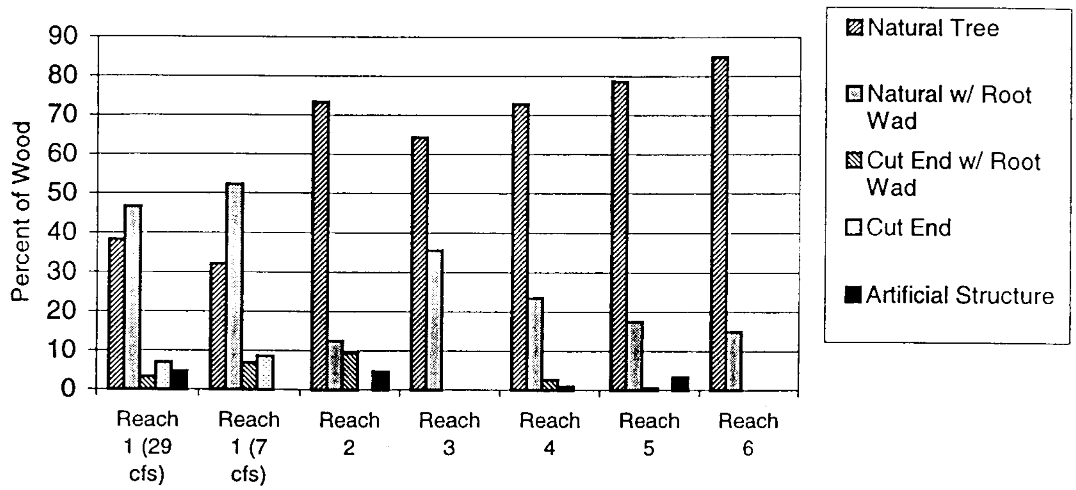



FIGURE 8. Percent of wood types found within the active flood channel using ODFW size classes.

## Fisheries

Historical Background:

Squaw Creek historically contained wild rainbow trout, summer steelhead, longnose dace, sculpin and possibly mountain whitefish in the upper section. It is not known if whitefish were ever present this far upstream. Spring Chinook were last documented near the mouth in 1959 (OSGC 1954 and 1961, cited by Nehlsen 1995). It has been speculated that the dewatering of Squaw Creek in 1912 may have denied them access upstream. Brook trout may have been first established through high lake stockings in the upper watershed. However, one record existed of 800 brook trout being directly stocked into Squaw Creek at an unknown location in 1966 (Fies et al. 1996). No records could be found of rainbow trout being stocked.

Summer steelhead smolts were stocked from 1952-1955. The first smolts were of unknown origin but in later years eggs were collected at a weir located near Camp Polk. Progeny of these fish raised at Wizard Falls were released back into Squaw Creek (Nehlson 1995). Steelhead redd counts were performed from 1951-1965 below the Camp Polk weir. Redd counts combined with fish numbers captured at the trap yielded index counts of 63 to 619 steelhead during the 1950's. It was estimated that 1,000 steelhead spawned in Squaw Creek during 1953 (Montgomery 1953, cited by Nehlsen 1995). During these surveys it was noted that some of the best spawning areas were located above the town of Sisters. These areas remained mostly unused because of the dewatered section through town. Steelhead could only access the upper reaches during periods of high water (Nielson 1950, cited by Nehlsen 1995). Numbers of adults declined in the

1960's (Nehlsen 1995). The last spawning survey and trapping occurred in 1964-1965. That year only two fish were caught at the weir and eight redds counted below it, but 113 steelhead were transferred from the Pelton Dam trap to Wizard Falls Hatchery (King 1966, cited by Nehlsen 1995). Many of these fish would have probably headed to spawn in Squaw Creek. The summer steelhead run ended in 1968 when passage was stopped at the Pelton Round Butte Hydroelectric Project on the Deschutes River. Fish passage facilities had been built, but collection of downstream migrating smolts failed (Don Ratliff personal communication).

Current:

Summer steelhead are the only native fish missing from the stream within the area surveyed. Some of the resident redband trout may be genetically similar to the summer steelhead. Amounts of spawning gravel were not quantified in this survey but there are suitable steelhead spawning locations in reaches 1-4. Reaches 1,2 and 4 offer the best spawning areas. Flows limit available spawning areas in reach 1. The stream in these reaches was characterized by a wide floodplain with gravel and cobble substrate.

Previous resident fish data was almost non-existent for this section of Squaw Creek. ODFW electrofished near the USGS gaging station and Pole Swamp in 1994 to collect genetic samples. They found both brook and redband trout (Steve Marx, ODFW, personal communication).

Trout species composition was 94% redband trout and 6% brook trout. Composition of all fish showed redbands dominating, followed by sculpins. The largest redband sampled was 11 inches by snorkeling and 7 inches by electrofishing (Figures 9 and 10). Mean redband sizes were 4.5 inches and 6.8 inches for shocking and snorkeling, respectively.

Aquatic invertebrate densities may be partially limiting growth of fish in the stream. Squaw creek had lower densities of invertebrates than the Metolius River or any of its tributaries sampled by Riehle (1993).

Brook trout were only found in reaches 5 and 6 while redband trout were found throughout. Brook trout may be present in low numbers throughout the stream. In reach 1 low numbers of redband trout were sampled and this may be a result of higher temperatures and reduced flows during the summer. Longnose dace were only found in reach 1 and sculpins were only observed in reaches 1-3. Unidentified trout fry one inch in length were observed in reaches 2-4 during September.

Snow Creek contains redband trout and may serve as a spawning area for Squaw Creek fish. Pole Creek has an eight foot waterfall that is probably only passable under certain water conditions. The lower portions of West Fork Squaw Creek and North Fork Squaw Creek may have historically had some limited steelhead spawning. The habitat condition and fish distribution in these streams is currently unknown.

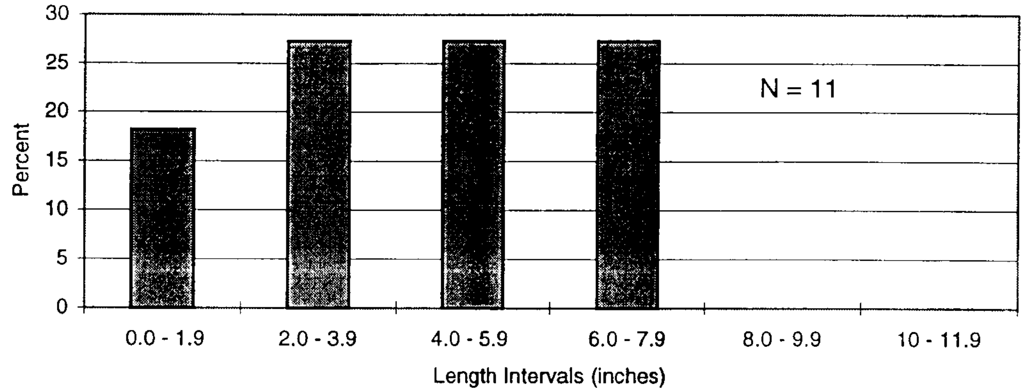



FIGURE 9. Length frequency of redband trout sampled elctrofishing

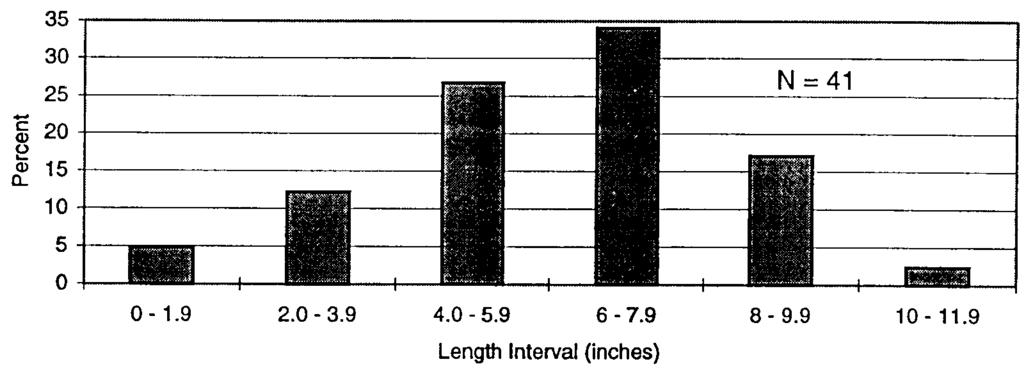



FIGURE10. Length frequency of redband trout estimated snorkeling.

## Temperature

Stream temperatures were recorded in 1991 and 1994 - 97 at the USGS gaging station using Hobo temperature data loggers. In 1997 temperatures were collected at the Barclay diversion (elevation 3180) upstream of Sisters (Table 3). Temperatures exceed the 12.8 °C requirement for native salmonid spawning, egg incubation and fry emergence (DEQ 1996) in all years at the USGS gaging station and at the Barclay diversion. Temperatures exceed the DEQ 17.8 °C requirement for salmonid fish rearing in reach one for ten days during the summer of 1997).

TABLE 3. Seven day average monthly maximum temperatures and days exceeding

12.8 and 17.8 °C for Squaw Creek from 1991, 1994-1997. Summer temperatures from June 15 through September 26.

| Site elevation (ft) | 3180 | | | 3510 | | |
|---|---|---|---|---|---|---|
| Year | 1997 | 1991 | 1994 | 1995* | 1996 | 1997 |
| | 7-day average maximum temperature (Degrees Celsius) | | | | | |
| July | 18.6 | 13.5 | 16 | - | 13.8 | 13.1 |
| August | 19.3 | 13.3 | 14.7 | 12.1 | 13.5 | 13.5 |
| September | 16.5 | 12.2 | 11.6 | 11.6 | 10.4 | 11.4 |
| | Number of days exceeding from 6/15-9/26 | | | | | |
| >12.8 °C | 73 | 29 | 49 | 2 | 24 | 12 |
| >17.8 °C | 10 | 0 | 0 | 0 | 0 | 0 |

* 1995 recorded temperatures only for August and September.

## Geology

Squaw Creek, from the wilderness boundary to the Pole Creek Swamp flows through valleys and channels carved by glaciers. From Pole Creek Swamp to the bottom of "Weir Grade" (near gaging station and upper canal intakes), the creek flows through a small non-glaciated canyon. Below "Weir Grade" the creek flows down the gentle western side of a large glacial outwash fan composed of sand and gravel. Occasionally, large floods course down Squaw Creek when snow melts rapidly in the Three Sisters-Broken Top area. Carver Lake was formed by a moraine in the 1930's at the end of the "Little Ice Age" and is located in the headwaters of South Fork Squaw Creek. In the next several decades the moraine dam poses a risk of failure that could release a major flood into Squaw Creek (Larry Chitwood, USFS Geologist, personal communication).

## Flow Regime

Squaw Creek is primarily snowmelt driven and fed by glaciers located on the flanks of the Three Sisters and Broken Top. Large flood events have occasionally occurred during the months of November and December (Army Corps 1978). Peak flows generally occur from May to July when snow melts at higher elevations. The stream experiences rain on snow events which raise the water level and turn it brown overnight. We experienced this on Sept 18, 1997 after one night of rain. The water came up six inches and turned chocolate brown. Normally the water is colored grayish blue from glacial "flour". The average flow for Squaw Creek over a 77 year period was 105 cfs. The highest flow recorded was 2,000 cfs on December 25, 1980. The daily mean flow for the February 9, 1996 flood event was 878 cfs. The daily mean flow for the 1997 New

Years Day flood event was 710 cfs (data subject to change, Ned Gates, OR State Watermaster, personal communication). The lowest flow recorded at the USGS gaging station was 18 cfs and occurred during the drought on February 17, 1993 (Fies et al. 1996). A flood plain study done by the Army Corps in 1978 estimated a 500-year flood event to be around 3,400 cfs at the USGS gaging. This was about 1,400 more cfs than occurred in 1964 and 1980. If the moraine dam breaks on Carver Lake it was estimated that it could produce a flow of 9,800 cfs through the town of Sisters (Fies et al. 1996, Laenan et al. 1992). This estimate is probably the maximum flood that could occur, other estimates have been lower (Larry Chitwood, personal communication).

There are eight water rights claims located in reaches 1 and 2. The first diversion was established in 1871. The claims within the surveyed section range from 0.7 cfs to 181 cfs. More water is claimed than is typically in the stream during the summer. The six claims made before 1895 have priority and usually use all of the water within the stream. This has resulted in the section from Sisters to the springs at Camp Polk being annually dewatered. The stream did not completely dry up this season but was reduced to a trickle. Only one of the eight diversions is reportedly screened for fish and as a result redband trout can be seen in several of the irrigation ditches until they are shut off in the fall (personnel observation). Because of a diversion, Pole Creek in reach 3 was reduced to <1 cfs during the summer months. Discharge varied during the survey because of tributary inputs and diversion withdrawals (Table 4).

TABLE 4. Flow changes during the survey. Instream flow measurements were made with a Marsh McBurney electronic flow meter.

| REACH | DATE | LOCATION | FLOW CFS |
|---|---|---|---|
| 1 | 3-Apr-97 | footbridge, Sisters City Park | 29 |
| 2 | 4-Apr-97 | 100 yrds above SCID Diversion | 89 |
| 1 | 26-Aug-97 | footbridge, Sisters City Park | 7 |
| 2 | 26-Aug-97 | 200 ft above SCID Diversion | 131 |
| 2 | 15-Sep-97 | 200 ft above SCID Diversion | 111 |
| 4 | 25-Sep-97 | tailout of 1$^{st}$ pool in reach 4 | 97 |
| 4 | 25-Sep-97 | 30 ft below road 1514 crossing | 81 |
| 6 | 14-Oct-97 | 1/8 mi above N.F. Squaw Creek | 74 |
| 6 | 14-Oct-97 | 1/8 mi above S.F. Squaw Creek | 36 |

## Substrate and Stream Bank Condition

Substrate was dominated by cobble then gravel in reaches 1-4, bedrock then cobble in reach 5, and gravel then cobble in reach 6. Reaches 3 and 6 had high amounts of bedrock while reaches 3-6 had high amounts of boulder. Reach 3 had the highest number of boulders/mile (Table 5). The boulders provided good pocket water habitat in many of the long riffles. During riffle snorkel counts fish could be seen using these boulders for cover.

TABLE 5. Estimated percent substrate, average percent of two pebble counts, D-50 (average particle size) and boulder counts/mile for reaches 1-6.

| REACH | METHOD | % SAND | % GRAVEL | % COBBLE | % BOULDER | % BEDROCK | D-50'S | BLDRS >3.3 FT DIA./ MILE |
|---|---|---|---|---|---|---|---|---|
| 1 @ 29 cfs | Estimate | 4.9 | 42.2 | 47.2 | 4.3 | 1.5 | | 60 |
| 1 @ 7 cfs | Estimate | 6.4 | 43.9 | 45.7 | 2.8 | 1.2 | | - |
| 1 | Avg. 2 Peb. Cnts. | 25.6 | 29.5 | 41.6 | 3.4 | | Very Coarse Gravel | |
| 2 | Estimate | 3.5 | 39.2 | 50.0 | 5.9 | 1.4 | | 66 |
| 2 | Avg. 2 Peb. Cnts. | 21.5 | 27.6 | 44.4 | 6.5 | | Very Coarse Gravel | |
| 3 | Estimate | 1.4 | 33.7 | 36.6 | 15.1 | 13.2 | | 342 |
| 3 | Avg. 2 Peb. Cnts. | 10.1 | 21.6 | 41.9 | 18.1 | 8.4 | Small Cobble | |
| 4 | Estimate | 1.7 | 42.3 | 45.7 | 10.3 | | | 102 |
| 4 | Avg. 2 Peb. Cnts. | 11.2 | 27.8 | 48.0 | 13.0 | | Small Cobble | |
| 5 | Estimate | 1.1 | 23.6 | 26.1 | 13.9 | 35.3 | | 226 |
| 5 | Avg. 2 Peb. Cnts. | 9.9 | 15.1 | 18.4 | 12.7 | 43.9 | Large Cobble/ Bedrock | |
| 6 | Estimate | 3.0 | 35.6 | 34.2 | 12.9 | 14.4 | | 157 |
| 6 | Avg. 2 Peb. Cnts. | 19.2 | 37.0 | 32.0 | 6.9 | 4.9 | Very Coarse Gravel | |

Even though the pebble counts generally showed a higher amount of sand, a trend in which types of substrates dominate can be seen with the exception of reach 6 (Table 5). A possible explanation might be that pebble counts were performed within bankfull and substrate was only estimated within the wetted channel. Most of the sand was encountered between the waterline and bankfull. In addition, pebble counts were performed in two riffles per reach while substrate was estimated in all main channel pools and riffles.

Length of unstable banks (both banks) was recorded for each habitat unit. An unstable bank was defined as one that was actively sloughing and/or had tension cracks in it. Reaches 1 and 2 had the highest percentage of unstable banks. Reaches 3 and 6 had the lowest amount of instability (Figure 11).

Reach 1 had 4.4 % of its banks rip-rapped, mainly around diversions and near Sisters. It also had 13.8 % of its banks bermed by an Army Corps of Engineers project completed after the 1964 flood.

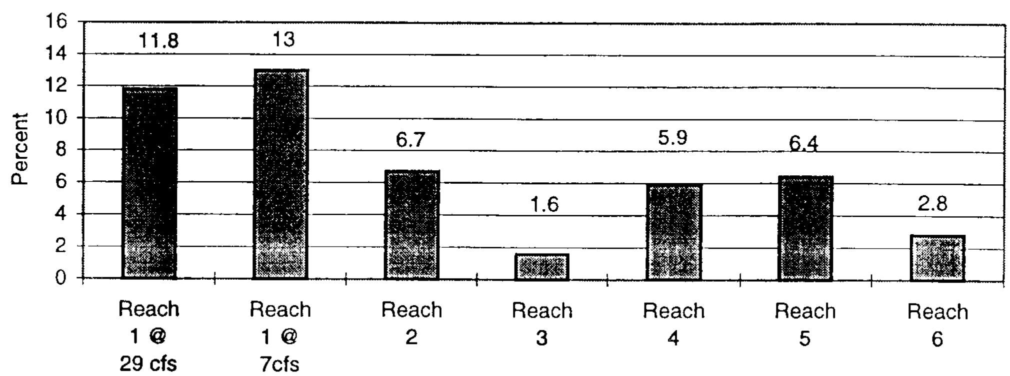



FIGURE 11. Percent unstable banks for reaches 1-6.

## Riparian Vegetation

Vegetative cover in reaches 1 and 2 was sparse because of the natural forest type and previous selective logging. The Squaw Creek fire of 1959 occurred in the lower end of reach 3. As a result trees were generally in the sapling/pole and small tree size classes. A few larger trees were present in scattered locations. The burned area was salvage logged down to the creek in several locations. Upstream of the burn larger trees are abundant and provide ample shade to the stream. Some past selective cutting was observed in reach 4. Reach 5 and 6 had relatively undisturbed riparian zones. Reach 6 is located within the wilderness boundary.

Shrub/seedling and Sapling/pole sized trees dominated the inner riparian zone in reach 1, while small trees dominated the other reaches (Figure 12). The outer riparian zone was dominated by small trees in reaches 1, 2 and 6 while large-sized trees dominated reaches 3-5 (Figure 13).

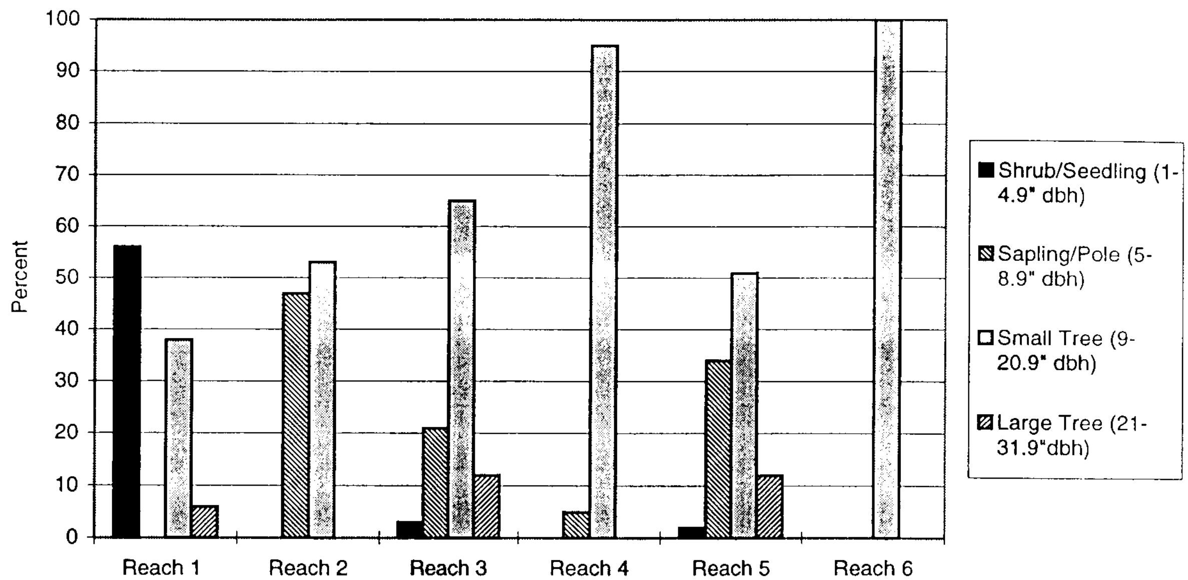



FIGURE 12. Percent composition of riparian vegetation by size class within the inner zone.

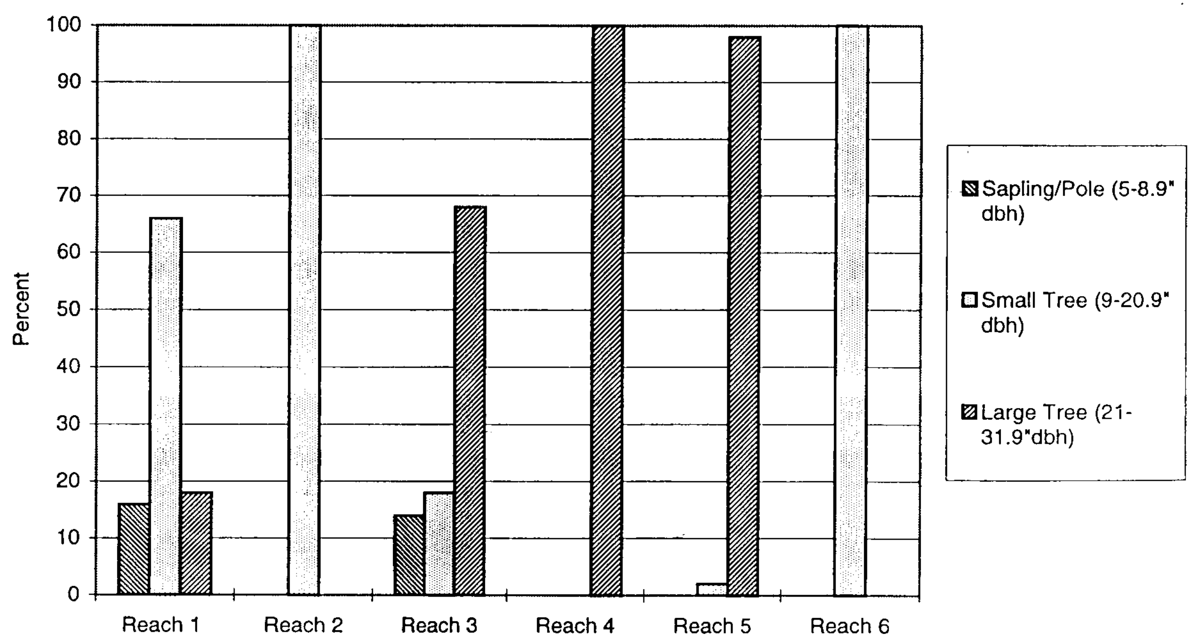



FIGURE 13. Percent composition of riparian vegetation by size class within the outer zone.

## Recreation

Camping is popular along the stream, especially in reaches 1 and 2. Several dirt roads access dispersed campsites in these reaches. Many of the campsites show signs of semi-permanent usage and have high amounts of trash in them. In reaches 4 and 5 campsites are also dispersed along the stream. These sites are mainly used by hunters. In reach 6 there is a popular trail that leads to Squaw Creek Falls and continues into the wilderness. This trail is mostly used by day hikers. The Metolius Windigo Trail crosses the stream in reach 3 and is used by horse enthusiasts and mountain bikers. Signs of light fishing pressure were present along the stream, primarily in reaches 1, 2, 4 and the lower end of reach 3. Fishing success by local anglers was reported to be good for small redband trout in the late summer and fall. Deer hunting was also a popular activity along the entire stream during hunting season.

## Historic Use

One of the first settlements in the area was in 1865 when Captain Lafollette and a band of 1st Oregon Volunteers set up a camp near the present day Camp Polk Bridge on Squaw Creek. During the late 1800's Sisters had several flourishing cattle and lumber companies. The cattle industry dwindled around the turn of the century (Army Corps 1978). Grazing presumably occurred around lower Squaw Creek and in the high meadows along South Fork Squaw Creek (Riehle 1990). Irrigation withdrawals for ranches and farms began along Squaw Creek in the late 1800's. Today Sisters economy is based primarily on tourism.

## Previous Surveys

- Riehle, M.D. 1990. United States Forest Service, Sisters Ranger District. Squaw Creek Survey Summary.
- King, D. 1964. Oregon Department of Fish and Wildlife stream survey.

## Roads and Trails

- Road 16 crosses Squaw Creek in the town of Sisters at river mile 20.6 and follows the stream for about four miles.
- Road 1514 crosses the stream at river mile 31.4 and is the break between reaches 4 and 5.
- Several small Forest Service roads paralleled the stream along the entire surveyed area, most of them at a distance above the steep canyon.
- Two unimproved roads ford the stream and several unnamed roads led to dispersed campsites along the stream in reach 1.
- The Metolius Windigo Trail fords the stream in reach 3.
- The Squaw Creek Falls trail runs above the stream in reach 6 and continues into the Three Sisters Wilderness.

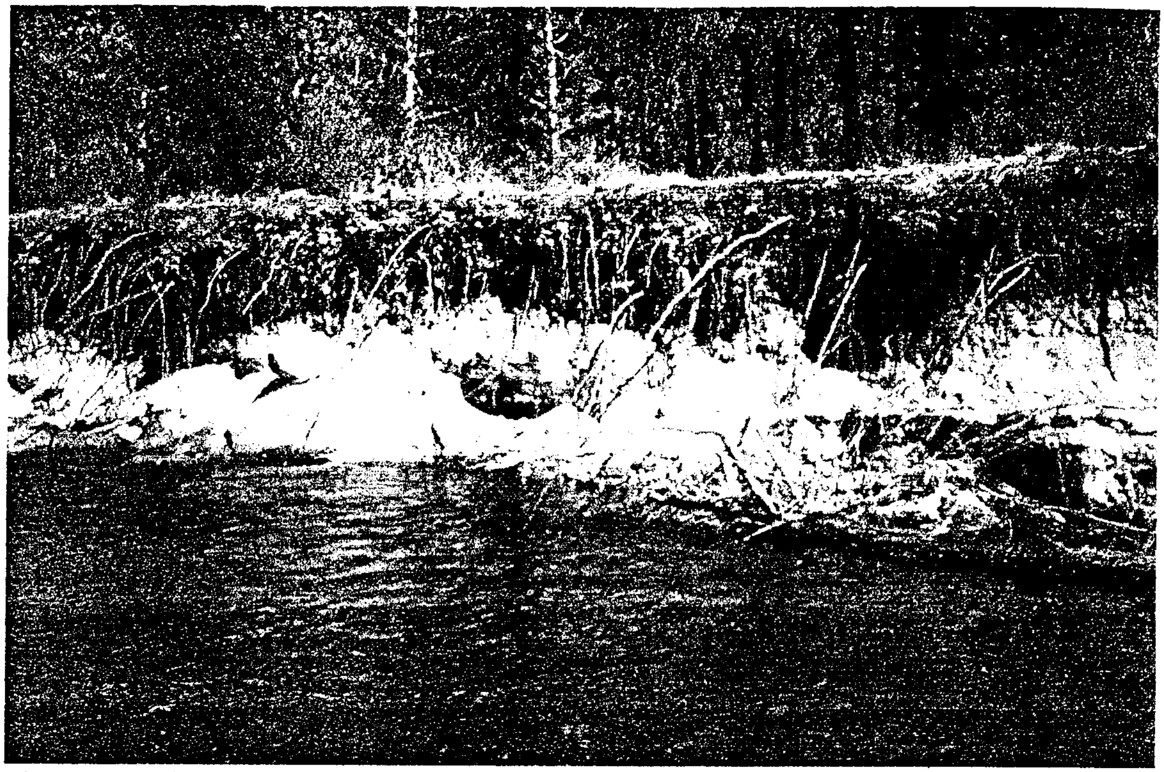


Photo 1: Bank instability/erosion a common feature in reach one.

Photo 2: Large boulders catching woody debris and creating a small falls in reach three.

Photo 3: Bedrock chute with large wood in reach three.

Photo 4: Wide cobble dominated riffle in reach four with braided section in the backround.

Photo 5: Small plunge pool in reach five created by the bedrock sheet in the background.

Photo 6: Large spruce in reach six that recently snapped off and is starting to trap other woody debris.

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Riehle, M.D. 1993. Metolius Basin water resource monitoring. 1988-1992 Progress Report. Sisters Ranger District. Deschutes National Forest. Sisters, OR.

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# Appendix F

## Squaw Creek Monitoring

## Historic Stream Channel Comparison

USFS Report

# A Historical Comparison of Stream Channel Conditions of Squaw Creek, Oregon[a]

Michael Riehle and Jens Lovtang
Sisters Ranger District
USDA Forest Service

*"With time and with water, everything changes"*

da Vinci

## Stream Channel and Habitat

The elevational profile (**Figure SH-2**) of Squaw Creek shows areas of low gradient, primarily in the channelized reach through Sisters and in the reach below Road 1514 (reach 4). It is clear from the plot that the most productive and lowest gradient reach is the 8 mile reach through the town of Sisters. Additional areas that provide thermal refugia may also be productive reaches, for example, areas near the springs in reach 4, areas near the Camp Polk Springs, and the lower 3 miles near Alder Springs.

Low gradient flats have been identified for Squaw Creek **(Figure SH 2).** Although these flats are important fish habitat, they are also the most susceptible to degradation from development. The flats are most readily developed for homes and agriculture. The flats are also areas where floodplains are the widest, conflicting with land uses that have encroached onto the floodplain. The channel in these flats tend to meander, relying on riparian vegetation to hold the streambank together. Much of the riparian vegetation on the floodplains has been lost from removal, channelization, or dewatering from irrigation. Since meandering streams dissipate their energy laterally, channelization and loss of riparian vegetation has had a destabilizing affect on these important habitats.

Aerial photo interpretation of the meander pattern of Squaw Creek shows the affects of channelization. Straightened reaches are located in the flat reaches from the Squaw Creek Irrigation District (SCID) diversion to below Camp Polk road. The reach was likely an important habitat for steelhead and chinook salmon spawning and rearing. Bank stablity is poor in this reach of Squaw Creek due to the trenching, increased gradient and lack of summer flow to support riparian vegetation. A similar reach above the channelized section showed half of the unstable banks (6-7%) as the channelized reach (12-13%) (Dachtler 1997).

The 100yr and 500yr floodplain of Squaw Creek has been mapped (Army 1978). There is a distinct

a- Excerpted from Sisters/Why-Chus Watershed Analysis
Sisters Ranger District, 1998

channel that at high flow branches off of Squaw Creek just upstream of the SCID diversion and reenters Squaw Creek just downstream of Indian Ford Creek. Some flood work may have been done to this channel to restrict the flood flow from this channel. Cutting off additional flood channels intensifies the flood in the main channel increasing erosion. The stream will erode and reshape until the channel reaches a profile that will fit the new flow regime.

Channel mapping from aerial photos from 1943 and 1991 show dramatic changes in Squaw Creek. In the reach from the SCID diversion to below Camp Polk Road, there has been a loss of stream complexity (**Figures SH- 9 and 10**). Stream length has been shortened by 1.4 miles, sinuosity has decreased 15% and gradient has increased (**Table SH-4**).

*Table SH-6. Stream miles, gradient and sinousity measured from aerial photos of Squaw Creek from 1943 and 1991. The stream was channelized in 1968 in response to the 1964 flood.*

| Reach of Squaw Creek | Stream Miles | | Gradient % | | Sinuousity | |
|---|---|---|---|---|---|---|
| | 1943 | 1991 | 1943 | 1991 | 1943 | 1991 |
| Reach 4 – not Channelized | N/A | 2.1 | N/A | 1.8 | N/A | 1.1 |
| SCID to 4606 Rd | 1.9 | 1.8 | 1.3 | 1.4 | 1.21 | 1.14 |
| 4606 Rd to Hwy 20 | 1.6 | 1.5 | 0.9 | 1.0 | 1.23 | 1.14 |
| Hwy 20 to Camp Polk Rd | 4.9 | 4.1 | 0.7 | 0.9 | 1.30 | 1.10 |
| Camp Polk Rd to Wood Bridge | 1.25 | 0.9 | 1.2 | 1.4 | 1.50 | 1.10 |
| **Total Combined Reach** | 9.65 | 8.3 | N/A | N/A | 1.30 | 1.10 |

N/A – Data was not available.

Changes in channel shape from trenching, dewatering, loss of cottonwood and willow, and removal of wood has destablized the stream and widened the channel shape. Lower depth and wider widths expose the stream to more solar heating and further push Squaw Creek outside of the historic range of stream temperatures which are already elevated by water diversions.

Off channel habitats offer rearing habitat for juvenile salmonids and create diverse habitat for invertebrates and amphibians. Off channel pools were inventoried in the 1997 stream survey (Dachtler 1997). Reach 1 (at 29 cfs) and reach 4 had the most area in off channel habitats. Low flow (7cfs) in reach one offered one third the off channel habitats than at higher flows (29cfs). These habitats included off channel pools, isolated pools, backwater pools, and alcoves. These habitats are also important for bull trout rearing cover, although they are scarce in this watershed.

Summer flows have been reduced, willow and cottonwoods have been removed, summer water temperatures have been increased, and migration routes for fish have been interrupted. The most severe change has occurred in Squaw Creek. The loss of stable stream banks combined with the unnatural flow regimes have made Squaw Creek highly unstable, threatening both fish habitat and development that has encroached onto the floodplain.

Squaw Creek was an important habitat for trout production in the Deschutes River Basin. Both steelhead and fluvial redband trout had open migratory routes connected to a diverse array of habitats. Cooler water temperatures maintained by riparian forest shade and spring-fed tributaries protected resident trout from high summer temperatures. Winter habitat was provided by diverse off-channel low velocity habitats and tributaries with warmer spring fed water. Pools were more abundant for rearing and migratory holding habitat due to the interaction of the cottonwood/conifer forest and the floodplain in the flats. Timing and upstream range of steelhead and salmon were not limited except by the size of headwater streams and bedrock falls near the wilderness.

Today, trout production is dependent primarily on those stream reaches having ample summer flows and lower water temperatures. Stream reaches not providing these habitats in the summer are barriers to trout migration. Other barriers such as Round Butte/Pelton Dams and most irrigation dams limit migration all year. Habitat quality in the middle reaches of Squaw Creek and Indian Ford Creek have declined from not only the loss of summer flow but from the simplification of the stream channel from loss of riparian vegetation, wood removal, and channelization.

Erosion of stream banks threatens both fish habitat and property values. Naturally occurring floodplains allow floods to spread and reduces the erosive power of the stream. The reduction of the floodplain area through riprap, trenching, building encroachment, and downcutting has increased the problem by concentrating the water into a single, swifter channel. Channelization has straightened the channel and increased the gradient and speed of the water, further increasing the erosive power of the stream. These changes have reduced fish habitat by reducing pools, off-channel habitats, fish cover, and increased water temperatures to harmful limits for trout.

**TREND SUMMARY**

- Streambank erosion has increased.
- Fish habitat has been degraded threatening native stocks.
- Riparian vegetation has decreased.
- Summer flows are decreased.
- Water temperatures have increased.
- Migration routes for fish have been interrupted or lost.
- Threats of flooding may be more severe.
- Developments within floodplains are threatened due to unstable streambanks.

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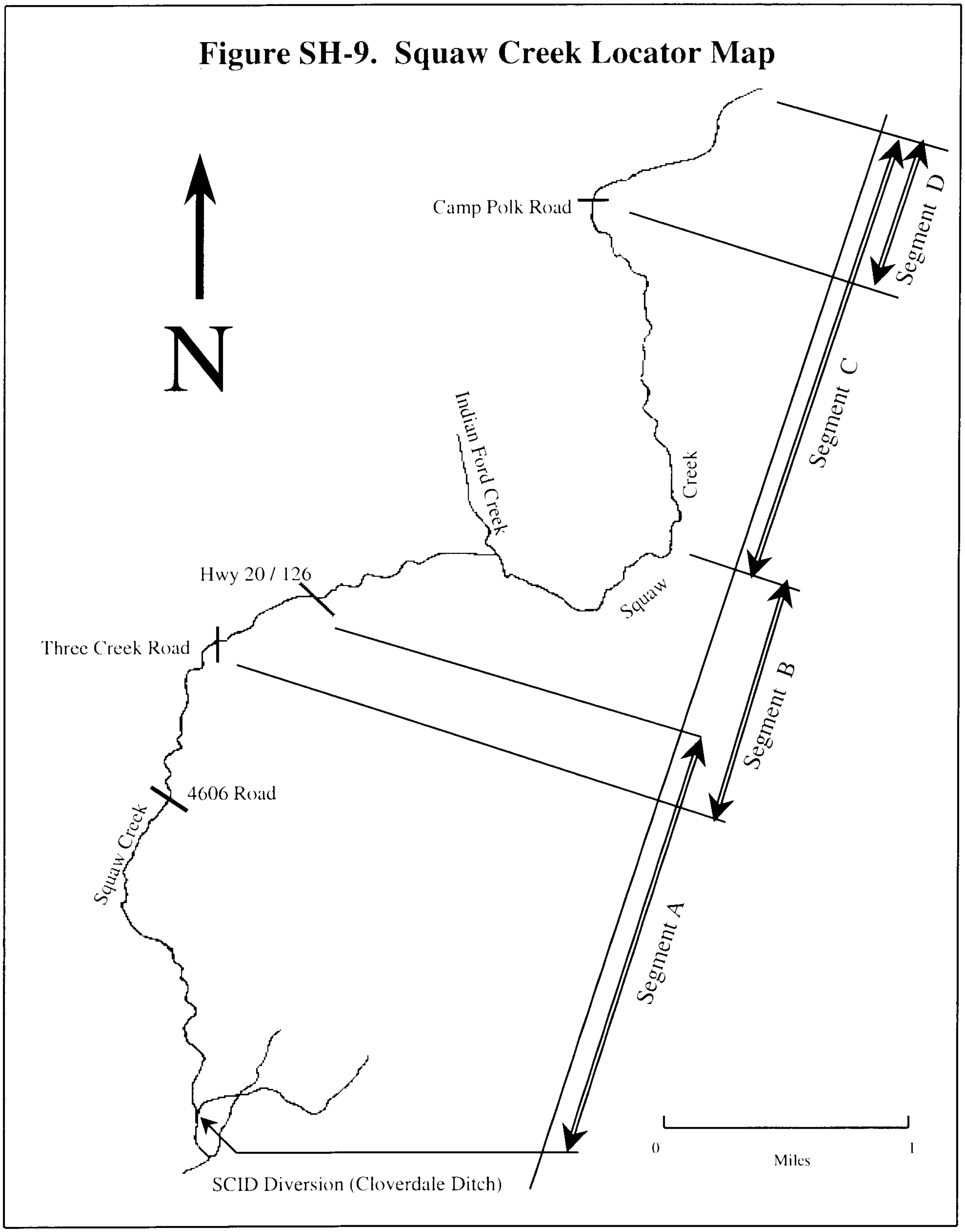



Figure SH-9. Location map of segments presented in figure SH-10. In each segment, the channel was mapped from air photos in 1943 and 1991.

# Figure SH-10B. Squaw Creek - Segment B

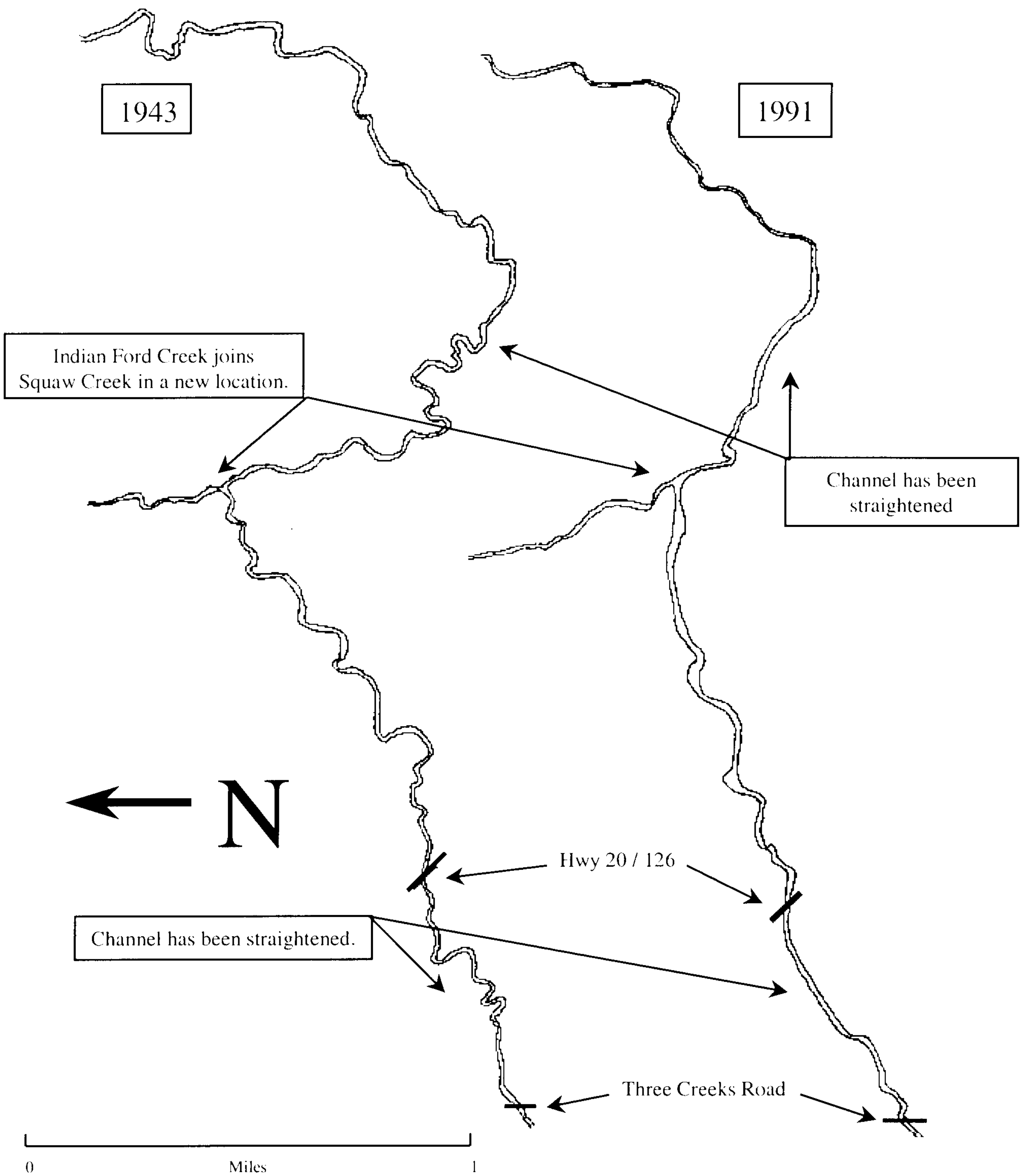


Figure SH-10C. Squaw Creek - Segment C

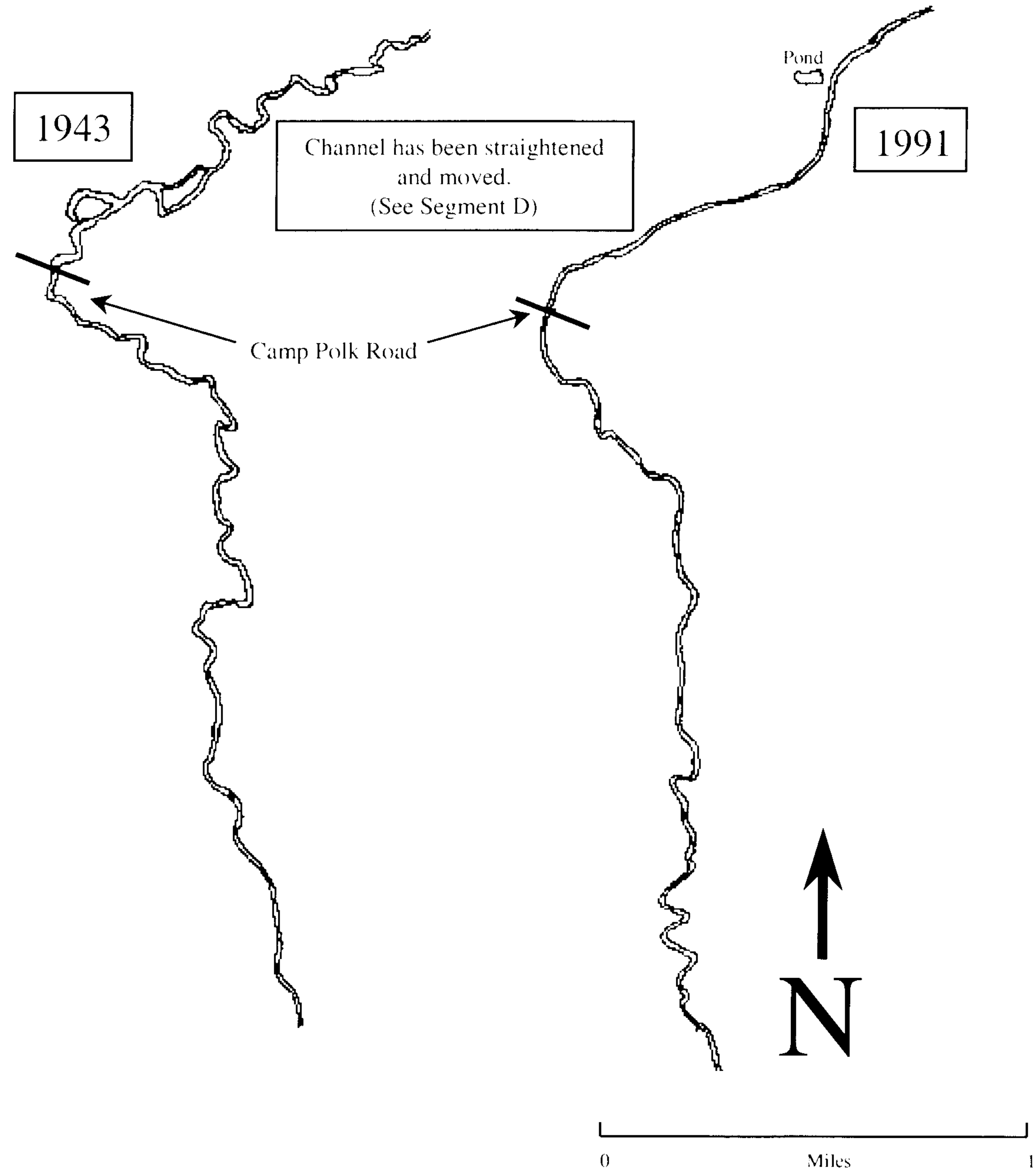
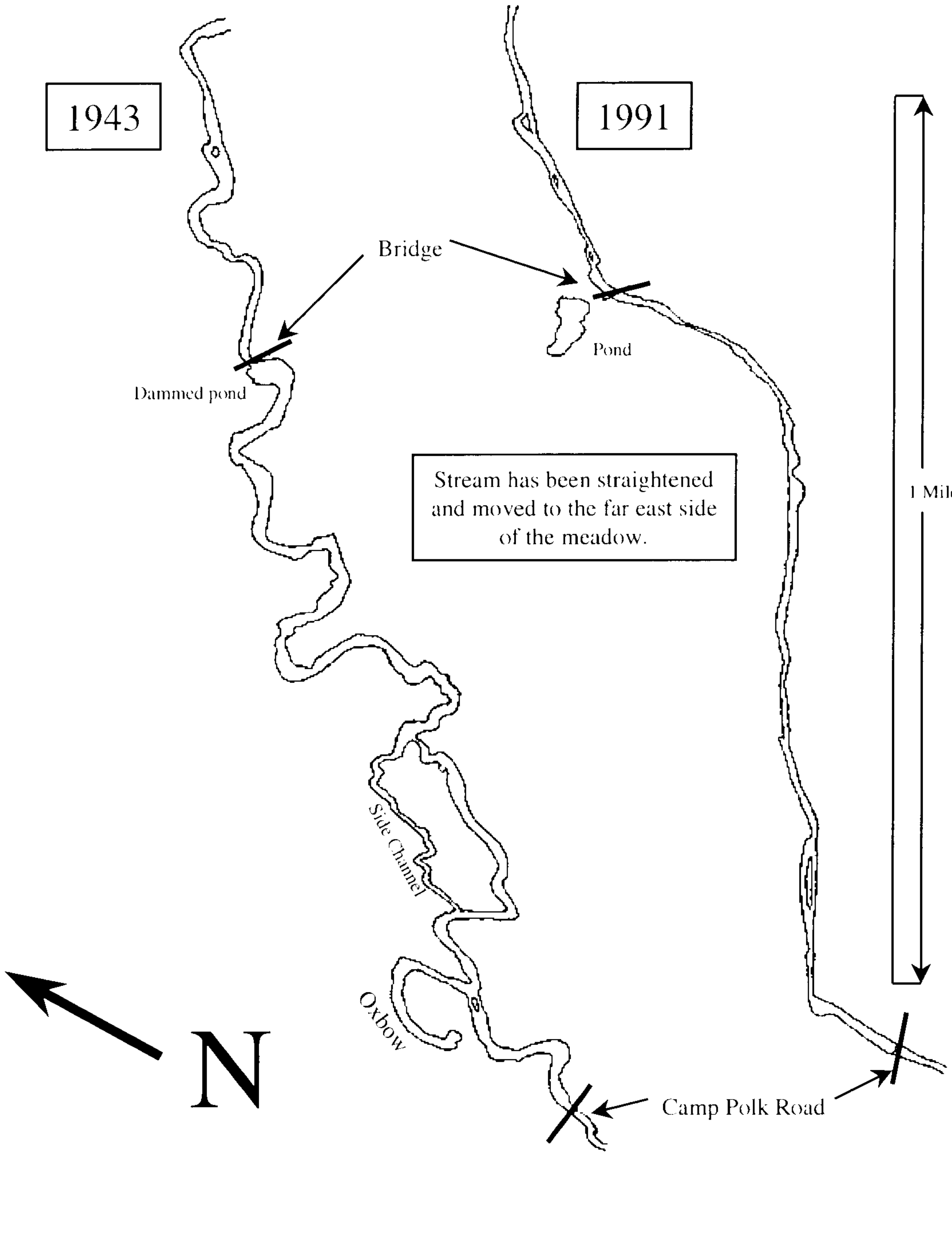


Figure SH-10D. Squaw Creek - Segment D



# Figure SH-10A. Squaw Creek Segment A.

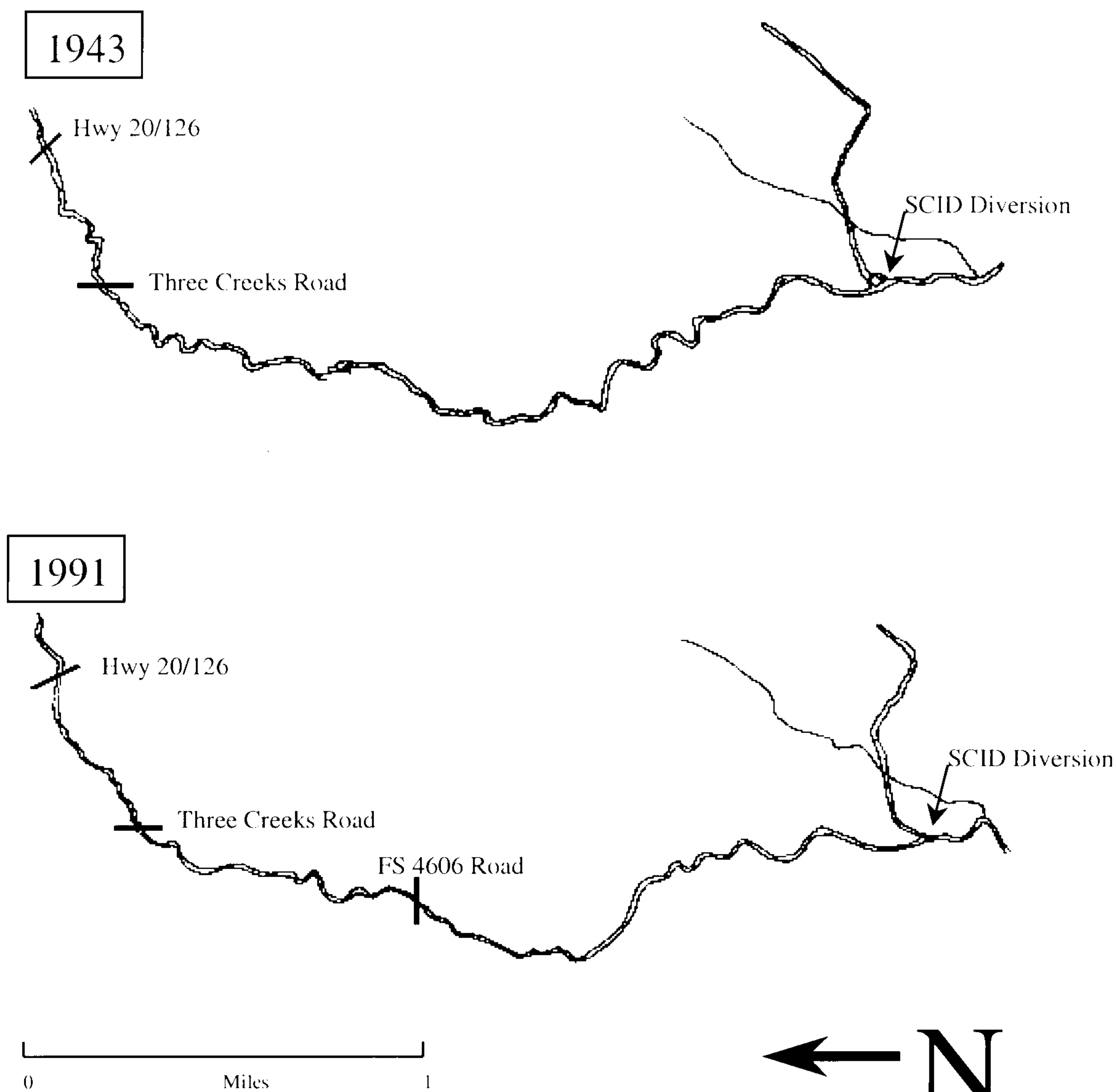
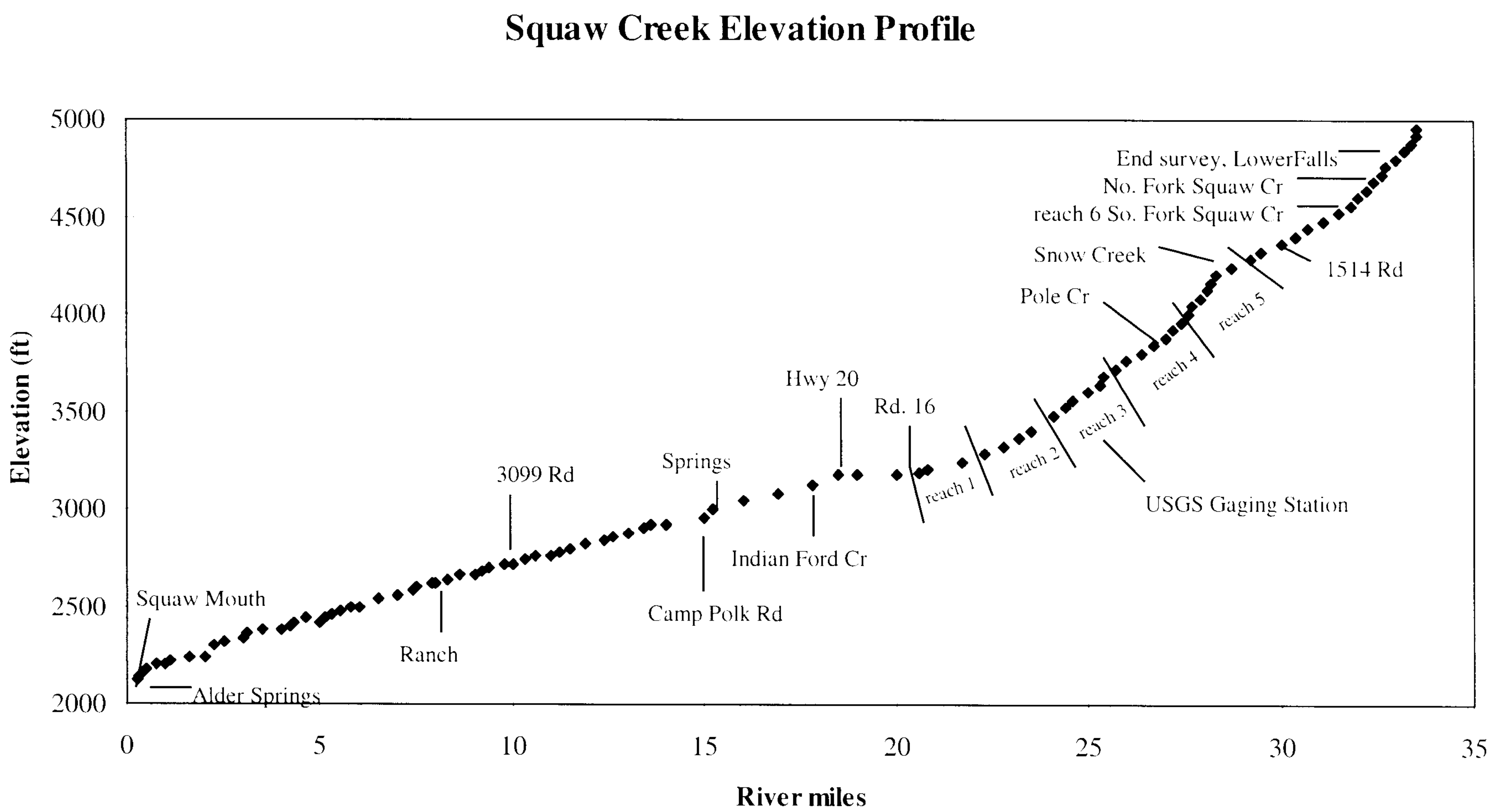



Figure SH-10 (A-D). Comparison of channel location and meander patter of Squaw Creek in 1943 and 1991. Segments A through D are shown in Figure SH-9 for larger perspective.



Squaw Creek Elevation Profile
Elevation (ft)
5000
4500
4000
3500
3000
2500
2000
River miles
0
5
10
15
20
25
30
35
Squaw Mouth
Alder Springs
Ranch
3099 Rd
Springs
Camp Polk Rd
Indian Ford Cr
Hwy 20
Rd. 16
reach 1
reach 2
reach 3
reach 4
reach 5
USGS Gaging Station
Pole Cr
Snow Creek
1514 Rd
reach 6 So. Fork Squaw Cr
No. Fork Squaw Cr
End survey, LowerFalls

# Appendix G

## Squaw Creek Monitoring

Squaw Creek Monitoring

## Watershed Monitoring Participants

# Squaw Creek Monitoring Grant Participants

| | Hours | | Hours | | Hours | | Hours |
|---|---|---|---|---|---|---|---|
| **USFS** | | **Sisters 5th Grade** | | **Sisters 6th Grade** | | **Sisters 7th Grade** | |
| Rod Bonacker | 64.0 | Jonathan Melton | 12.0 | Lindsay Chick | 22.0 | Tessa Kelley | 12.0 |
| Nate Dachtler | 64.0 | Chelse Murry | 12.0 | Shane Coffey | 22.0 | Amanda Kessel | 12.0 |
| Brad Houslet | 64.0 | Brandon Page | 12.0 | Shane Connor | 22.0 | Monica Lair | 12.0 |
| Mike Riehle | 184.0 | Cami Sitsler | 12.0 | Kelly Cundiff | 22.0 | Kristen Lamoreaux | 12.0 |
| Maret Pajutee | 28.0 | Rosemary Slavkousky | 12.0 | David Deaderick | 22.0 | Laura Leis | 12.0 |
| Bill Anthony | 3.0 | Justin Veloso | 12.0 | Amy Duarte | 22.0 | Melissa Little | 12.0 |
| Terry Craigg | 4.5 | William Walkemeer | 12.0 | Matthew Fegette | 22.0 | Evan Livsey | 12.0 |
| **ODFW** | | Michael Werner | 12.0 | Krystall Fitter | 22.0 | Jacquelien Mansker | 12.0 |
| Dave Warner | 64.0 | Troy Zeko | 12.0 | Brandon Georges | 22.0 | Jaoshua McConnell | 12.0 |
| Steve Marx | 64.0 | David Allbritton | 4.0 | Kelsey Gillespie | 22.0 | Koby McCorkle | 12.0 |
| **OSU** | | Erin Boyle | 4.0 | Maleah Glidewell | 22.0 | Nicole Mintiens | 12.0 |
| Kristy Groves | 64.0 | Shane Coffey | 4.0 | Isaac Gordon | 22.0 | Owen Moore | 12.0 |
| Six Students | 384.0 | David Deaderick | 4.0 | Kyla Grant | 22.0 | Anna Morton | 12.0 |
| **Sisters Stream Team** | | Amy Duarte | 4.0 | Jacklyn Grittman | 22.0 | Cooper Nagel | 12.0 |
| Matt Adams | 42.0 | Brandon Georges | 4.0 | Dustin Hammack | 22.0 | Dulce Ortega | 12.0 |
| Besse Ward | 31.0 | Zachary Gibson | 4.0 | Justin Hedemark | 22.0 | Meryll Palmer | 12.0 |
| Michelle Elpi | 25.0 | Maleah Glidewell | 4.0 | Cody Herburger | 22.0 | Brandon Phipps | 12.0 |
| Megan McGuire | 7.0 | Joe Green | 4.0 | Bradley Hermens | 22.0 | Lee Pyke | 12.0 |
| Amber Leis | 9.0 | Bradly Hermens | 4.0 | William Hill III | 22.0 | Angelina Ramirez | 12.0 |
| Anton Rius | 37.0 | Kristol Kolb | 4.0 | Daniel Holloman | 22.0 | James Richmond | 12.0 |
| Carolyn Franks | 9.0 | Lauren Marcy | 4.0 | Caitlin Houck | 4.0 | Marcy Sams | 12.0 |
| Casey Glick | 2.0 | Tyler McMeekin | 4.0 | Andrew Huff | 4.0 | Chris Sawyer | 12.0 |
| Steven Hyde | 2.0 | Alyssa Muir | 4.0 | Bryan Jimerson | 4.0 | Benhamin Scharf | 12.0 |
| Nathan Harpham | 4.0 | Iris Powell | 4.0 | Corey Johnson | 4.0 | Sheena Shuck | 12.0 |
| Leigh Hoagland | 2.0 | Kayla Ryan | 4.0 | Preston Kahl | 4.0 | Jeremiah Siler | 12.0 |
| Justin Little | 2.0 | Jeremy Seiber | 4.0 | Jacob Kendall | 4.0 | Hannah Simmons | 12.0 |
| **Stakeholders** | | Isiah Siler | 4.0 | Sara Kessel | 4.0 | Joshua Simone | 12.0 |
| Bob Bridgeford | 10.0 | Joe Tafte | 4.0 | Gennifer King | 4.0 | Sara Smith | 12.0 |
| Bob Brockway | 5.0 | Matthew Van Houten | 4.0 | Kristol Kolb | 4.0 | Shiara Spahn | 12.0 |
| Katherine Cerino | 6.0 | Amber Van Nostrano | 4.0 | Rachel Lee | 4.0 | Liana Straight | 12.0 |
| Tim Clasen | 5.0 | Peter Willits | 4.0 | Jackquelyn Linden | 4.0 | Zachary Sweeney | 12.0 |
| Steve Couche | 5.0 | Marissa Wyatt | 4.0 | Scott Little | 4.0 | Seth Teague | 12.0 |
| Brad Chalfant | 5.0 | Michaela Bennett | 4.0 | Linsey Lombardi | 4.0 | Alexandar Templar | 12.0 |
| Keith Cyrus | 5.0 | Nicholas Boro | 4.0 | Teresse Mackenzie | 4.0 | Ryan Trego | 12.0 |
| Ray Curry | 5.0 | Michael Chiaravalle | 4.0 | Gregory Malone | 4.0 | Chelsea Weber | 12.0 |
| Bill Dakin | 5.0 | Brandon Dean | 4.0 | Morgan Mansker | 4.0 | Lindsay Whent | 12.0 |
| Gretchen Dakin | 5.0 | Katlyn Diener | 4.0 | Lauren Marcy | 4.0 | Charly Williams | 12.0 |
| Ted Eady | 5.0 | Jacob Duncan | 4.0 | Jennifer Marsh | 4.0 | Amber Woods-Taylor | 12.0 |
| Jess Edgington | 7.0 | Clayton Dunn | 4.0 | Mackinzie McClain | 4.0 | Nicholas Yopp | 12.0 |
| Central OR Flyfishers | 4.0 | Tawny East | 4.0 | Tyler McMeekin | 4.0 | Angelina Zandonatti | 12.0 |
| Norma Funai | 5.0 | Jacirose Amsg-Estep | 4.0 | Brian McNerney | 4.0 | Emily Abslag | 12.0 |
| Cindy Glick | 5.0 | Erin Gough | 4.0 | Casey Meudt | 4.0 | Gretchen Addison | 12.0 |
| Mark Halley | 5.0 | Shannon Hanson | 4.0 | Daniel Miller | 4.0 | Ashely Albert | 12.0 |
| Ken Johnson | 5.0 | Ashley Kordish | 4.0 | Russell Miller | 4.0 | Kala Bafford | 12.0 |
| Didi Malarkey | 5.0 | Ashley Ladd | 4.0 | Shaban Mitchell | 4.0 | Brian Banks | 12.0 |
| Sykes Mitchell | 5.0 | Timothy McMilian | 4.0 | Sophia Mohl | 4.0 | Nicholas Berrey | 12.0 |
| Pat Neufeldt | 5.0 | Jeffrey Minke | 4.0 | Chris Morse | 4.0 | Nathan Boley | 12.0 |
| Al Neufeldt | 5.0 | Cory Muir | 4.0 | Nicolas Morton | 4.0 | Kalyn Brink | 12.0 |
| The Nugget News | 5.0 | Benjamin Nagel | 4.0 | Alyssa Muir | 4.0 | Kiersten Brown | 12.0 |
| Doro Sokol | 6.0 | Lydia Pepperling | 4.0 | Caitlin Partridge | 4.0 | Conner Burck | 12.0 |
| Steve Shunk | 7.0 | Jesse Prichard | 4.0 | Ezra Patterson | 4.0 | Reilly Burdick | 12.0 |
| Jens Lovtang (PGE) | 48.0 | Sam Pyke | 4.0 | Cortney Peters | 4.0 | Laura Campbell | 12.0 |

# Squaw Creek Monitoring Grant Participants

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Debbie Smith | 5.0 | Shannon Quillin | 4.0 | Chance Phipps | 4.0 | Devon Ceccacci | 12.0 |
| Marc Thalacker | 5.0 | Claire Rerat | 4.0 | Becke Pierce | 4.0 | Alex Christensen | 12.0 |
| OR Water Resources | 80.0 | Heather Schaab | 4.0 | Stephanie Pledger | 4.0 | Nathaniel Church | 12.0 |
| Terry Whatley | 5.0 | Steven Waltosz | 4.0 | Michelle Porterfield | 4.0 | James Cochran | 12.0 |
| Ken Merrill | 64.0 | Keith Weatherford | 4.0 | Iris Powell | 4.0 | Amber Craigg | 12.0 |
| **St. Francis Students** | | Alyssa Boley | 4.0 | Casey Pyke | 4.0 | Justin Crofoot | 12.0 |
| Jackson Baber | 34.5 | Ben Bushnell | 4.0 | Julia Ramsey | 4.0 | Jocob Crowder | 12.0 |
| Jessica Black | 34.5 | Shane Connor | 4.0 | Brittany Reed | 4.0 | Sunny Curtis | 12.0 |
| Christina Faria | 34.5 | Matthew Fegette | 4.0 | Joshua Reuter | 4.0 | Everett Dahl | 12.0 |
| Lauren Frei | 34.5 | Kyla Grant | 4.0 | Spencer Ross | 4.0 | Alan Dale | 12.0 |
| Megan Frost | 34.5 | Jacklyn Grittman | 4.0 | Kayla Ryan | 4.0 | Jawan Davis | 12.0 |
| Ashley Gage | 34.5 | Justin Hedemark | 4.0 | Andrew Sherrell | 4.0 | Dustin Dean | 12.0 |
| Joe Greer | 34.5 | William Hill | 4.0 | Samuel Shuck | 4.0 | Brandon Debates | 12.0 |
| Jill Hector | 34.5 | Daniel Holloman | 4.0 | Lauren Sims | 4.0 | Kelina Duran | 12.0 |
| Gable Hofman | 34.5 | Corey Johnson | 4.0 | Nicole Sonnier | 4.0 | Yuridi Durantes | 12.0 |
| Catherine Jager | 34.5 | Gennifer King | 4.0 | Christopher Stahn | 4.0 | Rachel Eady | 12.0 |
| Elizabeth Jarrett | 34.5 | Scott Little | 4.0 | Ashley Strader | 4.0 | Kelly Fitzjarrell | 12.0 |
| Melissa Mangin | 34.5 | Brian McNerney | 4.0 | Chrisopher Straight | 4.0 | Dawn Flory | 12.0 |
| Matt Markham | 34.5 | Sophia Mohl | 4.0 | Joseph Tafte | 4.0 | Erica Glick | 12.0 |
| Ali McCool | 34.5 | Caitlin Partridge | 4.0 | Tyler Trask | 4.0 | Whitney Hamberger | 12.0 |
| William Mennesson | 34.5 | Ezra Patterson | 4.0 | Molly Van Acker | 4.0 | David Helton | 12.0 |
| Bryce Merritt | 34.5 | Stephanie Pledger | 4.0 | Kristi Van Blaricum | 4.0 | Rodney Helwig | 12.0 |
| Daniela Minnin | 34.5 | Casey Pyke | 4.0 | Matthew Van Houten | 4.0 | Bryan Henry | 12.0 |
| Andy Ortiz | 34.5 | Samuel Shuck | 4.0 | Andrew Waldron | 4.0 | Matthew Hodge | 12.0 |
| Erica Porter | 34.5 | Lauren Shultz | 4.0 | Stephanie Warren | 4.0 | Tani Honea | 12.0 |
| Hillary Roberts | 34.5 | Katherine Sims | 4.0 | Jordon Weber | 4.0 | Ryder Hornbeck | 12.0 |
| Lindsay Ruble | 34.5 | Tyler Trask | 4.0 | Brianna Wellman | 4.0 | Crystal Irish | 12.0 |
| Kristin Sayeg | 34.5 | Brianna Wellman | 4.0 | Kyle Whipps | 4.0 | Jenna Kipper | 12.0 |
| **St. Francis Teacher & Parents** | | Kimberly Wilson | 4.0 | Peter Willitts | 4.0 | Vance Kotal | 12.0 |
| Bill Baber | 6.5 | **Sisters 6th Grade** | | Kimberly Wilson | 4.0 | Jared Lake | 12.0 |
| Robin Baber | 5.5 | Kala Bafford | 12.0 | Stephanie Yopp | 4.0 | Amy Lange | 12.0 |
| Colleen Lynch | 50.5 | Nathan Boley | 12.0 | **Sisters 7th Grade** | | Andie Lesowske | 12.0 |
| Melanie Mangin | 6.5 | Kaylin Brink | 12.0 | Christopher Adams | 12.0 | Misty Macauley | 12.0 |
| Danelle Markham | 6.5 | Justin Crofoot | 12.0 | Erik Armbruster | 12.0 | Jordan Mc Cabe | 12.0 |
| Maryanne Merritt | 6.5 | Everett Dahl | 12.0 | Evan Armbruster | 12.0 | Heather McConville | 12.0 |
| Lori Ortiz | 12.0 | Dustin Dean | 12.0 | Trace Barrett | 12.0 | Jonathan McMillan | 12.0 |
| Maria Porter | 5.5 | Yuridi Durantes | 12.0 | Jordon Beck | 12.0 | Amanda McNerney | 12.0 |
| Miriam Ruble | 5.5 | Rachael Eady | 12.0 | Bethany Benhower | 12.0 | Crystal Metcalf | 12.0 |
| Joan Sayeg | 5.5 | Kelly Fitzjarrell | 12.0 | Andrea Beus | 12.0 | Kerani Mitchell | 12.0 |
| **Bend Community School** | | Dawn Flory | 12.0 | Benjamin Boro | 12.0 | Britta Manaco | 12.0 |
| Julie Robertson | 33.0 | Rikki Glick | 12.0 | Christopher Boyle | 12.0 | Nickalaus Newport | 12.0 |
| 11 Students | 231.0 | Matt Hodge | 12.0 | Elyse Brownson | 12.0 | Krista Pagano | 12.0 |
| 8 Parents | 32.0 | Tani Honea | 12.0 | Patrick Burke | 12.0 | Katie Pearson | 12.0 |
| **Sisters Teachers & Parents** | | Crystal Irish | 12.0 | Grayson Bushnell | 12.0 | Jason Pederson | 12.0 |
| Glen Herron | 17.0 | Vance Kotal | 12.0 | Garrett Campbell | 12.0 | Nick Pierce | 12.0 |
| Cheryl Butler | 58.0 | Andie Lesowske | 12.0 | Angela Chick | 12.0 | Derek Ramsey | 12.0 |
| Kathy Kemper | 19.0 | Derek Ramsey | 12.0 | Emily Clasen | 12.0 | Rosita Rerat | 12.0 |
| Carol Packard | 43.0 | Jeremy Reznick | 12.0 | Kori Colburn | 12.0 | Jeremy Reznick | 12.0 |
| Wes Estvold | 4.0 | Corey Rood | 12.0 | Hegner Durantes | 12.0 | Corey Rood | 12.0 |
| Heidi Smith | 4.0 | Ryan Rowe | 12.0 | Tessa Durdan-Shaw | 12.0 | Nicole Rushton | 12.0 |
| David Hewitt | 19.0 | Andrea Straight | 12.0 | Jessica Durham | 12.0 | Crystal Sanchez | 12.0 |
| 18 Parents | 200.0 | Ashley Sweeney | 12.0 | Towner Dyer | 12.0 | Vanessa Schwartz | 12.0 |
| **Sisters 5th Grade** | | Natha Teeny | 12.0 | Savina Elmore | 12.0 | Megan Smith | 12.0 |
| Taylor Barrett | 12.0 | Justin Thomas | 12.0 | Kalin Emrich | 12.0 | Daniel Spezza | 12.0 |
| Levi Boyce | 12.0 | Cassandra Toney | 12.0 | Katherine Engstrom | 12.0 | Andrea Straight | 12.0 |

# Squaw Creek Monitoring Grant Participants

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Andrew Burke | 12.0 | Amy Vasquez | 12.0 | Anna Evered | 12.0 | Ashley Sweeney | 12.0 |
| Dylan Burke | 12.0 | Roger Wert | 12.0 | Andrew Fegette | 12.0 | Ashley Sweeton | 12.0 |
| Patrick Christensen | 12.0 | Hayden White | 12.0 | Kathleen Garrett | 12.0 | Nathan Teeny | 12.0 |
| Elyss Clasen | 12.0 | Marissa Abegg | 22.0 | Cheri Gormley | 12.0 | Justin Thomas | 12.0 |
| Daniel Connor | 12.0 | David Allbritton | 22.0 | Patrick Hammons | 12.0 | Julianne Tierney | 12.0 |
| Prescott Coombs | 12.0 | Brica Banks | 22.0 | Ryan Harper | 12.0 | Cassandra Toney | 12.0 |
| Grant Dahl | 12.0 | Bradford Bauer | 22.0 | Nathan Harpham | 12.0 | Kimberly Werner | 12.0 |
| Carter Davenport | 12.0 | Erin Boyle | 22.0 | Melissa Heap | 12.0 | Hayden White | 12.0 |
| Alesha Fairs | 12.0 | Christopher Brock | 22.0 | Drew Herburger | 12.0 | Bethany Wood-Taylor | 12.0 |
| Brenna Fischer | 12.0 | Daniel Brownston | 22.0 | Chelsea Hill | 12.0 | Bill Young | 12.0 |
| Becky Kalebaugh | 12.0 | Patrick Bryan | 22.0 | Robin Hoagland | 12.0 | | |
| Whitney Kellher | 12.0 | Kyle Buckner | 22.0 | Perry Holloman | 12.0 | | |
| Cristal Leis | 12.0 | Benjamin Bushnell | 22.0 | Joshua Kelleher | 12.0 | | |
| Kaitlin McAlister | 12.0 | | | | | | |
| **Sub Total** | 3,218.0 | | 952.0 | | 1,124.0 | | 1,404.0 |
| | | | | | | | |
| **Total** | | **6,698** | | | | | |