Umpqua Basin Watershed Council

Stream Temperature Management Strategies for the Central Umpqua Basin

Development and Evaluation

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Contents:

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Summary:

This report provides a technical framework to develop a temperature management plan with specific information and examples for the Central Umpqua Basin defined as the region above the tidal influence and below 3000 feet elevation within the Umpqua River Basin. The resource data for the watershed indicates that there is significant potential for reduction in stream temperatures with corresponding benefits to the cold-water fishery resource. However, there is evidence that suggests that simply increasing shade cover alone will not be sufficient to bring stream temperatures down to levels experienced under anthropogenic conditions.
A stream temperature management strategy for all perennial streams that is consistent with aquatic and riparian habitat management objectives is recommended. The utilization of adaptive management techniques might be appropriate.

Introduction:

It is well know that stream temperatures are an important issue within the Umpqua Basin. Many large-scale changes in our environment are causing a decline of the cold-water fish species such as trout and salmon. Cool stream temperatures are important for spawning and rearing of healthy fish that are strong enough to return from the ocean to spawn. Stream temperature management programs to cool warm streams are an important part of the Oregon Plan for Salmon and Watersheds.

The objective of this report is to identify management practices that can have a net positive effect on stream temperature and to provide specific resources and techniques for effective implementation of stream temperature management projects in the Central Umpqua Basin. It is recognized that the local land manager generally knows best how to manage his or her land. The intent of this report is to assist land mangers and planners in developing the best strategy for their stream management activities using the best available information.

It is expected that this report may be helpful in the development of a temperature Water Quality Management Plan. Appendix F shows the requirements for such a plan and how this report would contribute to the development of a plan.

Basic Stream Heating Concepts:

There are many processes and conditions that affect the temperature conditions in the riparian/ stream zone and a common understanding of these concepts will lead to better management decisions. Numerous references cover stream-heating concepts in detail (i.e. Satterlund 1972, Theurer 1984, and Sinokrot and Stefan 1993). This discussion will focus on the general aspects that are directly related to management activities.

Thermal Loading within a Watershed

In order to manage stream temperature at the local scale it is helpful to understand how watersheds heat at the watershed scale. Appendix A Heat Exchange and Thermal Loading Notes, provides more discussion of this topic.

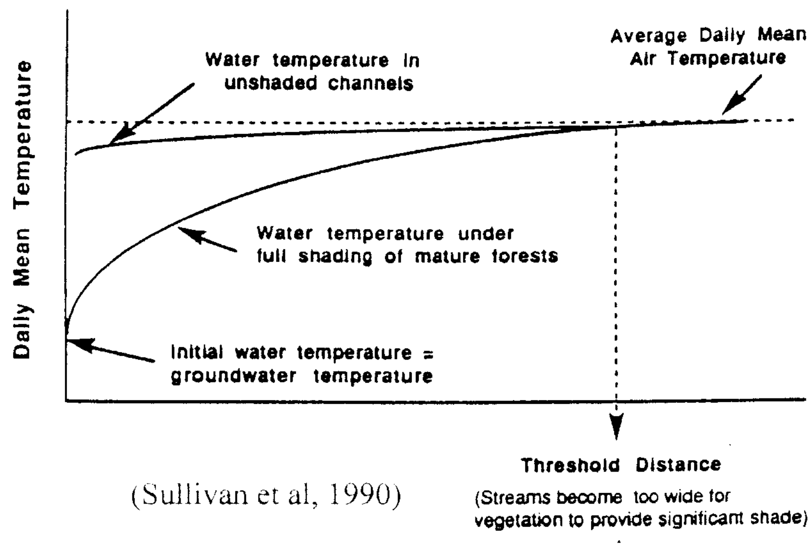
Upstream Influence on Stream Temperature

Appendix A asserts that, for most small streams under low flow conditions (less than .5 cfs flow), the character of the riparian area in the zone extending 1000 feet upstream from the point of interest greatly influences the stream temperature. For the purpose of this report, it is assumed that riparian management activities in this area would have the greatest potential to affect the local stream temperature.

Optimal Obtainable Temperature

Appendix A also shows that stream temperatures tend to increase in the downstream direction and that optimal achievable stream temperature tends to increase with stream size. Figure 1 shows the general pattern. An example of this pattern from the Lower Umpqua is shown in the Current Condition section of this report. Because of this distribution pattern, the temperature of the ideal cool stream will generally increase as the stream becomes larger. Comparison of the temperature of similarly sized streams can provide a relative indication of which streams may be excessively warm and may benefit from stream temperature management.

Figure 1 *Hypothesized temperature patterns for daily mean and diurnal fluctuation in watersheds.*



(Sullivan et al, 1990)

Factors Affecting Local Stream Temperature

As discussed above, local conditions can have a strong influence on the stream temperature and management activities can significantly alter these conditions. Understanding how these conditions affect stream heating can result in better riparian management strategies.

Shade Condition

Management of stream shade is the most common temperature management activity. To effectively manage shade, it is important to understand the fundamentals of the subject. Appendix B contains some key definitions and concepts. It is generally accepted that a tall, dense shade wall effectively reduces the amount of direct solar energy that reaches the stream, resulting in cooler stream temperatures. Stream buffers that have a closed canopy over the stream are even more effective. Generally, a high shade canopy is more effective than a lone one since long wave heat is radiated from the buffer trees.

Channel Condition

For the same amount of direct solar radiation, water in wide, shallow channels will heat more than narrow, deep channels because it receives more heat radiation per unit volume of water. For the same reason, deep pools are typically cooler than shallow pools.
Channel stability is important to minimize erosion and keep the riparian vegetation intact. Generally, stable, low gradient streams have an active flood plain that remains vegetated after flood events thus having effective shade over the long term.

Flow Conditions

Channels with high water tables and/ or storage capacity will tend to have higher summer flows. Higher streamflow equates to deeper flows and smaller temperature increases.

Hyporheic flow is the subsurface flow component of a stream that can occur in streams with large quantities of permeable gravel in the streambed. The amount of hyporehic flow can typically vary from reach to reach (Constanz 1998). Consequently, some reaches appear to be gaining surface water while others appear to lose water. Since the hyporheic flow is difficult to detect and measure there is not much information available about it. However, the cooler subterranean environment may cool the water passing through the soil. (Appendix B contains more information about hyporheic flows.)

Channels that appear to be dry may contain significant quantities of hyporheic flow to a pool or stream. Isolated pools may experience a steady-state supply of hyporheic flow that provides a continuous supply of cool water that offsets the direct solar heating.

Groundwater, entering from underground storage areas, can also effectively cool a stream. It should be noted that, under low flow conditions, the ratio of groundwater or hyporheic flow to surface flow often increases with a corresponding increase in cooling influence.

Bed Composition

Bedrock channels may affect the amount of groundwater inflow, also retain heat, and cause shallow, sheet flow to occur. Large gravel and cobble that protrude above the surface can significantly increase the heat-exchange contact surface area between the water and solar-heated rocks.

Relative influence of the condition components

There are an infinite number of combinations of the factors that influence local stream temperature. Computer temperature models can be used to show the effect of varying one of the input values on the final temperature. A computer model such as SSTEMP (Bartholow, 1989) can be used to estimate stream temperature for a scenario typical for the Central Umpqua Basin. In this example, the values of the inflow, groundwater inflow and shade are individually changed from the initial condition. Table 1 shows the corresponding values of the width, depth, mean temperature and maximum temperature that result from these changes. While this range of change may be typical for stream in the Umpqua, Basin, it should be noted that the magnitude of change might vary for different conditions.

	Initial Condition		Boxed value indicates changed parameter							
Inflow cfs	1		1.5	0.5	1	1	1	1	1	1
roundwater cfs	0.1		0.1	0.1	0	0.2	1	0.1	0.1	0.1
Veg Shade	50.00%		50.00%	50.00%	50.00%	50.00%	50.00%	25.00%	75.00%	95.00%
Width ft	12.62		13.65	11.091	12.5	12.74	13.55	12.62	12.62	12.62
Depth ft	0.165		0.222	0.102	0.151	0.178	0.279	0.165	0.165	0.165
Mean Temp	70.4		70.41	70.33	71.19	69.69	65.76	72.63	68.11	66.25
ax Temperature	82.35		82.13	82.51	82.58	82.09	79.68	86.11	78.28	74.82

Low temperature due to high proportion of groundwater.

Low temperature due to high shade values.

Note that this example shows that a high proportion of groundwater inflow can cause a significant reduction in water temperature. This condition is more likely to occur under low flow conditions as flows in small streams recede.

General Management Considerations

Generally, streams that are stable with an effective flood plain and a good pool riffle ratio and riparian vegetation will have cooler stream temperatures. In contrast, a highly incised channel may have a reduced area but other factors such as reduced groundwater and shallow depths will cause a net increase in temperature. Consequently, streams that are functioning well and have good fish habitat generally have good temperature characteristics. However, exceptions to this rule may occur.

Stream restoration guides such as the one recently published by the Oregon Plan for Salmon and Watersheds (OPSW 1999) describe projects that will generally be consistent with good temperature management practices.
The key beneficial use associated with stream temperature is generally the cold-water fishery resource. Since both cool temperatures and good habitat conditions are critical, the management activities should be compatible with both temperature and habitat objectives. Small streams in particular should not be ignored. Needle Branch, a tiny stream in the Coast Range has a minimum flow of about four gallons per minute often with no visible flow between isolated pools. However, fisheries scientists determined that it was an important rearing area for coho salmon and cutthroat

trout (Satterlund, 1972, p 298). Many of the small streams in the Umpqua Basin have high fishery resource values with little or no summer flow. French Creek, a tributary of the North Umpqua near Glide, is a notable example (personal communication ODFW).

Sample Practices

The following examples are provided as suggestions for effective stream temperature management. The innovative land manager may find other approaches that meet the objectives. Numerous federal, state and county agencies can provide financial and technical assistance.

Riparian Shade Enhancement

Most of the perennial streams in the Umpqua Basin have some type of vegetative buffer. However, trees that have reached their maximum potential growth for the site would provide a shade wall with maximum closure over the channel and have optimal shade benefit for the stream. A shade density goal of at least 80% for the wall is recommended for maximum effectiveness. Appendix B discusses the "shade wall" and other basic concepts relating to shade management.

Even though not all the trees along a stream may be essential for shading the stream, it is a good general practice to maintain a well-stocked buffer on both sides of the stream. The tree roots in a buffer zone can help prevent stream banks from eroding during high water and reduce soil erosion from water flowing down off the side slopes. The buffer zone provides good habitat to terrestrial and aquatic life that is beneficial to the area.
Tree-line buffer areas may pass flood flows more effectively than brush-lined streams resulting in lower flood levels and less flood damage. Buffers are also a source of woody material for streams, providing essential structure needed to maintain high water tables and diverse aquatic habitat. A full sized buffer can also affect the microclimate of the riparian area by reducing wind speeds and soil temperatures causing additional reduction in stream temperature.

It may take a long time to develop an effective shade wall. Trees are generally better than brush since they will eventually reach higher and block more sunlight. Properly managed, shade buffers should become denser and taller each year until they reach the fully mature site potential condition.

There is some controversy over possible adverse effects of increases water transpiration associated with riparian vegetation. This effect may be countered in part by the reduction of direct evaporation through unvegetated soil.

It has been noted that an overly shaded stream can have a negative effect on stream biota by limiting primary productivity (ODFW 1998). However, in the warm streams (greater than 64 °F) the benefits of cooler temperatures should generally outweigh any reduction primary productivity. In general, improving stream shade in the Umpqua Basin will directly benefit the aquatic resources.

Large Wood Placement

Large wood placement adds wood to the channel area where it provides structure to dissipate energy, entrap gravels and promote pool development. While the key objective is generally fish habitat, stream temperature may also benefit from the changes as well. These projects need to be carefully planned to avoid stream destabilization or increase risk of flooding.

Channel Restoration

Intact, well-functioning streams characteristically have good riparian vegetation, good flows, high water table, non-incised channel, minimal solar exposure and an intact flood plain. Bringing a damaged stream reach back to this condition will typically improve temperature conditions as well.

Erosion Control

Eroded soils tend to be transported to the stream system and become part of the stream sediment load. Exceptionally large inputs of soil material may "overload' the stream system and cause it to become unstable – resulting in even more erosion. At a minimum, pools may become filled and bed gravel covered with silt material. This condition may reduce the quality of the habitat and rate of hyporheic flows.

Since erosion can occur anywhere within a watershed, good erosion control practices are important in areas where there is high likelihood of sediment transport to the stream system.

Flow Management

Stream depth will increase with streamflow with a corresponding reduction in stream heating potential. Consequently, higher flows are generally consistent with better stream temperatures as well as providing more volume for habitat.

Keeping water withdrawals to a minimum during the high temperature period is the most obvious flow management technique. Since the maximum temperatures occur late in the day, scheduling minimum withdrawal during that time may be helpful.

Stream groundwater recharge from field irrigation may have a positive effect. Water removed from the streams and applied to a field may become cooled as it moves back to the stream through the ground. However, since the portion returned to the stream would represent only a fraction of the water removed the benefit of the cooler water may not offset the adverse effect of the reduced stream flows. This area could benefit from further study.

Cold water released from impoundments can have a cooling effect on the downstream temperatures. The amount of temperature change depends upon the difference in temperature and the relative quantity of water involved. The distance that this effect persists depends upon the quantity and velocity of the flow - it may range from a few hundred feet to several miles.

Flow augmentation with water of similar temperature may also be beneficial since a larger quantity of water will reduce the effect of direct solar heating.

Priority Considerations

Even though the Oregon stream temperature standard applies to the entire Umpqua Basin, a key underlying objective is to improve conditions for the cold-water fisheries resource. For that reason it may be appropriate to put emphasis on locations that directly this resource.

The following are some points to consider when establishing priorities:

1...The cold-water aquatic system contains many other temperature sensitive organisms besides fish. Lowering the temperature of any hot (exceeding 64 °F) stream will be beneficial locally and will contribute to improvement of the entire system.

2. It is difficult to effectively shade the larger streams and the river. However, these larger bodies of water provide essential habitat for the larger fish at different points in their life cycle and this use may occur in the summer months. Cold-water inflow points provide critical refuge areas for the fish during the summer period. Often these cold-water inflow points are associated with tributaries; even apparently dry tributaries and draws can be sources of cold groundwater inflow. Keeping the mouths of these waterways well shaded will help assure colder water in the refuge areas.

3... The shade wall discussion indicated that taller trees are needed on the south side of the stream. For local planning, it may be beneficial to put emphasis on shade management in this area.

4. Many smaller streams tend to go dry or transform into a series of pools that are isolated from surface flow. However, these pools are often kept relatively cool by subsurface flow and can provide habitat for essential cold-water organisms and small fish. Shade in these areas can provide a positive cooling effect.

5. Many of the streams in the Umpqua Basin have buffers that are comprised of brush species. Conversion to tree species would produce more effective buffers without taking additional land out of production.

Adaptive Management

It is apparent that there are many areas of uncertain information or general knowledge associated with stream heating and associated riparian management activities. Typical management practices use the best available knowledge to generate a "best guess" management strategy that is then changed as new information modifies the "best guess". Adaptive management identifies uncertainties and then establishes methodologies to test hypotheses concerning those uncertainties. Adaptive Management serves as a tool to change the system and also learn about the system (Ref ARM 1999). Challenges to the adaptive management approach include difficulty in modeling, lack of data, high risks, stakeholder self-interest, and conflicts in ecological values (Walters, 1997). Appendix C provides more information on adaptive management. The temperature data available for the Central Umpqua Basin could provide a basis for developing key hypotheses to test through an adaptive management approach.

Adaptive Management Challenges:

Conversion of brush species to tree lined buffers.
Study transpiration effects of riparian vegetation on stream flow
Study effects of irrigation inflow in stream temperatures.

Temperature Management In The Central Umpqua Basin

Current Conditions

Three factors need to be considered for an effective temperature management program:

- Current local stream temperature conditions.
- Riparian Condition.
- Expected streamflow in the area

Current Temperature

Since 1998, the UBWC has been systematically conducting an Umpqua Basin Stream Temperature Characterization Study to establish current stream temperature conditions within the river basin. These studies consist of stream temperature data collected at 30-minute intervals from monitoring sites distributed in a sub watershed at a density of about one site per 10 square miles. Data has been collected for most of the Central Umpqua Basin and the reports can be found in Appendix E. Specific data files can be obtained through the Umpqua Basin Watershed Council (UBWC). Appendix E contains the following reports:

- 1998 Elk Creek (North County) Temperature Study (28 monitoring sites).
- 1999 Calapooya Creek Temperature Study (29 monitoring sites).
- 1999 South Umpqua Temperature Study (excluding Cow Creek) (119 monitoring sites)
- 2000 Cow Creek Temperature Study (excluding W Fork) (89 monitoring sites).
- 2000 Main Umpqua Temperature Study (49 monitoring sites).
- 2001 Lower North Umpqua Data (22 sites).

The UBWC also collected stream temperature and air temperature multi-year data from five reference sites to provide opportunity for inter year comparison.

- Camp Creek @ mouth 2000, 2001
- Pass Creek @ mouth 1998, 1999, 2000, 2001
- Calapooya Creek above Cabin Creek 1999, 2000, 2001
- North Myrtle Creek @ mouth 1999, 2000, 2001
- Windy Creek @ Glendale 2000, 2001

Appendix D contains a procedure that utilizes the reference site data to transform new data to a specified time period. For example, if new data was collected in Myrtle Creek, the procedure could transform the data to the same time period as the rest of the data available for the Myrtle Creek area. This would facilitate direct comparison between the sites.

Additional stream temperature data for this time period may be available from the various land management agencies, organizations and individuals.

On July 25, 2000 a FLIR (Forward Looking Infrared Radiometry) flight was completed on Cow Creek for Oregon Department of Environmental Quality by Watershed Sciences, LLC of Corvallis, OR. In 2001 a flight was conducted on most of the Umpqua System. The resulting images provide detailed point-in-time views of the stream temperature pattern for the entire survey area. This information is very helpful in identifying the variability of the temperature distribution pattern.

Sample Results of the Characterization Studies

The characterization studies provide the raw data of the seasonal temperatures for the period of study, summary statistics, and synoptic spatial distribution information.

Chart 1 shows the spatial distribution of the seasonal maximums for the 48 sites in the Lower Umpqua study that was completed in the summer of 2000. The 7-day average of the daily maximum temperatures tended to be consistently about 3 °F lower than the corresponding

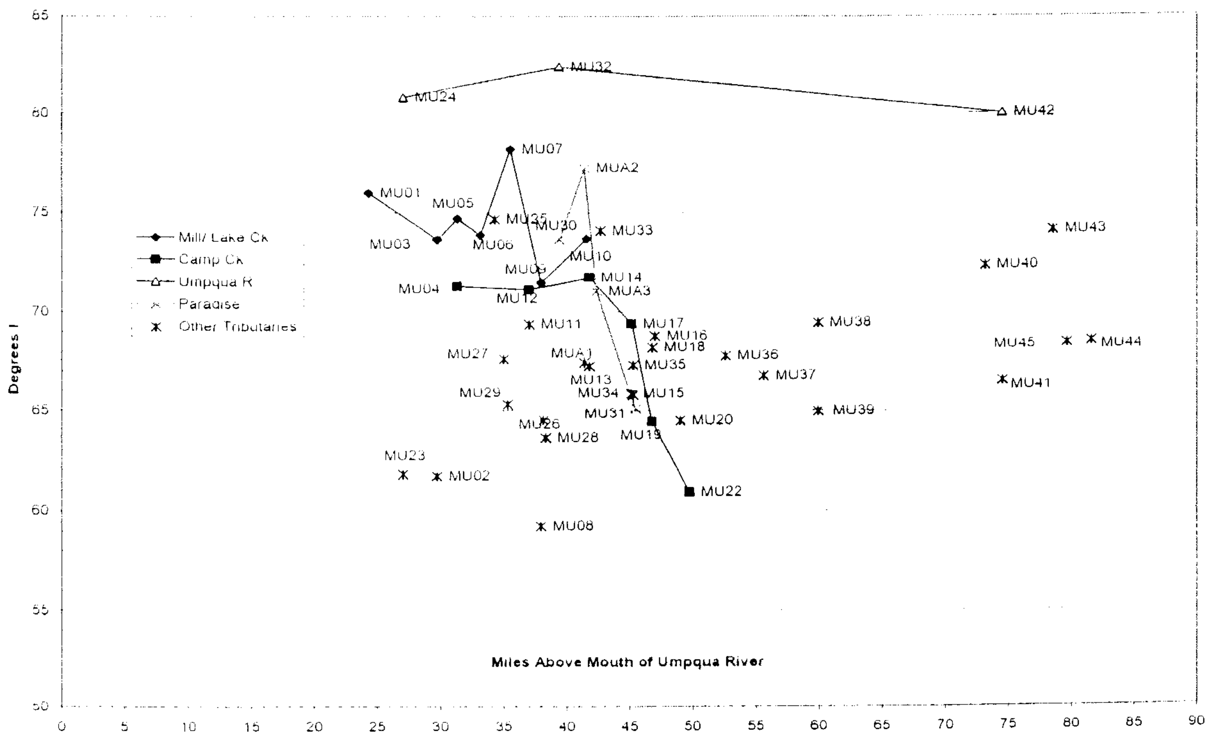


Chart 1 Maximum Temperature vs. distance from mouth of the Umpqua River.

seasonal maximum.

There are several key observations to be made:

1. Many of the sites exceed the 64°F value indicating that much of the watershed would qualify for listing as water quality impaired for temperature.
2. The tributary streams are consistently cooler than the main river.

3. The stream temperatures tend to increase in the downstream direction. This observation is consistent with other research (Sullivan et al 1990) and has been observed consistently in the other studies.

Chart 2 shows the same data plotted against the distance to the respective source ridgeline. This type of plot tends to sort the sampled streams by size. For example, 5-mile streams are likely to have different physical characteristics than a 1-mile stream or a 10-mile stream.

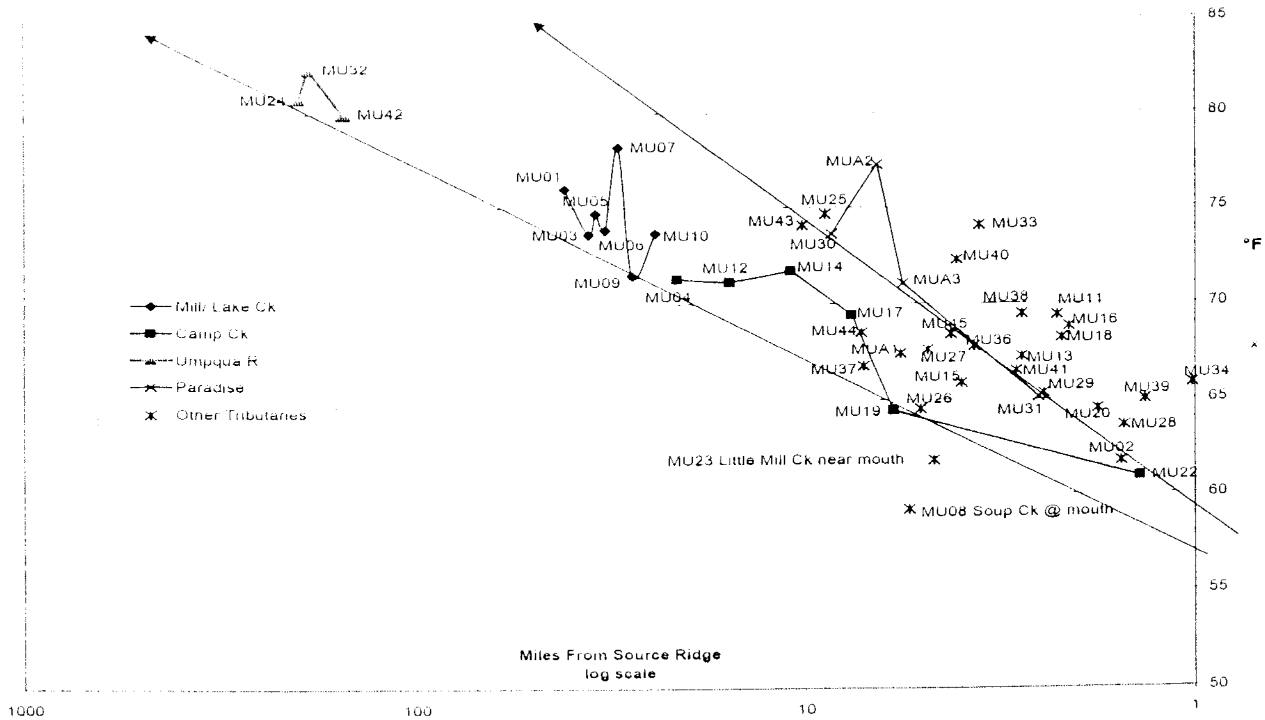


Chart 1 Maximum Temperature vs. distance from the source ridge.

The sorting by size again shows that the stream temperature of the tributaries also appears to be highly dependent on stream size. The bottom edge of the data cluster is of particular interest since it represents the best temperatures observed under existing

conditions. It follows that the sites with temperatures further above the "best conditions" line have some condition that is causing them to run warmer than optimum. Managing the riparian conditions and/ or the flow regime to correct the "problem" conditions may reduce these elevated stream temperatures.

The data provided from these studies provides a good overview of the stream temperature situation in the Central Umpqua Basin. Using this information, the user should be able to determine which areas are likely to exceed the 64 °F criteria. In the event that precise data is needed for a particular site, appropriate temperature measurements should be collected.

Riparian Condition

As mentioned in the Sample Practices section, managing for optimal habitat is generally consistent with good stream temperature management. Generally, shade improvement is the most direct method to improve local stream temperatures. For the warm stream areas achieving a shade wall of mature "site potential" trees represents the best achievable condition. Riparian areas in warm stream areas with shade walls that are at less than site potential provide an opportunity for shade management. There are many ways to assess the riparian condition.

Local Survey

The optimum shade wall can easily be determined by walking the stream in the project area and using the methodology described in Appendix B. Full-grown trees that form a dense wall to the sunlight represent the best that can be achieved for the site. Portions of the stream that have gaps, brush, or undersized streams may be opportunities for shade management projects.

Other Resources

Aerial photographs can be used to identify riparian areas with gaps or undersized trees.

The ODFW Aquatic Inventory Data project provides detailed stream survey information for over 1,600 of the 2000 miles of perennial stream in the Umpqua Basin. This database is a key resource for aquatic Habitat Management Planning on the Umpqua and includes sampling of the amount of "open sky" above the stream. Appendix C shows an example how this database can be used to assess the local shade needs for the stream of interest. Details of this database and assessment tool are in Appendix C: Historic and Current Riparian Conditions.

Watershed assessments conducted by the UBWC and watershed analysis by the US Forest Service and the BLM also provides information about riparian condition at the 5th field scale.

Streamflow in the Central Umpqua Basin

Streamflow is useful to provide an indication of the quality of habitat and to assist with any stream temperature modeling effort.

Generally, the larger fish are associated with larger streams. However, during the spawning season streams may be used that go dry in the summer. The timing and utilization of these streams by fry and smolts can be a critical period in the life cycle of a particular species.

In western Oregon, the streams typically reach an extreme low flow period near the end of summer. This characteristic is very important to the modeling effort because the processes affecting stream temperature can change significantly, as this extreme low-flow condition is approached. For example, a flow stream may transform into a series of pools that acts as a series of small reservoirs. Likewise, the evaporation, wind, groundwater and solar radiation will have a stronger influence on the reduced volume of water. Perhaps cobbles will protrude at the surface affecting the heat transfer properties of the interface. All of these factors make accurate modeling more difficult as the low flow condition is approached.

There are numerous gaging stations in the Umpqua Basin and the data is available through the USGS. Sampling typical August flows indicates that summer flows are in the order of about .04 cfs per sq mile. The implication is that most of the 100 square mile subbasins the watershed will produce summer flows of less than 0.5 cfs.

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List of Appendices

Appendix A: Heat Exchange and Thermal Loading Notes

Heat as a pollutant

It is well documented that excessive heat in streams can adversely affect beneficial uses associated with the aquatic Environment (Oregon DEQ, 1955). Stream temperature provides a direct measurement of the concentration of heat in the water so it is a convenient index of the amount of thermal pollution that has occurred.
The ultimate source of most heat is the sun and direct solar radiation is the dominant supply source of heat for streams. The friction of moving water and geothermal inputs are other natural sources that will be considered negligible for this discussion. Without direct solar radiation, the system cools down rapidly as evidenced by the typical diurnal pattern. It is apparent that there is a direct positive association between the amount of direct solar radiation received and the maximum stream temperatures achieved. Conversely, it is apparent that increased shade will typically reduce maximum stream temperatures.

Heat Exchange Processes

Stream temperature at a given point at a given time is determined by two general factors: the rate that heat is entering and leaving from local effects and the rate that heat is being introduced from upstream and removed by water flowing past the point.

There are six processes that exchange heat energy between water moving in a stream and its environment: solar energy, long wave radiation, evaporation, convection, stream bed conduction, and groundwater inflow/ outflow (Boyd and Sturdevant, 1997). The amount of heat at a fixed point in a flow stream is also influenced by the heat in the water flowing from upstream. Details on these processes are available in many references.

Upstream Influences

When planning a temperature management strategy for a section of stream it is important to have an idea of the extent that upstream conditions influence the stream temperature in the reach of interest.
One way to assess this effect is to consider a stream that is under steady-state conditions with an upstream steady environment "A" with temperature T1 and a downstream steady environment "B" with temperature T2. As water passes from environment "A" to "B" the water temperature will gradually change from T1 to T2. The attached report, "Heat Exchange and Transport in Small Mountain Stream", calculates the time necessary for this recovery. Since water has high heat capacity, the time required is relatively long compared with most other materials. Larger flows require longer recovery times but, for small streams with depths of a few inches, recovery will typically occur within 8 hours.

Effective Velocity

To determine the upstream influence distance, it is necessary to determine the rate that the water moves downstream. It is difficulty to directly measure the effective velocity the but tracking the movement of a slug of dye can provide an accurate measurement. The report "Yoncalla Creek Dye Study" indicates that Yoncalla Creek flowing a 0.2 cfs had a effective transport velocity of 50 feet per hour. Using a eight-hour recovery time equates to an influence distance of 400 feet. It should be noted that Yoncalla Creek consisted of a series of pools and may be representative of the slower streams.

However, experience and other studies have indicated similar recovery. In Washington studies Type 4 streams that averaged 0.02 cfs had upstream influence zone that were typically 150m (Caldwell et. al., 1991, p55). Satterlund also indicates that in well-shaded downstream areas, stream temperatures can to return to back to "normal" condition. (Satterlund, 1972, p 299.)

Factors that affect downstream heating

Stream temperature data consistently shows that streams tend to heat in the downstream direction. This occurs in spite of the fact that the temperature may be independent of conditions that occurred further upstream. There are several factors that can contribute to this increasing trend. At the source point, 100 % of the emerging flow is from ground water which typically runs about 52°F. At points further downstream, the flow consists of a combination of surface flow and contributing groundwater inflow. As the stream gets larger, the proportion of the ground water contribution decreases and its cooling effect lessens while the surface receiving solar energy is increasing. It should be noted that groundwater contribution is not uniform and that some areas will have a higher influence. However, in general, larger streams will have a smaller percent of groundwater contribution.

As streams get larger, they get wider and more difficult to shade. Also, their bed characteristics change, the channel gradient changes and the elevation decreases.

Hyporheic flow

Hyporheic flow describes the exchange of streamflow and groundwater in the permeable, course grained gravel deposits within the channel and flood plain. The National Water-Quality assessment that was conducted in the Willamette River indicated that hyporheic exchange can be significant (Wentz and others, 1998). As flows recede the ratio of hyporheic to total flow increases. Flows out of the gravel into the stream tend to provide local cooling by adding cooler water. Flows into the gravel from the stream also tend to provide cooling by dissipating the excess heat in to the landmass. For example, an isolated pool that is experiencing hyporheic circulation could remain relatively cool; the inflow would bring in cool water and the outflow would remove the heated water, thereby avoiding an accumulation of heat.

Hyporheic flow can be observed in small channels during the low flow period. It is common to see a small channel disappear into the gravel bed and then reappear further down stream. The effect is harder to notice in isolated pools when the flow rate is small with respect to the volume of water in the pool. Nevertheless, in many cases it is likely that hyporheic flow can be associated with the pool. Naturally, if the level of the pool is remaining constant, the inflow must be equal to the outflow.

It is difficult to directly measure the effect of hyporheic flow directly. Comparison of careful flow measurements may provide an indication. For example, flow measurements in bedrock control reaches would tend to have a minimal component and could be compared with flows in nearby reaches with more permeable streambeds.
Channels with permeable beds may contain a longitudinal hyporheic flow component that varies along the channel as the permeability of the channel bed changes. For example, upwelling may occur flow with a corresponding increase in surface flow when a channel changes from a permeable bed to a nonpermeable bedrock bed and then lose flow through downwelling when the bed changes back to a permeable condition. These changes in flow patterns contribute to hydrologic retention. Water moving through the substrate material would have more time to interact with the cooler subterranean environment. (Boulton et al, 1998, p 66.)

Lateral groundwater inflow may occur from neighboring source areas. "Dry tributaries" that show no surface flow may supply significant quantities of cooler groundwater.

The reaches along a stream channel may be described as gaining or losing surface flow with appropriate adjustments in the hyporehic component to balance the total net flow. Elevated temperatures can reduce the viscosity of water, which can cause an increase in the infiltration component. A temperature increase from 0°C to 25°C results in a doubling of the infiltration rate. Streambed infiltration rates may vary as much as 20% in losing streams (Constantz, 1998, p1610).

Dye studies could also be used to determine the flow by measuring the concentration of the dye in the pool over time (Linsley et al, 1975).
Under steady state conditions streams can appear to lose or gain surface flow at different points along the stream.

Effect of Pools

Under typical low-flow conditions, which is also the time of peak seasonal stream temperatures, channels in the watershed tend toward a pool dominate system and may even degenerate to a series of isolated pools. This fact is important because the hydraulics of the stream under these conditions are much different than that under higher flow conditions that are experience the rest of the year. Computer models often have a requirement for "uniform flow" conditions which occurs when the depth of flow is the same at every section of the channel (Chow, 1959). Typically gradually varying flow occurs across the pool and then changes to rapidly varying flow at the control weir and continues downstream until a hydraulic jump occurs and the flow reverts back to gradually varying flow.

During summer low flows the ratio of the volume of the pool to the quantity of flow increases dramatically. The dimensions of this ratio are time and is analogous to the "time constant" associated with capacitive/ resistive electronic circuits. In electronics these circuits tend to filter or smooth the waveform of an electrical signal. Likewise, the pools can tend to smooth out a time dependent water quality parameter such as temperature. For example, a rectangular pool 50 feet x 12 feet x 1.5feet has a volume of 900 cubic feet. Dividing this value by a flow of 0.2 cubic feet/ second gives "pool exchange time" value of 4500 seconds or 1.25 hours. Since mixing is occurring in the pool, the output from the pool represents a value averaged over the previous 1.25 hours. (See pool chart)

Low Flow

Peak seasonal temperatures occur during low flow conditions that represent the extreme end of the hydrologic regime. The absence of significant precipitation and the reduction of stored groundwater result in steadily receding surface flows in the late portion of the summer.

Effect of Shade on Temperature at Elk Creek Temperature Monitoring Sites

As discussed above, the amount of departure between the desired target temperature value and the actual value depends upon the relative effect of the various heat processes. The temperature monitoring data for Elk Creek provides an opportunity to determine the extent that shade considerations is responsible for the excessive heat.

Table 1 compares the amount of deviation of the seasonal maximum temperatures from the ideal target temperature with the deviation of the 350m average % closure value with the ideal site potential value.

Stream Name	km abv I mouth	MI fron I Ridge	350m ave Clos	Site Potei Closure	Diff clos Closure	Seasonal Max Temp	Site Pote max Ter	Temp Diff
11 Elk Ck abv Pass Ck		23.0	61.008	45	-16	84.0	84.0	0.00
20 Adam's Ck @ Mouth		6.1	70.987	83	12	69.7	69.7	0.00
10 Pass Ck @ moutl	0.00	16	56.843	65.00	8.16	80.20	80.20	0.00
15 Pass Ck abv Roc	4.83	12	62.986	78.00	15.01	77.10	76.67	0.43
7 Hardscrabble @ Mouth		7.2	78.224	83	4	72.3	71.5	0.82
14 Rock Ck @ mouth		7	68.815	83	14	72.3	71.3	1.01
21 Elk Ck abv Adam's Ck		12	80.841	79	-2	78.0	76.5	1.50
3 Brush Cr @ Mouth		12.0	47.503	79	31	78.9	76.9	1.96
19 Yoncalla @ Halo		7	47.707	83	35	72.9	70.8	2.14
8 Billy Ck @ Mouth		9.7	82.203	81	-1	77.7	74.7	2.98
9 Bear Ck @ Mouth		5.0	87.529	84	-4	70.6	67.4	3.17
22 Elk abv stockpile		8	75.990	82.00	6.01	75.8	72.6	3.21
17 Yoncalla Ck @ mouth		10	66.270	81	15	80.5	75.0	5.51
16 Pass Ck @ Park	12.75	6	43.524	83.50	39.98	75.90	69.01	6.89
23 Elk Ck abv Cause	10.93	3.7	45.989	84.50	38.51	77.70	67.85	9.85

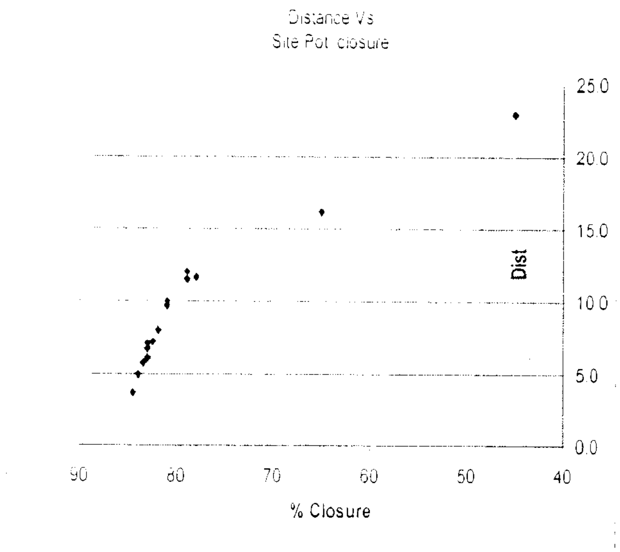
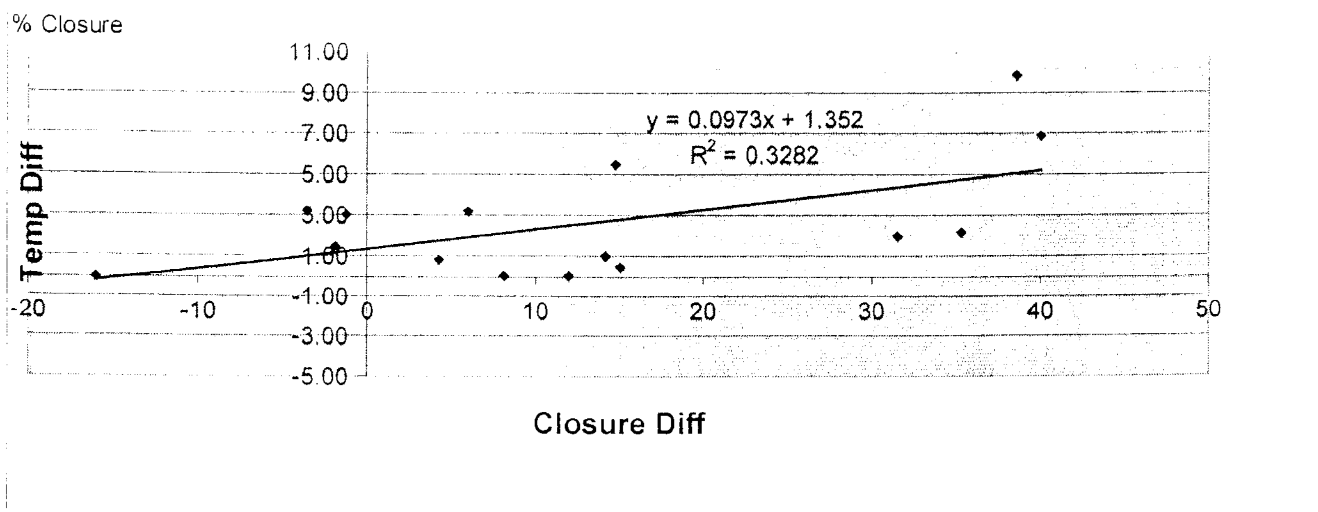


Chart 1 shows the curve used to establish the site potential values. For the purpose of this analysis, the sites at target temperatures were assumed to be at site potential.

Chart 2 shows that the difference in shade as detected by using the 350 m average value accounted for about 33% of the variability.



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Appendix B Shade Notes

This section contains background stream shade related information to supplement the main report.

There are many good references that discuss the physics of solar heating and the associated shade effect. I found that the documentation that supported the SSHADE model that was developed by the Instream Temperature Model group to be particularly useful. (Theurer et al 1984).

Historic Shade Conditions

The ODFW developed an analysis of historic, current and desired conditions for streams in western Oregon for the 1998 Oregon Plan for Salmon and Watersheds annual report (ODF&W, 1998). In the report they estimate that between 15 and 25% of coastal watersheds in Oregon may have been in the recently disturbed condition at any given time due to floods, landslides and stand resetting fires.

They also established a reference condition database by sampling streams that had reference condition characteristics. The table shows that 25% of the "reference condition" sites had 90% or better closure while 75% of them had better than 68% closure.

Quartile	Amount of exposed sky in Degrees	Percent Sky Exposure (% of 180 degrees)	Percent Closure
1st	18 degrees	10%	90%
2nd median	32 degrees	18%	82%
3rd	57 degrees	32%	68%

The paper notes that some possible bias was identified in the study, which was not based on a random sample. Modern fire suppression may have reduced the percentage of disturbed areas. Also, the channels had an average channel width of 52 feet. Smaller channels would tend to have to have a higher percentage of closure.

Shade Measurement Methodology

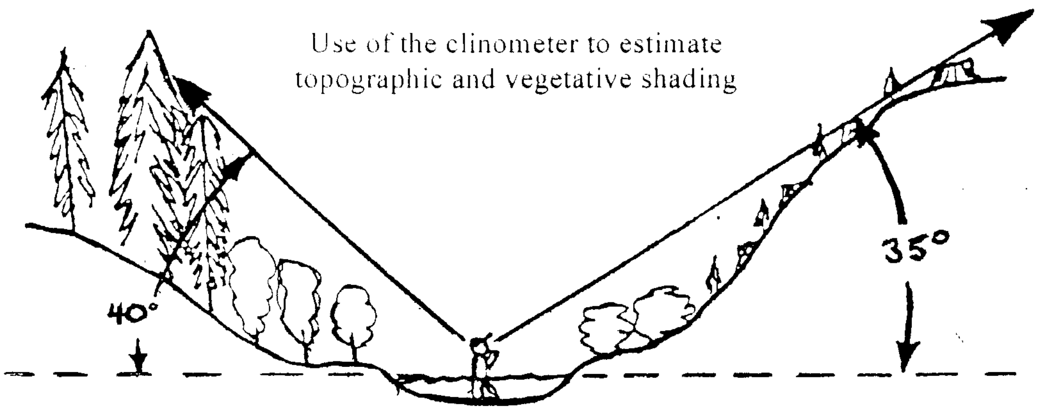
There are several terms and methods being used to designate the quantity of stream shade and generally the associated values are not directly interchangeable. For that reason, care must be taken in comparing shade values between studies that are using different methods and possibly different measured values.

In this report the following definitions apply:

1. % View-to-sky – Forest densiometer. A spherical densiometer provides an estimate of the % sky visible in the total hemispherical view. Readings typically taken in four directions from mid-channel and averaged.

2. % Shade- Solar Pathfinder®. The Solar Pathfinder® displays the hemispherical view and shows the solar path for any given date. This allows for the determination of the % Shade specifically for any date of interest.

3. % Closure- a hand held clinometer measures the angle from the horizontal to the edge of open sky as viewed at right angles to the stream. The sum of these angles is subtracted from 180° and then divided by 180° to give a % Closure value. Figure 1 shows an example with closure of 42%. Often the % Open Sky is cited which is simply 100 - % Closure.



In this example the Percent Closure is 75/180 or 42%.

4. Vegetative Shade density- Vegetative shade density is a measure of the effectiveness of vegetation to block sunlight. For example, a tree with 70% vegetative density would block 70% of the direct solar radiation passing through it.

5. Reach Shade Density- Reach shade density is a measure of the effectives of the riparian shade wall to block sunlight. Since the shade wall may have voids with not vegetative shade, the reach shade density is the product of the percentage of cover times the average vegetative density. For example, if the average shade of the trees were 70% and the shade wall along the reach contained only 50% trees, the reach shade density would be 35%.

6. % Effective Shade- This value is calculated using an algorithm that calculates the total shade received by a stream for a specified day and gives an average "effective value" for the entire day. The calculations typically require stream width, tree height, reach shade density and overhang information. The value

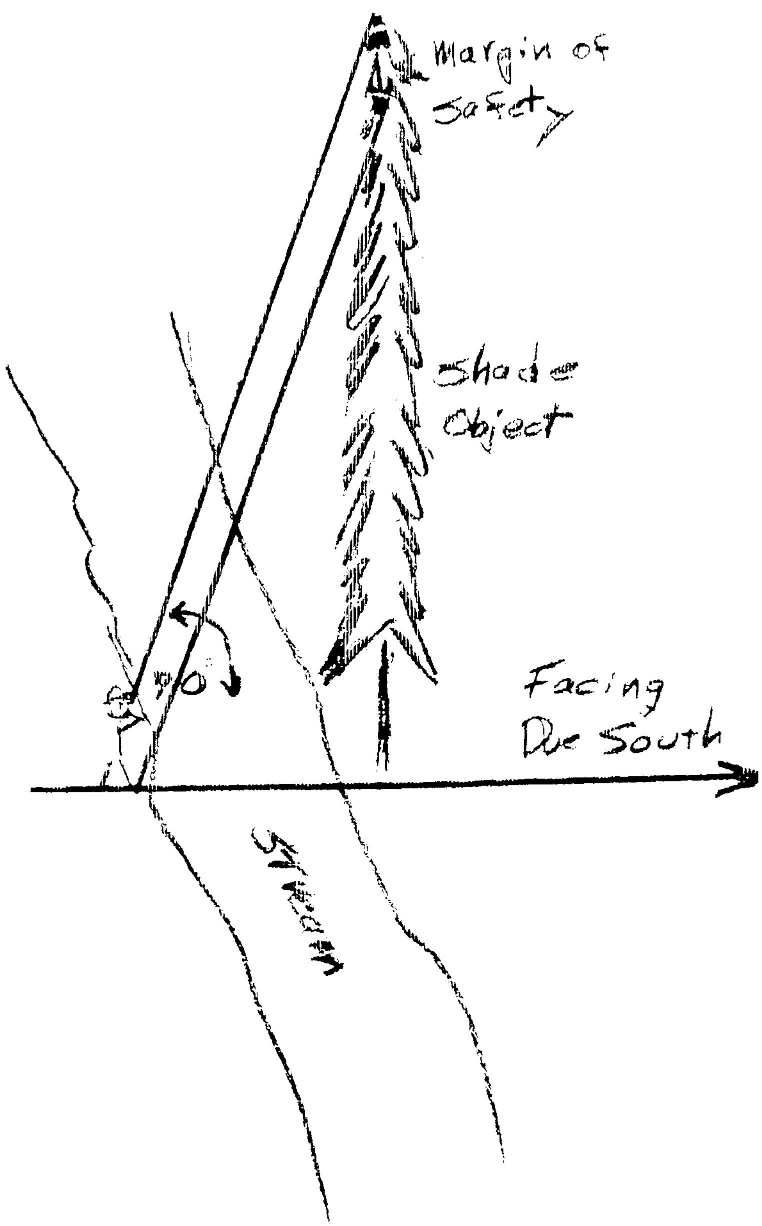
calculated should correspond to the % Shade measured by the Solar Pathfinder®. The SSHADE model which was developed as a utility for the SSTEMP and SNTEMP models (Theurer et al, 1984) was modified to run in Excel® and used for this project to calculate % Effective Shade. The SHADOW program developed by Chris Park also calculates effective shade.

It should be noted that the model calculates shade as 100% density and then adjusts the output by the corresponding reach density value.

The Shade Wall

The shade wall concept is helpful in determining exactly what trees shade the stream and how high they have to be to provide full shade during the critical summer months. During the spprine and summer the sun moves across the sky in an arc starting in the morning in the NE, rising maximum at the due South direction at noon and then descending and setting in the evening in the NW. This arc gets higher as the summer progresses reaching a maximum noon altitude angle at the summer solstice on June 22. This is the most restrictive time for stream shading.

Direction	Solar Altitude
East	36°
SE	65°
South	70°
SW	65°
West	36°



The table shows the maximum altitude angle of the solar path for a latitude of 43.25° for different aspects. This latitude is consistent with the Roseburg area which is about average for the Umpqua Basin. (A table of angles for other latitudes can easily be developed). The table can be used to define the effective shade wall that is necessary to fully shade a stream during any time of the year. For example, in the sketch the observer is looking due south across the stream and sees the top of the vegetation on the opposite bank at a 70° angle. In this case, the shadow of the tree will extend from the base of the tree to or beyond the observer at any time of the year when the sun is at the noon position.. If the observer turned to either the SE or the SW, the effective shade angle would be 65°, which determines the shadow length for mid morning and mid afternoon.. This procedure can be used to determine the maximum solar path and the corresponding shade wall needed to fully shade a stream for any time of the day. Vegetation that extends above this imaginary line will not provide shade to the stream at any time. For wide streams it becomes obvious that it is impossible to have trees tall enough to completely shade the stream around the summer solstice period. The maximum height of the mature trees ("site potential") determines the maximum possible shading for a given section of stream.

It is worth noting that the shade wall extends to the north and south directions since the sun rises in the NE and sets in the NW during the summer months.

Note also that the height of the observer adds a "margin of safety" since the shade wall height could be reduced by the height of the observer if s/he is standing upright at the edge of the stream.

Effectiveness of Shade Management

A 1995 study (Hatten 1995) sponsored by the Northwest Fisheries Commission looked at several variables associated with stream heating in 11 unmanaged streams and 15 managed streams in the temperate rain forests of the Olympic Peninsula. No significant differences in mean air temperatures were found between the monitoring sites in unmanaged and managed sub-basins. However, significant differences were found between group means of all five variables used to characterize the water temperatures of the study sites. For all water temperature variables, the managed group had significantly warmer mean temperatures than the unmanaged group. These significant differences between group means persisted even when the effects of environmental variables that may influence water temperatures such as stream elevation and amount of shade were removed. Only after controlling for the differences between the unmanaged and managed groups in the proportion of each sub-basin classified as late seral stage forest did the differences in mean stream temperatures become non-significant. The proportion of sub-basin classified as later seral stage forest was also the best single variable for predicting mean average hourly and mean maximum water temperatures at both managed and unmanaged sites (Hatten, 1995).

This result appears to be consistent with a study on Oregon (Beschta and Taylor 1988) that also found a relationship between stream temperature and extent of watershed management. These studies suggest that shade alone may not be sufficient to eliminate all stream heating. The exact mechanisms of the other contributing factors are not well understood at this time however they may involve differences in quality of riparian shade such as height of the shade canopy, groundwater quantity and temperature, channel characteristics such as width or hyporheic flow patterns.

Effect of canopy height

The SSTEMP model indicates that a high proportion (order of 2200 BTU/ft^2/day) of the heat flux is can be supplied by long-wave radiation from an overhead canopy. Basic principles from physics dictate that while radiation intensity from a point source varies inversely as the square of the distance, the intensity experienced at a point near a large radiating surface will vary inversely as the normal distance from the surface. For example, a stream under a 90-foot canopy will receive 1/3 of the long-wave radiation from the canopy as a stream under a 30-foot canopy. Consequently, buffers with a tall canopy may be more effective than low canopy buffers even though they have otherwise identical shade characteristics.

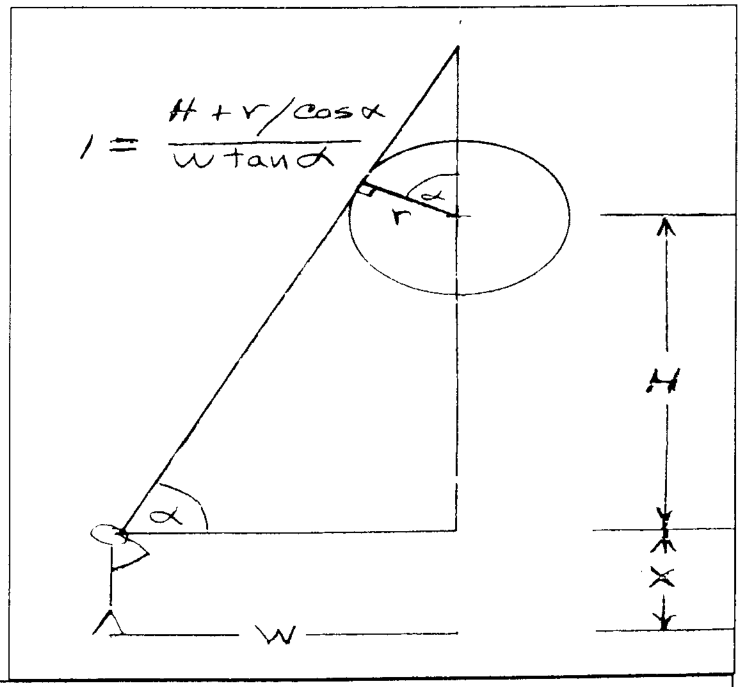
Relationship Between % Closure and % Effective Shade

Since data is available both as % Closure and % Effective Shade it is helpful to understand the relationship between these measurements.

Figure 1 shows the general geometric relationships.

Canopy = 2r
Tree Height = X +H +r
Observer Eye Level = X
Distance between trees= 2W

The equation can be solved with iteration methods to obtain an effective tree height from the percent closure angle.



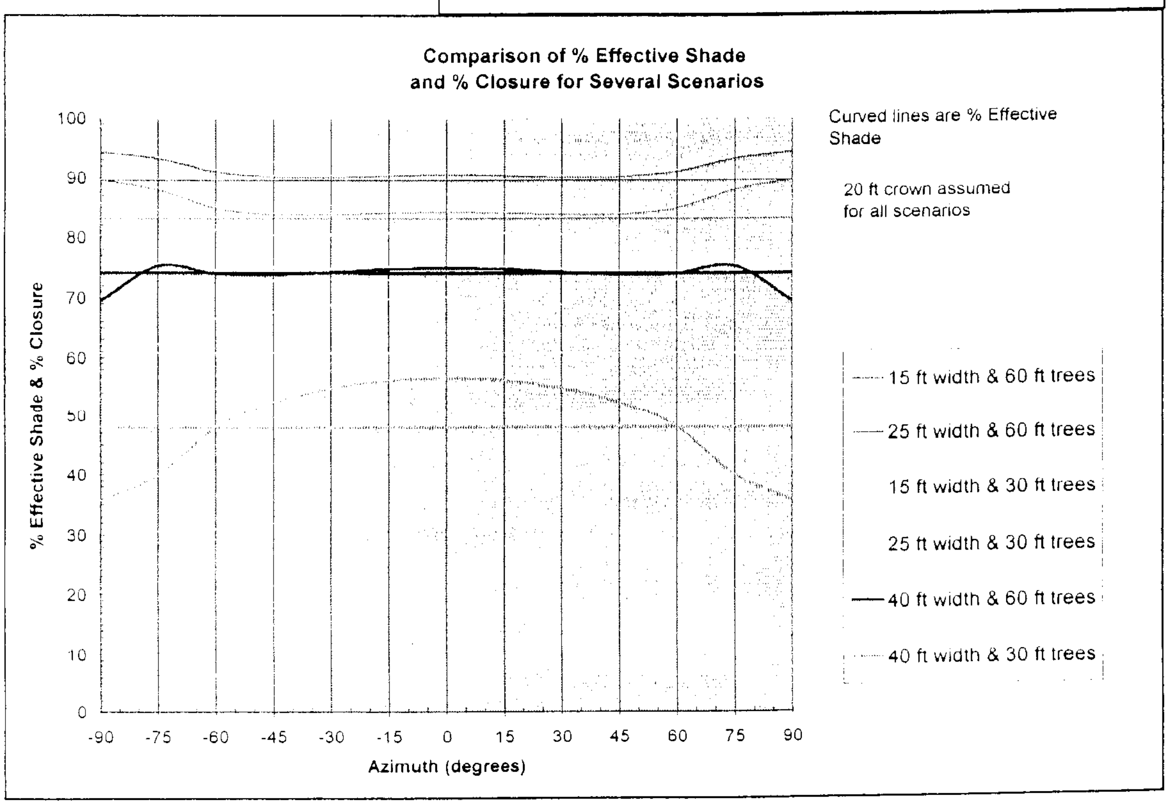


Chart 1 compares % Effective Shade and % Closure for several scenarios. The % Effective shade was calculated using SSHADE and a 100 % shade density was assumed. Since shade density is a simple correction factor, both values can be corrected the same way.

Since most of the values were within 10%, the %Closure value appears to provide a reasonably accurate measure of effective stream shade. It may not be precise enough for detailed modeling but it should suffice for general assessment purposes.

It should be noted that the azimuth data can be combined with the % Closure data to obtain the more accurate result.

Appendix C Adaptive Management

The following material was obtained from the following site:

Updated: Wednesday, 15-Sep-1999 10:20:01 PDT by Court Smith
URL is http://www.orst.edu/instruction/anth481/ectop/ecadm.html

History

Experimentation to learn more about the operation of complex systems is the essential feature associated with adaptive management. Adaptive management has the attributes of being flexible, encouraging public input, and monitoring the results of actions for the purpose of adjusting plans and trying new or revised approaches.

Holling and several colleagues developed adaptive management at the University of British Columbia's Institute of Resource Ecology in the late 1960s. "The first exercise in adaptive management was the Gulf Island Recreation Land Simulation (GIRLS) study in 1968 (Gunderson et al. 199:490). Adaptive management reached the scientific literature in C.S. Holling's book, Resilience and Stability of Ecological Systems, published in 1978. The emphasis of the Holling approach is to experiment to learn the boundaries of natural systems. Holling and his colleagues worked with resource managers in British Columbia on a number of management experiments and public participation workshops, testing the process.

Walters (1986:8) outlined the adaptive management as beginning "with the central tenant that management involves a continual learning process that cannot conveniently be separated into functions like research' and ongoing regulatory activities,' and probably never converges to a state of blissful equilibrium involving full knowledge and optimum productivity." Walters (1986:9) saw the value of adaptive management as questioning some of the basic management assumptions. He characterized adaptive management as the process of

- bounding management problems and recognizing constraints;
- representing existing knowledge in models of dynamic behavior that identify assumptions and predictions so experience can further learning;
- representing uncertainty and identify alternate hypotheses;
- designing policies to provide continued resource productivity and opportunities for learning.

Adaptive management became an important concept in U.S. resource management when Lee introduced it to the Northwest Power Planning Council in 1984. Lee learned about adaptive management from Randall Peterman, who in February 1984 gave a talk about experimental management (Halbert 1991:138). Lee (1993) uses the metaphor of compass and gyroscope to emphasize the process scientific analysis and civic participation in adaptive management. Compass and gyroscope integrate science and democracy, in which science, "linked to human purpose is a compass, a way to gauge directions when sailing beyond the maps;" and democracy, "a way to maintain our bearing through turbulent seas," is the gyroscope (Lee 1993:6). The compass, grounded in the scientific method, warns when the direction is off course, while the bounded conflict of the democratic process lends stability when humans encounter turbulence in their relations with nature. Subsequently, different forms of adaptive management have become part of the Northwest Forest Plan, the Oregon Plan for Salmon and Watersheds, the Oregon Department of Forestry Plan to manage state forests, and many other resource planning processes.

Bormann et al. (1995) proposed an adaptive management process consisting of four phases--plan, act, monitor, and evaluate. The Northwest Forest Plan is the first large-scale regional application of adaptive management in forestry (Bormann et al. 1998:17). It established ten adaptive management areas, but the Record of Decision directed that adaptive management be applied on all forestlands, not just the adaptive management areas (Bormann et al. 1998:19). The Northwest Forest Plan set in motion an evolving process for managers, scientists, and citizens to work together to manage ecosystems to achieve societal goals.

The Oregon Plan for Salmon and Watersheds calls for "active adaptive management." Active adaptive management is a "process of testing alternative hypotheses through management action, learning from experience, and making appropriate change to policy and management practice" (Oregon Plan). Key to active adaptive management is testing alternative practices. In its use of adaptive management, the Oregon Department of Forestry sees a three-stage process of planning, action, and monitoring.

As the use of adaptive management has become more widespread and diverse in meaning, Holling and his colleagues have referred to adaptive management as adaptive environmental assessment and management (AEAM). Often people think of adaptive management as "learning by doing," but this misses the essential goal of needing to experiment with complex systems to learn from them.

Definitions, Theory, Method

"Adaptive management is an inductive approach, relying on comparative studies that blend ecological theories with observation and with the design of planned interventions in nature and with the understanding of human response processes" (Gunderson, Holling, and Light, 1995, p. 491 in Barriers and Bridges)

An adaptive management system has two elements: a monitoring system to measure key indicators and the status of things, and a response system that enables modifying key indicators. (Adapted from Ray Hilborn and John Sibert, Marine Policy, April 1988:115-116.)

Theory: "Resilience and stability of ecosystems," paper by Holling about 1970. He worked with Carl Walters in the development. Walters was excellent at seeing critical points.

Method: Computer modeling in workshops conducted by Holling and Walters out of the Institute for Animal Resource Ecology at the University of British Columbia.

Problem: The spruce budworm and salmon on the West Coast served as the examples for development of the concepts.

Basic Assumptions:

1. knowledge will never be adequate
2. many questions can only be answered by experience and experiment
3. knowledge does not accumulate, it gets discarded
4. analyses get simplified
5. nothing is certain
6. much of what we know is wrong, we just don't know what

Procedure:

1. Identify key indicators; what do you want to learn from the system, what are the key elements and relationships?
2. bound the system
3. represent current understanding of the system
4. represent the uncertainties
5. design policies to probe for better understanding

Adapted from Carl Walters, Adaptive Management of Renewable Resources, 1986.

Critique

- allows experimental approaches
- recognizes that we can't know all about natural resource systems
- acknowledges uncertainties and complexity
- permits learning by doing
- encourages an evolutionary path
- people may not find "experimenting", evolution, or learning by doing desirable, particularly if they know what they want to happen
- society is unwilling to invest in monitoring
- How do you select between experiments?
- not enough time is given to decide the effectiveness of experiments, nor are people willing to let experiments go long enough to decide
- Can adaptive management actually handle the complexity of bicultural systems?

Four key books:

1. Adaptive Environmental Assessment and Management. 1978. C.S. Holling
2. Adaptive Resource Management. 1986. Carl Walters
3. Compass and Gyroscope. 1993. Kai N. Lee

4. Barriers and Bridges to Renewal of Ecosystems and Institutions, Lance Gunderson, C.S. Holling, and Stephen S. Light

OTHER REFS:

"Objectives, Constraints, and Problem Bounding," pp. 13- 41, In Adaptive Management of Renewable Resources, Carl Walters (1986).

"Point of View, Kai Lee," pp. 16-24, by Dulcy Mahar, In Northwest Energy News, September/October 1990. Discusses Kai Lee's role in bringing adaptive management to the Northwest Power Planning Council.

FEMAT (Forest Ecosystem Management Assessment Team), 1993, "Adaptive Management," pp. VIII-1 to VIII-54, In Forest Ecosystem Management: An Ecological, Economic, and Social Assessment, Portland, Inter-agency Working Group. Summarizes the adaptive management approach recommended for the FEMAT process for forests of Western Oregon.

Bernard T. Bormann, Patrick G. Cunningham, Martha H. Brookes, Van W. Manning, and Michael W. Collopy, 1994, Adaptive Ecosystem Management in the Pacific Northwest, Pacific Northwest Research Station, General Technical Report PNW-GTR-341, Forest Service, U.S. Department of Agriculture. Further development of the adaptive management process outlined in FEMAT.

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URL is http://www.orst.edu/instruction/anth481/ectop/ecadm.html

Umpqua Basin Watershed Council

Appendix D

Use of a Control Site to Reduce Inter-Year Variability in Stream Temperature Data in the Umpqua Basin

Prepared by InSight Consultants
PO Box 10, Yoncalla, OR

Umpqua Basin Watershed Council

Use of a Control Site to Reduce Inter-Year Variability in Stream Temperature Data in the Umpqua Basin

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PO Box 10, Yoncalla, OR

Use of a Control Site to Reduce Inter-Year Variability in Stream Temperature Data in the Umpqua Basin

Summary:

This report compares summer stream temperature data from six locations in the North Umpqua Watershed over a period of four years. The simple average of the ratios of the daily maximum and minimum values with corresponding values in a control stream over a 50-day period appear to effectively reduce the inter-year variability in the stream temperature data. These ratios can serve as an index of the heating characteristics of the individual sites and can facilitate the comparison of data from different years.

The Problem:

Stream temperature often is identified as an important parameter when assessing watershed conditions. The development of thermistor type data loggers has made the collection of large quantities of digital data possible. In the Pacific Northwest, stream temperatures in the late summer months are often of interest and seasonal data files of the order of 4000 readings can be easily collected at a point of interest.

Figure 1 shows a pair of typical patterns from the Umpqua Basin for a given year. Note the similarity between the patterns, suggesting that both sites are responding to similar conditions. The differences in the data between these sites are an indication of the relative thermal response of each site to prevailing conditions and are of particular interest for stream temperature assessment.

Figure 1 Typical data from year 2000.

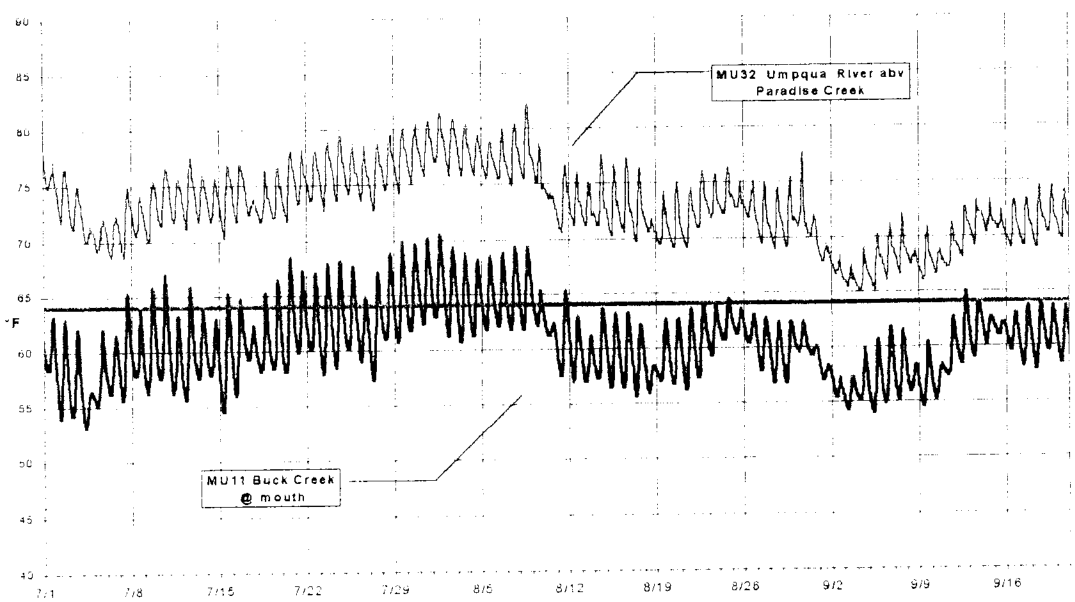


Figure 2 shows the temperature response of a typical site for three different summer seasons. The changes between seasons are due to different weather patterns and streamflow conditions as well as any change in the physical condition of the site. This variability makes it difficult to compare the thermal response of different sites for different years.

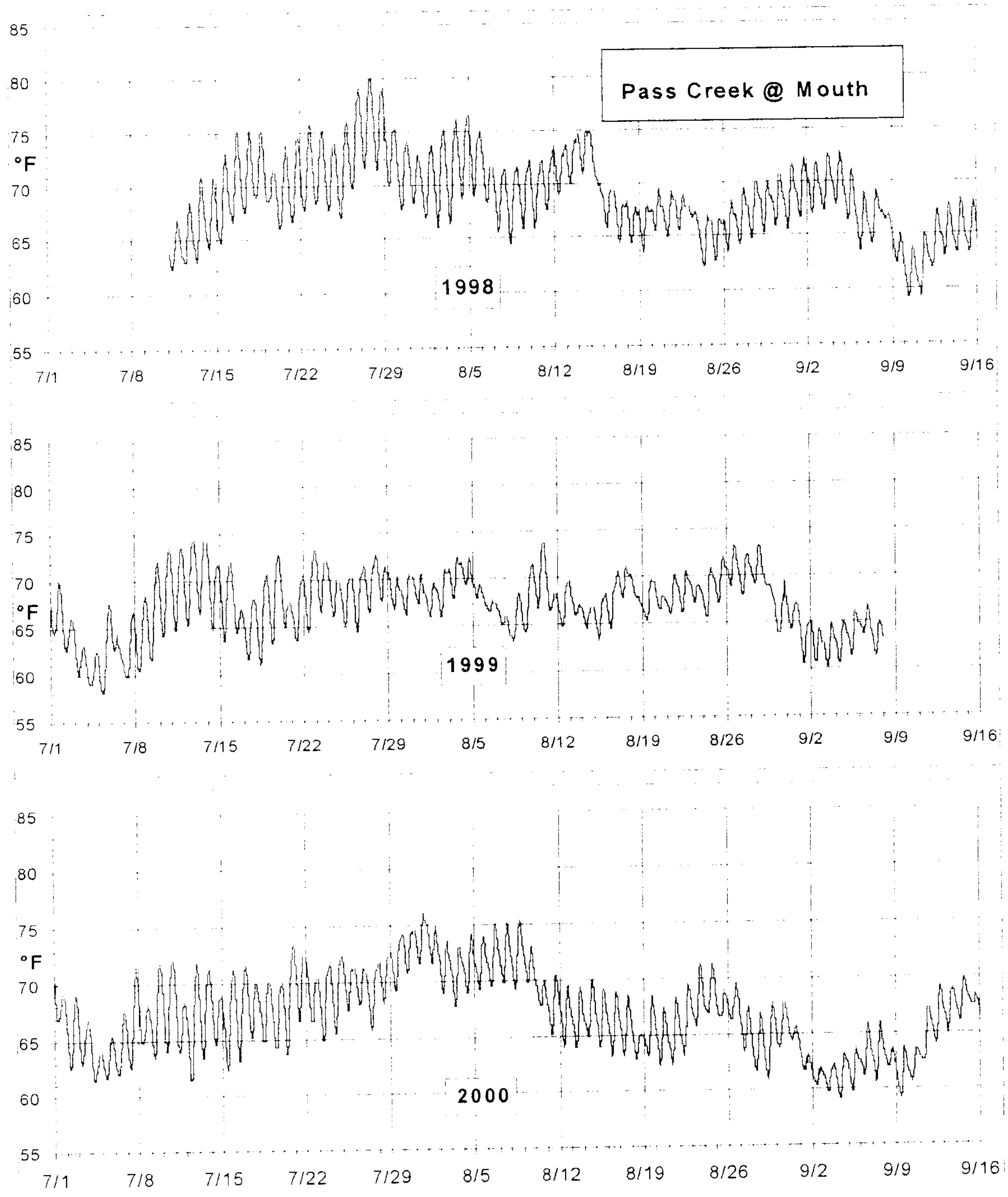


Figure 2 Three years of data from one monitoring site.

The goal is to develop an index that quantifies the relative thermal response of a site that is independent of the year of collection.

Rationale: Stream heating is a complex process with many factors that influence the final temperature. The basic principals are well understood and there are many models that attempt to predict stream temperature for a given set of conditions. The limitation of the models often is directly related to the difficulty of obtaining sufficient accurate data to fully describe the thermal response of the various components. An empirical approach compares the actual net effect of these factors under changing conditions.

The similarities between the graphs of the empirical data suggest that a simple relationship may exist between them and the use of one site as a control may effectively reduce some of the variability. The use of a control site to reduce inter-year variability is a common practice for "paired watershed" studies.

Several factors contribute to the seasonal variability and may affect stream temperatures at different locations in different ways. The following is a discussion of the relative significance of these factors.

> ***Solar Path:*** Since the streams have different aspects, topographic features and shade conditions, the relative effect of the changing solar path at the various sites would be different at different times of the summer. To minimize this effect, the same 50-day time interval was used for each year.
>
> ***Flow Conditions:*** Under low flow - high temperature conditions, the interrelationship between surface flow, groundwater inflow and hyporheic flow becomes increasingly important. For example, as surface flow decreases, the proportion of cooler ground water contribution may increase with a corresponding shift in the stream temperature. Likewise, as flow recedes the stream becomes more like a series of interconnected pools that act as small reservoirs relative to the flow passing through them. A consequence of these trends is that the local environment has an increasing influence over the stream temperature.
>
> A basic assumption of this procedure is that the temperature of all of the streams in the same general vicinity (1,000 square miles) is responding in a similar (proportional) manner to the prevailing flow conditions. The accuracy of the results is a measure of the extent that this assumption is true. It is apparent from the results that it is not equally valid for all sites.
>
> ***Local Heat Capacity:*** High temperatures occur in the late summer later than the summer solstice because the earth is still heating more than it is cooling each day and the excess heat accumulates in the environment. At the local level, surface conditions can influence the rate and extent of this accumulation. For instance, a bedrock-dominated system may accumulate heat in a different manner than a soil/gravel riparian zone. These differences would contribute error in this method that may appear as a uniformly changing error over the sample period.

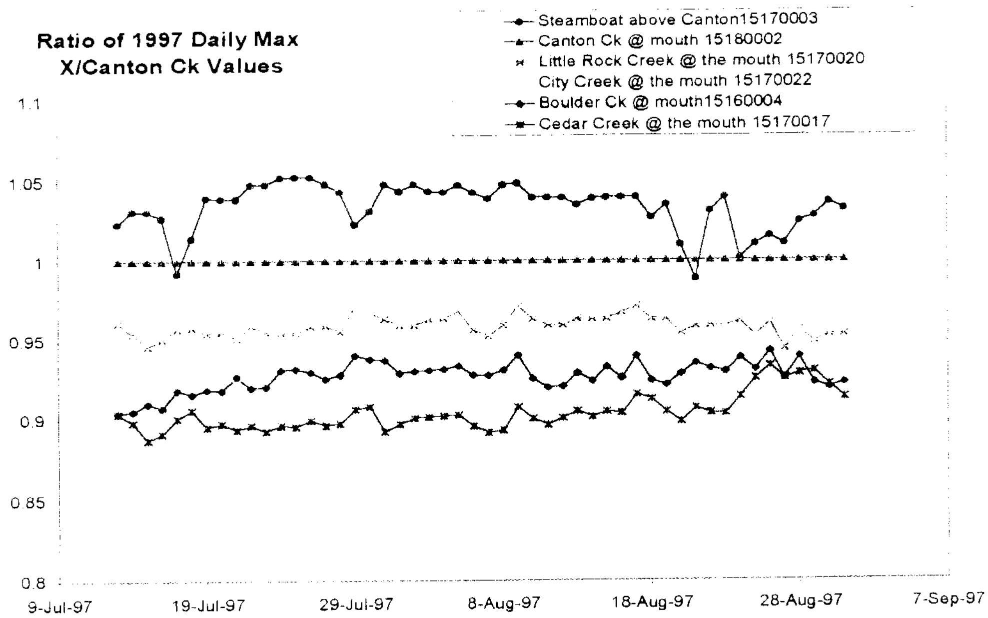
The Method: The procedure used in this report consists of simply finding the average of the ratio of the daily maximums and the daily minimums between the site of interest and a "control site" for the "reference year." The pair of ratios associated with a site can then be applied to the daily maximum and minimum values at the control site for another year to generate the corresponding calculated daily maximum and minimum for the site of interest. In this study, a 50-day interval between July 13 and August 31 was used.

To test this method it was necessary to have multi-year data from several sites that was collected in a consistent manner over the same period. This study used stream temperature data collected over 4 years from six sites on the Umpqua National Forest in the Steamboat Creek area in the North Umpqua Watershed (See Table 1) The data collected in 1997 was selected arbitrarily and used as the "Base Reference Year" and Canton Creek at the mouth was selected arbitrarily as the "Control Site." The 50-day period of July 13 to August 31 was selected as representative of the "high temperature" period for the streams.

Table 1 1997 Average Ratios

Monitoring Site	Daily Maximum		Daily Minimum		Watershed Area
	Average Ratio	Standard Deviation	Average Ratio	Standard Deviation	Square Miles
Canton Creek @ Mouth (Control)	1	na	1	na	62
Steamboat above Canton	1.034	0.015	1.021	0.013	165
Boulder Ck @ mouth	0.927	0.009	0.954	0.007	35
Cedar Creek @ the mouth	0.904	0.011	0.912	0.018	12
Little Rock Creek @ the mouth	0.959	0.006	0.961	0.007	15
City Creek @ the mouth	0.945	0.014	0.929	0.016	10

The ratios Max Site X/Max Control and Min Site X/ Min Control were determined for each day at each site in the 1997 period and are shown in Figure 3.



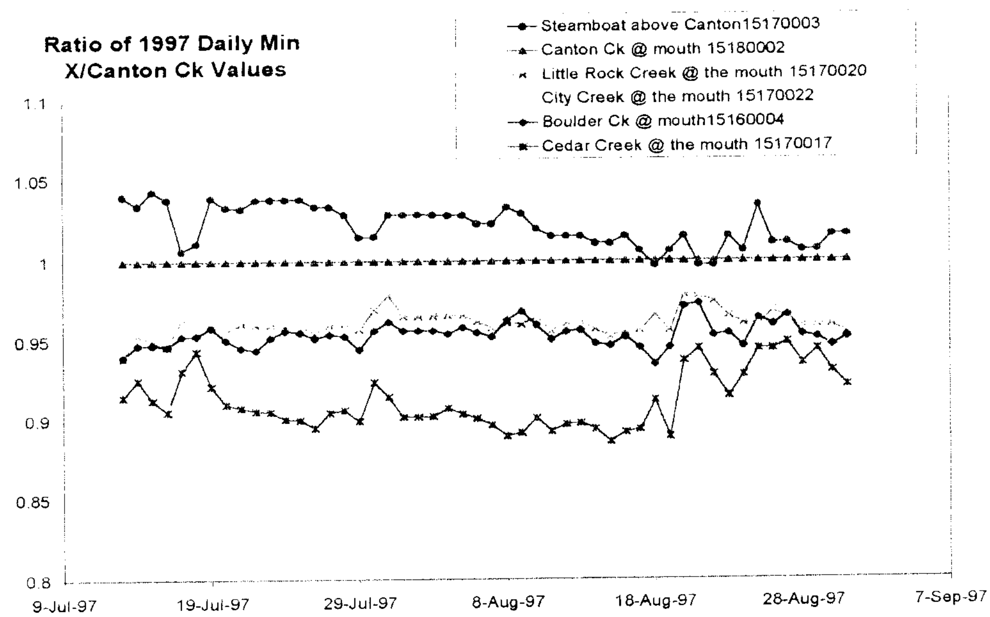


Figure 3 Ratios of 1997 daily maximum and minimum temperatures for several streams compared to the reference stream (Canton Creek).

The average of these ratios over the 1997 50-day interval was determined for each site (Table 1). The standard deviation in the ratio table provides an indication of the quality of the proportional relationship.

The five sets of site ratios were then applied to the control site values for the years 1998-2000 to generate calculated daily maximum and minimum values for each site for the years 1998-2000. The Appendix shows the calculated results compared with the actual stream temperatures measured at the five sites.

Table 3 compares some common summary statistics generated from the calculated values with those generated from the actual temperatures data.

MaxMaxT - Maximum temperature for the period of record for each year (7/13-8/31).
MinMinT - Minimum temperature for the period of record (7/13-8/31).
AveMaxT - Simple average of the daily maximum temperatures.
AveMinT - Simple average of the daily minimum temperatures.
HrAbv64 - The total hours that the stream temperature was above 64 °F for the period of record.
Max7DayAve - The maximum value of the seven-day average of the daily maximums for the period of record.
Note: All temperatures in degrees Fahrenheit

The value for the "Hours above 64 °F" statistic was derived for each day by simple interpolation between the daily maximum and minimum temperatures. Since the time of the daily maximum and minimum was not exactly the same for the control site and the stream of interest, the average difference was determined from the 1997 data and applied to the reference sited data for the subsequent years to get an estimated time for the stream of interest.

Table 2 shows the time correction values used in the calculations.

Monitoring Site	Average Time Shift (hours)			
	Maximum Hours	Standard Deviation	Minimum Hours	Standard Deviation
Steamboat above Canton	0.009	4.090	-0.211	4.123
Boulder Ck @ mouth	-1.774	2.689	-0.004	2.636
Cedar Creek @ the mouth	-0.180	2.652	-1.440	3.138
Little Rock Creek @ the mouth	-0.345	2.768	-0.555	2.440
City Creek @ the mouth	-1.616	2.765	-1.546	3.344

Table 2 Time correction used to compute exceedance hours.

Table 3 Comparison of common seasonal statistics - Actual values Vs Calculated values

1997 Calibration Year

Steamboat above Canton	MaxMaxT	MinMinT	AveMaxT	AveMinT	HrAbv64	Max7DayAve
Actual Value	77.21	60.66	71.80	64.58	1078	75.53
Calculated Value	76.54	60.41	71.78	64.58	1096	74.76
Difference	0.67	0.25	0.02	0.00	-17	0.77

Boulder Ck @ mouth	MaxMaxT	MinMinT	AveMaxT	AveMinT	HrAbv64	Max7DayAve
Actual Value	68.70	55.60	64.36	60.29	287	67.29
Calculated Value	68.62	56.40	64.36	60.30	270	67.03
Difference	0.08	-0.80	0.00	0.00	17	0.26

Cedar Creek @ the mouth	MaxMaxT	MinMinT	AveMaxT	AveMinT	HrAbv64	Max7DayAve
Actual Value	66.32	54.12	62.74	57.66	34	64.95
Calculated Value	66.92	53.95	62.76	57.68	54	65.37
Difference	-0.60	0.17	-0.02	-0.02	-19	-0.42

Little Rock Creek @ mouth	MaxMaxT	MinMinT	AveMaxT	AveMinT	HrAbv64	Max7DayAve
Actual Value	70.82	55.58	66.59	60.77	555	69.46
Calculated Value	71.00	56.84	66.59	60.77	530	69.35
Difference	-0.18	-1.26	0.00	0.00	25	0.11

City Creek @ the mouth	MaxMaxT	MinMinT	AveMaxT	AveMinT	HrAbv64	Max7DayAve
Actual Value	69.32	54.18	65.58	58.71	313	68.23
Calculated Value	69.93	54.93	65.58	58.73	324	68.31
Difference	-0.61	-0.75	0.00	-0.01	-11	-0.07

1998

Steamboat above Canton	MaxMaxT	MinMinT	AveMaxT	AveMinT	HrAbv64	Max7DayAve
Actual Value	79.09	71.11	73.57	66.00	1101	77.61
Calculated Value	78.46	69.83	73.16	65.41	1114	76.87
Difference	0.63	1.28	0.41	0.59	-13	0.75

Boulder Ck @ mouth	MaxMaxT	MinMinT	AveMaxT	AveMinT	HrAbv64	Max7DayAve
Actual Value	71.11	66.13	66.80	62.26	667	70.09
Calculated Value	70.35	65.20	65.59	61.07	498	68.92
Difference	0.76	0.93	1.21	1.20	168	1.17

Cedar Creek @ the mouth	MaxMaxT	MinMinT	AveMaxT	AveMinT	HrAbv64	Max7DayAve
Actual Value	67.78	62.85	63.95	58.64	214	66.61
Calculated Value	68.61	62.37	63.97	58.42	213	67.21
Difference	-0.83	0.48	-0.02	0.22	0	-0.60

Little Rock Creek @ mouth	MaxMaxT	MinMinT	AveMaxT	AveMinT	HrAbv64	Max7DayAve
Actual Value	72.62	66.41	67.89	61.81	721	70.95
Calculated Value	72.79	65.71	67.87	61.54	679	71.31
Difference	-0.17	0.70	0.02	0.27	41	-0.36

City Creek @ the mouth	MaxMaxT	MinMinT	AveMaxT	AveMinT	HrAbv64	Max7DayAve
Actual Value	72.60	63.49	68.00	59.85	592	70.77
Calculated Value	71.69	63.50	66.84	59.48	473	70.23
Difference	0.91	-0.01	1.16	0.37	119	0.53

Table 2 Continues

1999

Steamboat above Canton	MaxMaxT	MinMinT	AveMaxT	AveMinT	HrAbv64	Max7DayAve
Actual Value	75.35	66.70	70.82	63.21	835	73.95
Calculated Value	74.36	68.05	71.16	64.73	927	72.72
Difference	0.99	-1.35	-0.34	-1.52	-92	1.22

Boulder Ck @ mouth	MaxMaxT	MinMinT	AveMaxT	AveMinT	HrAbv64	Max7DayAve
Actual Value	66.42	63.23	62.33	58.51	117	65.29
Calculated Value	66.67	63.53	63.65	60.08	190	65.20
Difference	-0.25	-0.30	-1.32	-1.57	-72	0.09

Cedar Creek @ the mouth	MaxMaxT	MinMinT	AveMaxT	AveMinT	HrAbv64	Max7DayAve
Actual Value	64.57	60.29	62.08	57.10	13	63.83
Calculated Value	65.02	60.78	62.07	57.48	18	63.59
Difference	-0.45	-0.49	0.01	-0.38	-5	0.24

Little Rock Creek @ mouth	MaxMaxT	MinMinT	AveMaxT	AveMinT	HrAbv64	Max7DayAve
Actual Value	68.73	63.80	65.37	59.98	375	67.74
Calculated Value	68.98	64.03	65.86	60.55	470	67.46
Difference	-0.25	-0.23	-0.49	-0.57	-95	0.27

City Creek @ the mouth	MaxMaxT	MinMinT	AveMaxT	AveMinT	HrAbv64	Max7DayAve
Actual Value	67.28	60.93	63.37	57.08	167	65.66
Calculated Value	67.94	61.88	64.86	58.52	259	66.45
Difference	-0.66	-0.95	-1.49	-1.44	-92	-0.79

2000

Steamboat above Canton	MaxMaxT	MinMinT	AveMaxT	AveMinT	HrAbv64	Max7DayAve
Actual Value	77.52	69.03	72.24	63.90	999	75.88
Calculated Value	76.22	68.34	70.77	63.85	997	74.45
Difference	1.30	0.69	1.47	0.05	2	1.44

Boulder Ck @ mouth	MaxMaxT	MinMinT	AveMaxT	AveMinT	HrAbv64	Max7DayAve
Actual Value	69.33	64.09	65.01	60.48	382	68.29
Calculated Value	68.34	63.81	63.46	59.61	229	66.75
Difference	0.99	0.28	1.55	0.87	152	1.54

Cedar Creek @ the mouth	MaxMaxT	MinMinT	AveMaxT	AveMinT	HrAbv64	Max7DayAve
Actual Value	66.02	60.29	61.99	56.62	41	64.94
Calculated Value	66.64	61.04	61.88	57.03	52	65.09
Difference	-0.62	-0.75	0.11	-0.41	-11	-0.15

Little Rock Creek @ mouth	MaxMaxT	MinMinT	AveMaxT	AveMinT	HrAbv64	Max7DayAve
Actual Value	70.22	64.09	65.87	59.82	434	69.07
Calculated Value	70.71	64.31	65.65	60.08	419	69.06
Difference	-0.49	-0.22	0.21	-0.26	15	0.01

City Creek @ the mouth	MaxMaxT	MinMinT	AveMaxT	AveMinT	HrAbv64	Max7DayAve
Actual Value		No	Data	Available		
Calculated Value		malfunctioning	Data	recorder		
Difference						

Discussion:

Errors

While the method appears to eliminate much of the variability in the data, the remaining variability shows up as errors between the calculated and actual values.

Table 2 and Figure 4 show some statistics for the error values (difference between actual and calculated) for the 7-day moving average results for the evaluation sample. It appears that the ratio method underestimated the measured 7-day mean by an average of .32 °F with a maximum error of 1.54 °F for the nineteen samples.

Table 3 Statistics of the error (°F) in the 7-day average results.

Mean	0.316083
Standard Error	0.156461
Median	0.241216
Standard Deviation	0.681997
Sample Variance	0.46512
Range	2.32652
Minimum	-0.78891
Maximum	1.537606
Largest(1)	1.537606
Smallest(1)	-0.78891

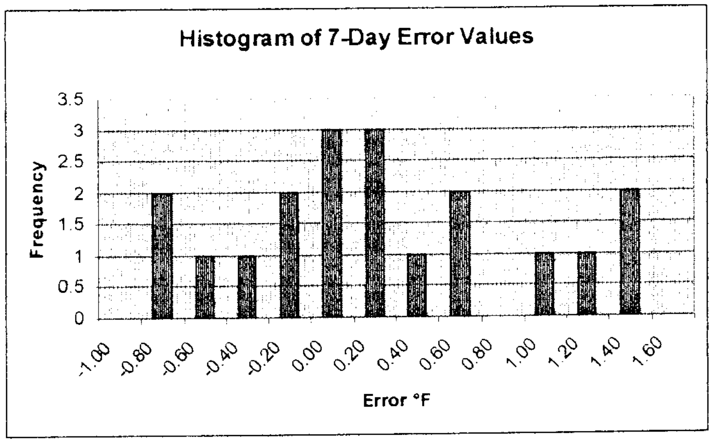


Figure 4 Histogram of the 7-day error values.

Figure 3 provides an indication of the variability that is not accounted for by the method. If the method eliminated all of the variability these the graphs would be a series of parallel horizontal lines. The uniform deviation from the horizontal suggests seasonal scale differences such as differences in the relative local heat capacity. Examination of the temperature charts for 1997 (appendix) shows that much of the "noise" in figure 3 appears to be associated with periods of rapid temperature change; suggesting that the streams do respond to change at different rates.

Likewise, the results for 1997 in the Appendix shows the error introduced by using the average ratio method compared to the actual data. This is an indication of the limitations of this methodology.

Site Information

The data provided by the Umpqua National Forest was part of their routine monitoring program and was not designed specifically for this type of study. The monitoring records indicate the following:

1. The same thermograph was used at each site throughout the study.
2. All units had a low probability of exposure to surface air.
3. The location for the Canton Creek site was changed after 1997 and the location of the Boulder Creek site was changed after 1998.
4. All sites had cobble-dominated substrate.
5. The 2000 data for City Creek was discarded by the Forest Service since the readings were erratic and not consistent with previous patterns observed by the agency.

Limitations of method

While the ratio method may prove to be a useful tool, several limitations need to be considered when using it.

1. Due to the nature of the method used, the temperature units used to develop the ratios must also be used to apply the method. In this example, Fahrenheit data must be used since the ratios were developed with Fahrenheit data. Celsius data must either be converted to Fahrenheit or used with the following formula:

$$T_{IC} = R \cdot T_{RC} + 32(R-1)/1.8$$

where:

$T_{IC} \equiv$ Temperature of stream of interest in Celsius
$T_{RC} \equiv$ Temperature of control stream in Celsius
$R \equiv$ Ratio for stream of interest

2. This method assumes similar responses between the watersheds being compared. Examination of the data for the calibration year should show patterns with similar shape and the corresponding daily ratios should be constant across the season for the season as shown in figure 3. Sites strongly influenced by reservoir releases, erratic withdrawals / augmentation, tidal influences would probably produce poor results. Ratios with a large standard deviation (see Table 1) will produce less reliable results.

3. Riparian areas are dynamic and changing conditions can change temperature changes over time. Trend type changes identified by this method will be the result of changes in both the reference site and the site of interest. It is expected that the change associated with changes in the reference site could be determined by analysis of changes in data from multiple sites relative to the reference site.

4. For critical applications, further verification of the accuracy of the predicted values is highly recommended. While the preliminary evaluation has shown good results within the Umpqua Basin, additional verification is encouraged until more sites are checked.

4. This method assumes uniform weather conditions between the watersheds. This is a common condition in the Umpqua Basin during the summer months but may not hold as well in other areas.

Further Work

!. The ratio values may have potential for quantifying the thermal characteristics at a site. As an example, Figure 5 shows the relationship of watershed area and the corresponding ratios. Note that the data shows the familiar heating with increased stream size. However, the scatter in the data may provide a quantification of the physical differences between the sites (i.e. Little Rock Ck and Cedar Ck). Relating these differences to the differences in site characteristics and flow regime may provide some additional insights stream assessment and management.

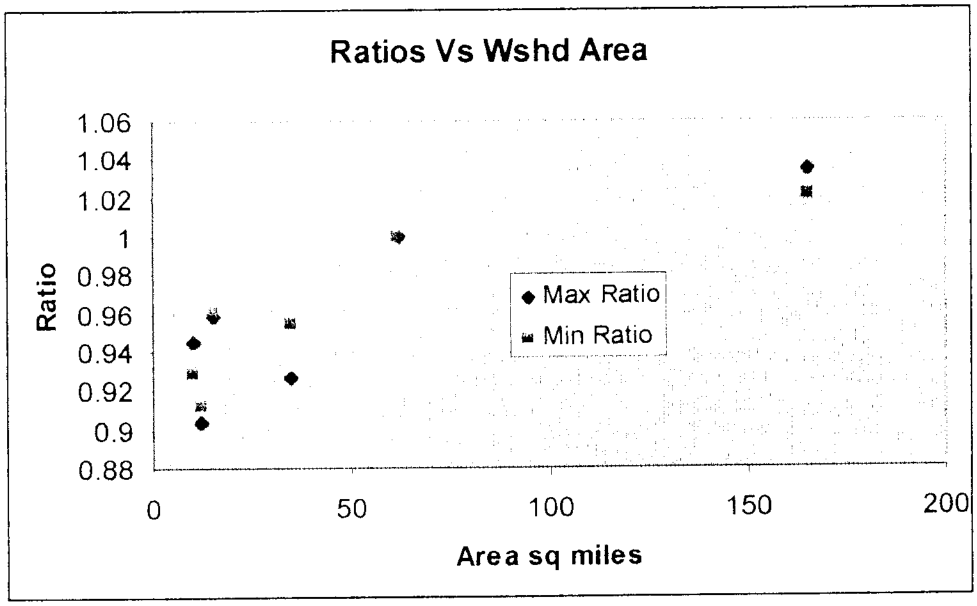


Figure 5 1997 Maximum and Minimum ratios vs. associated watershed area.

2. The central portion of the Umpqua Basin has summer stream temperature data from over 400 locations over the last three years. Several sites have been monitored each year that could serve as reference sites. The ratio method could be used to generate summer statistics for all the sites for a give year (i.e. summer 2000). This result would provide a look at the relative thermal condition of the entire central basin. This information could be helpful in identifying water quality concerns, evaluation of fish habitat, temperature management project development, and baseline monitoring in the Umpqua Basin.

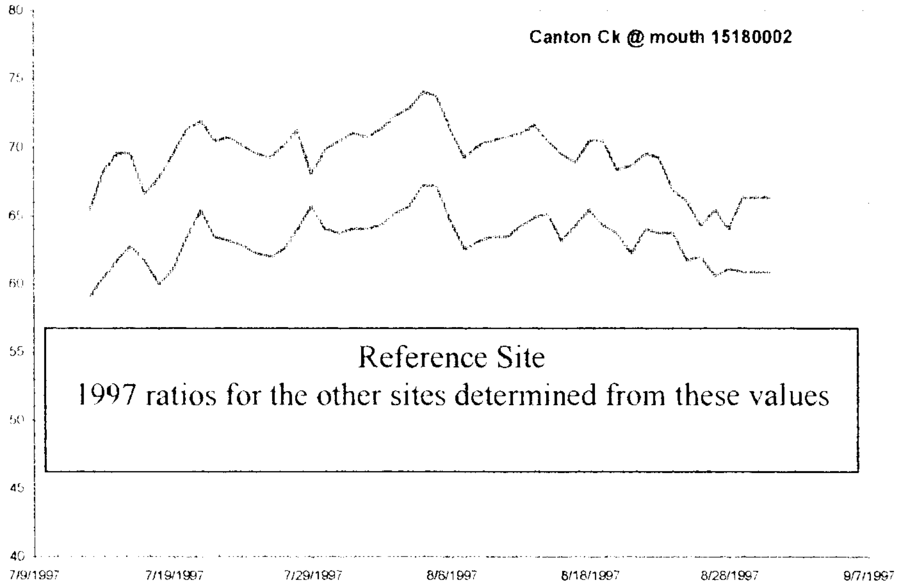
3. The development of the index could be refined by using a linear regression across the sample season in lieu of a simple ratio. Another option is to refine the ratio development by excluding rapid transition periods. This approach may give better estimates of the seasonal maximum values that usually occur during the more steady periods.

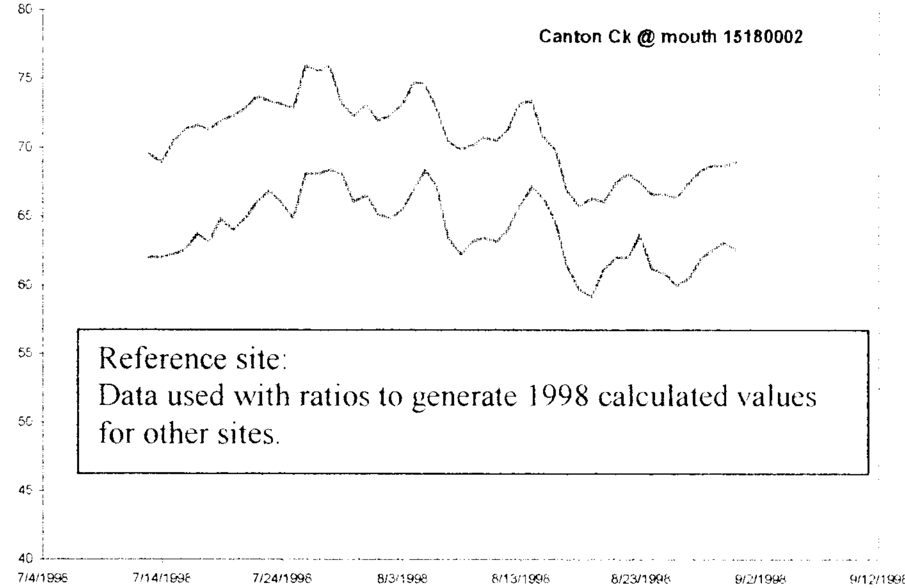
3. If the method is used extensively, verification should be continued and with a cumulative record of the statistics for all of the verified sites.

Appendix

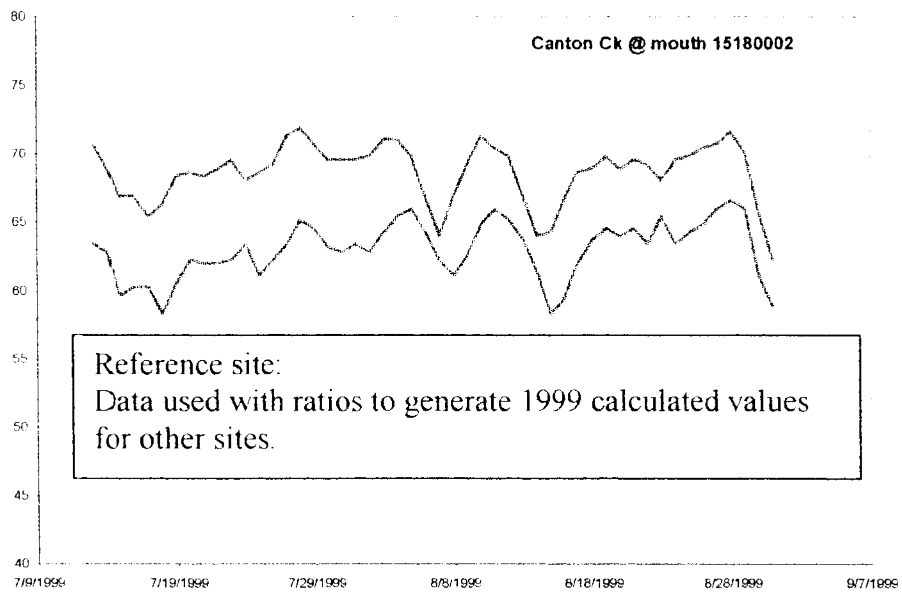
Stream Temperature Data for 7/13-8/31 for years 1997-2000:

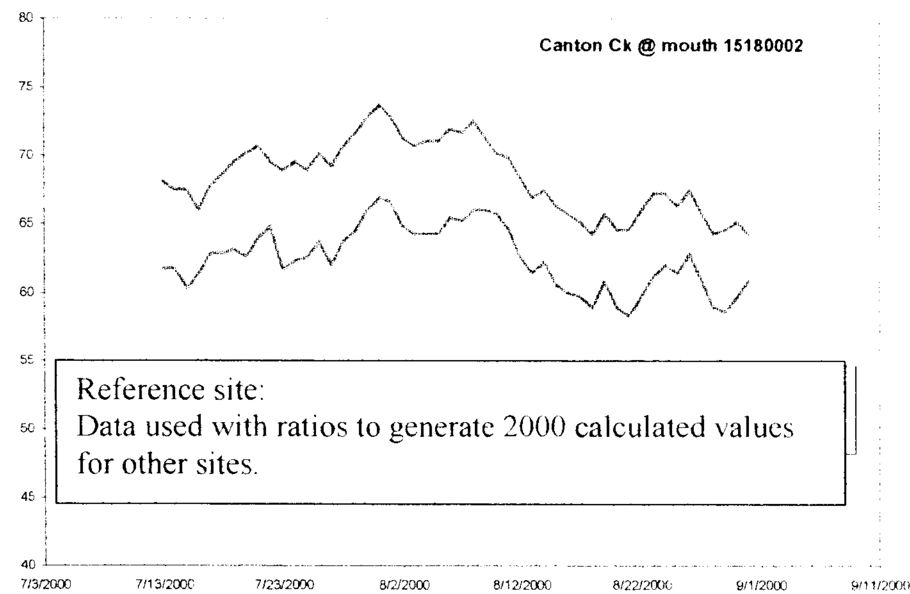
- Canton Creek @ mouth
- City Creek @ mouth
- Little Rock Creek @ mouth
- Cedar Creek @ mouth
- Boulder Creek @ mouth
- Steamboat Creek above Canton Creek

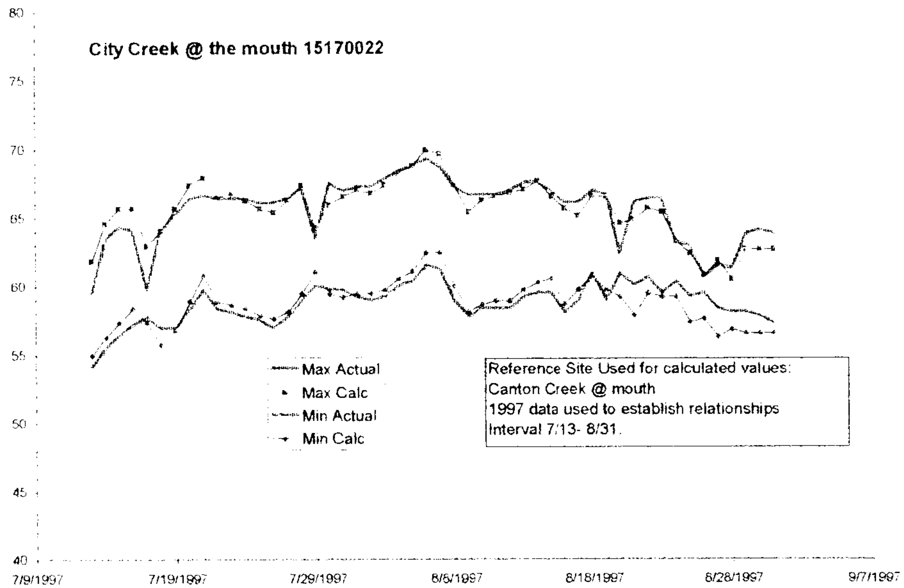


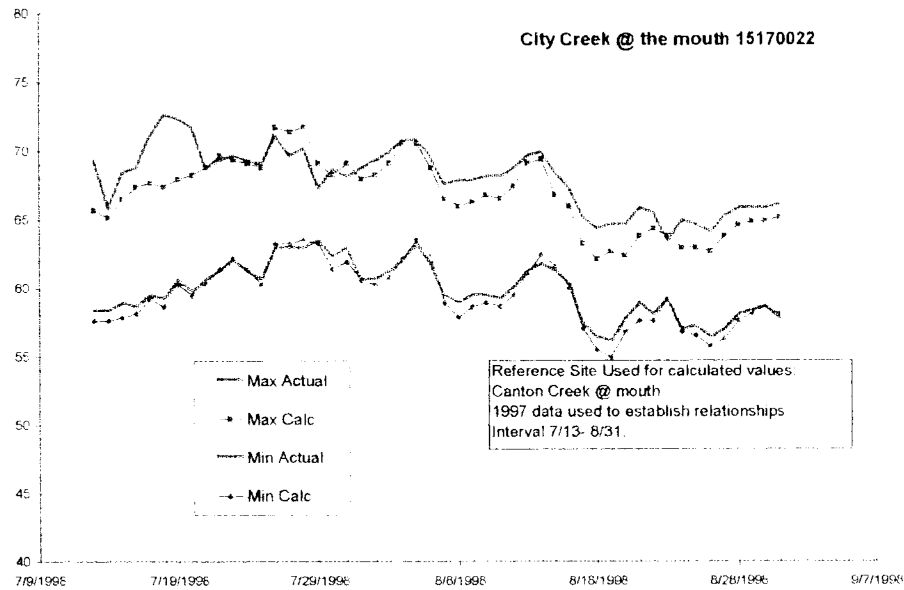


Canton Creek at mouth   Used to generate 1997 ratios and calculated values for subsequent years.

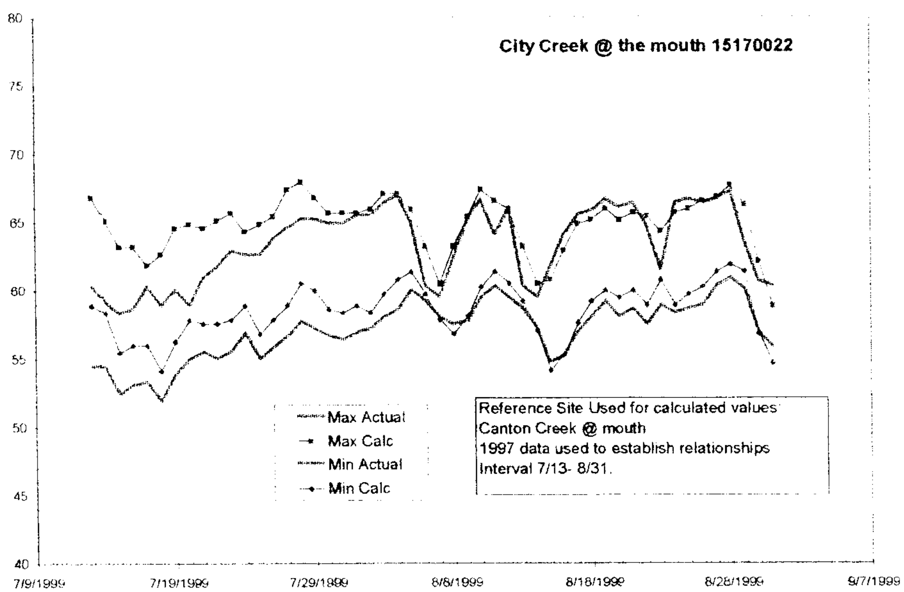


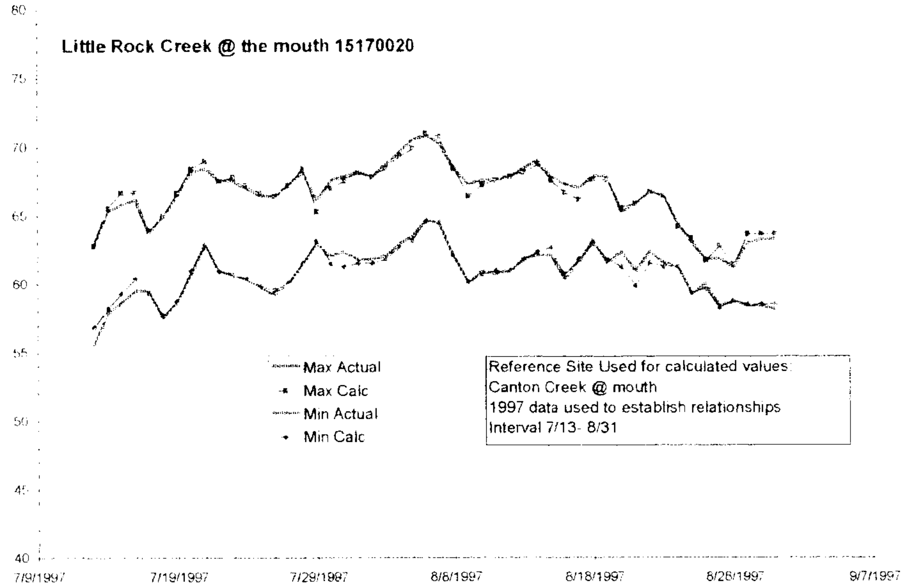


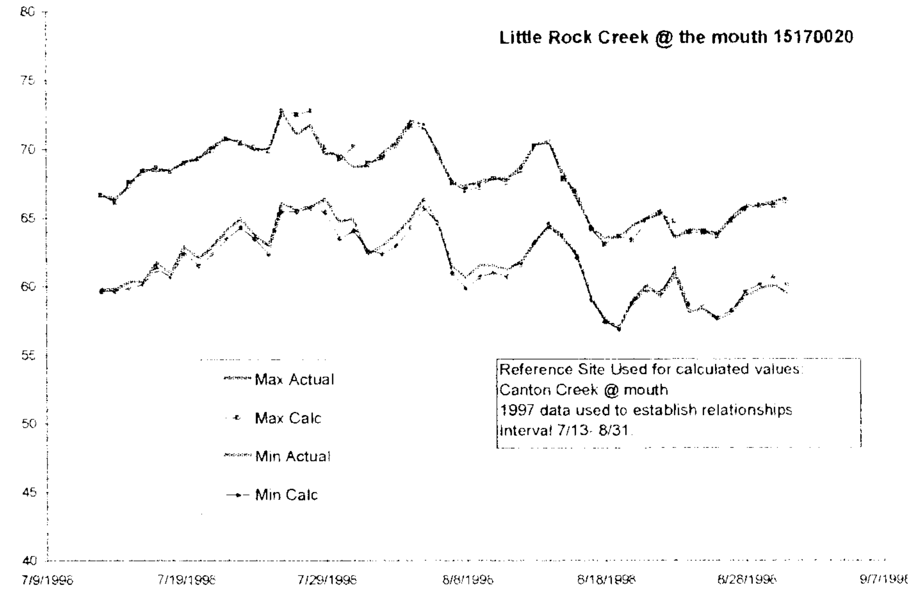




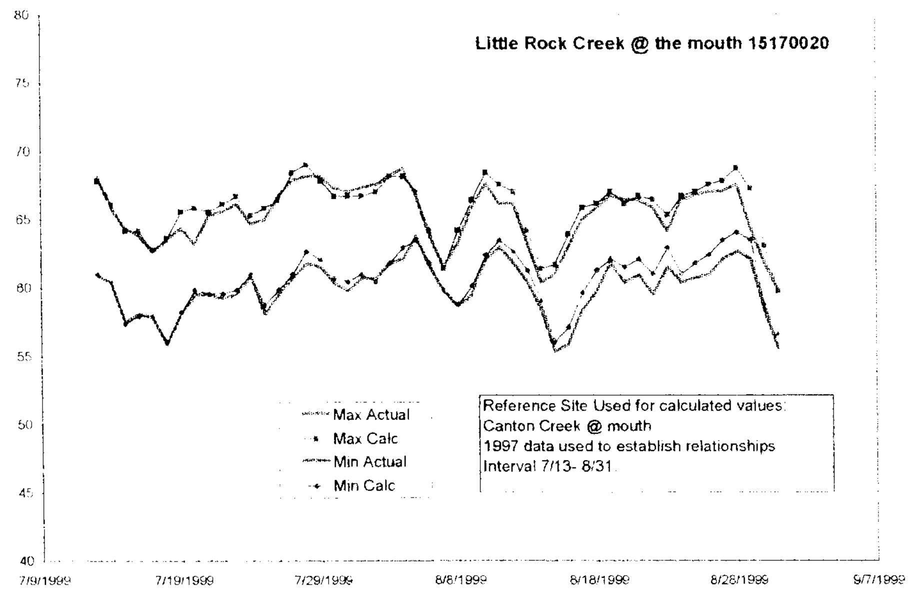
City Creek at mouth

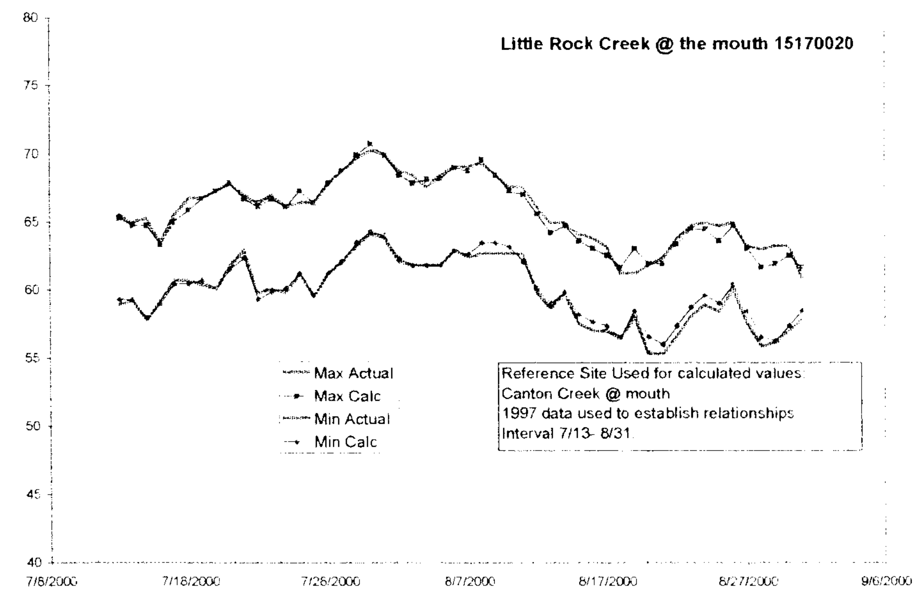


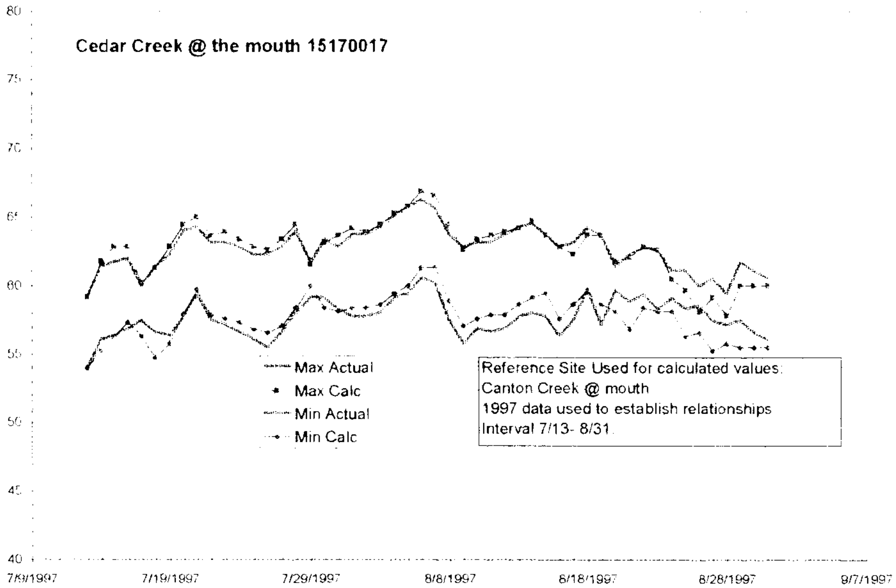


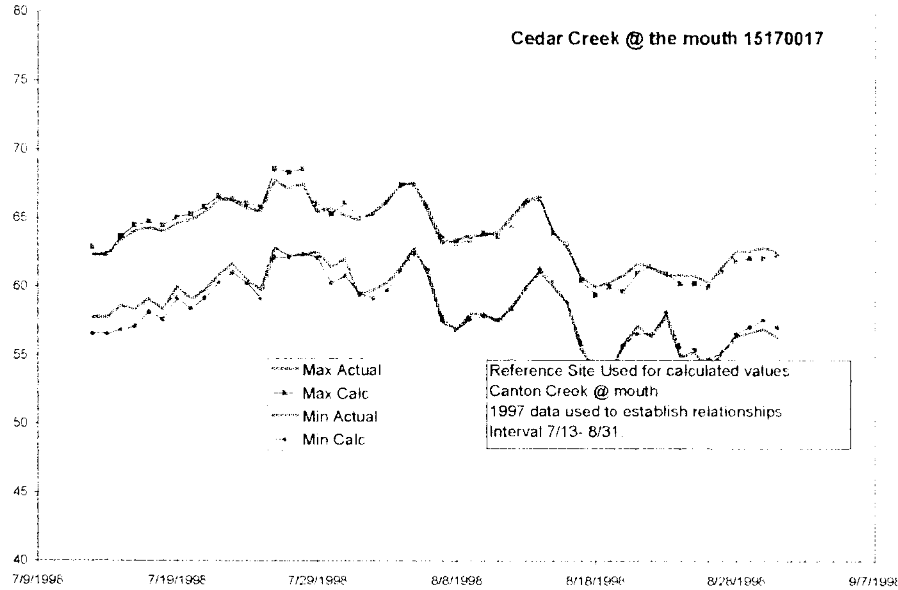


Little Rock Creek at mouth

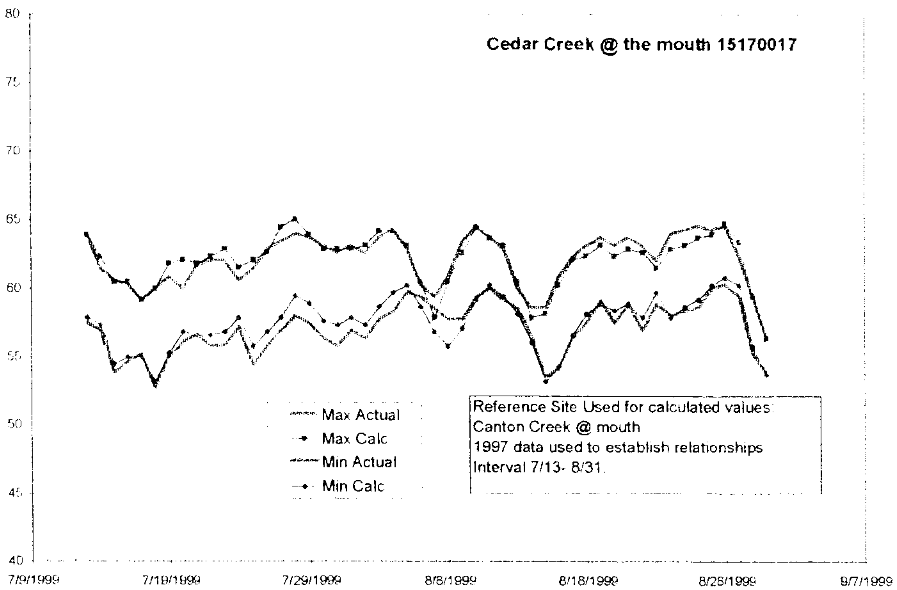


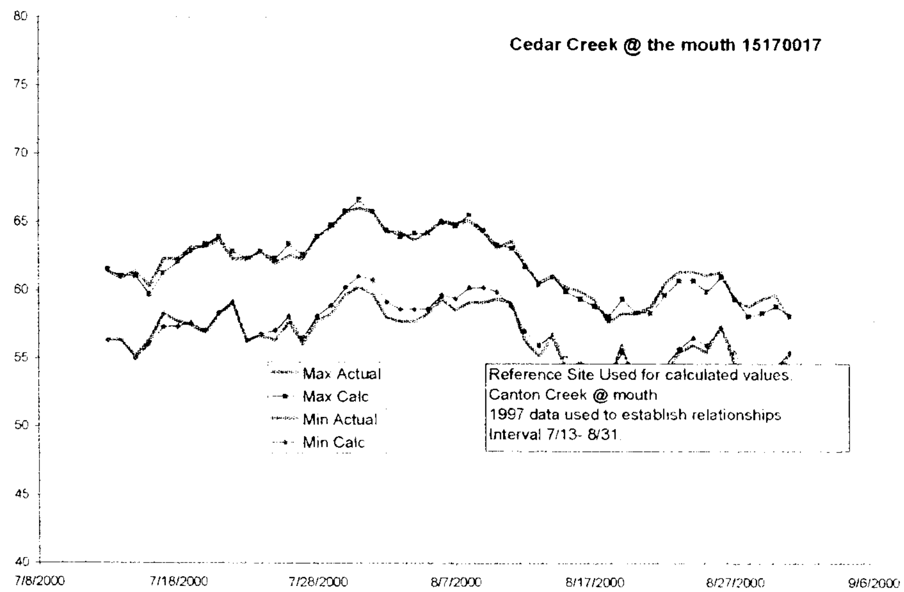


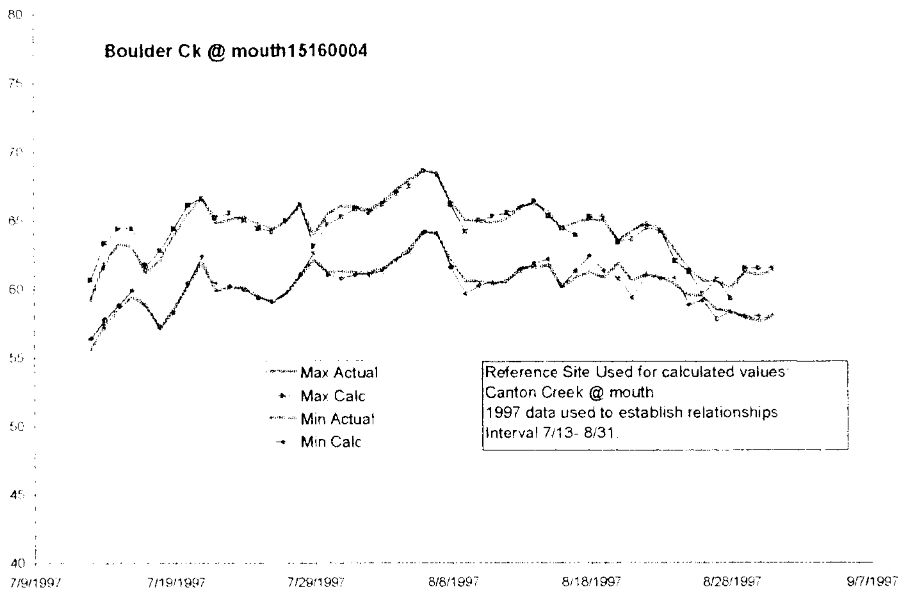


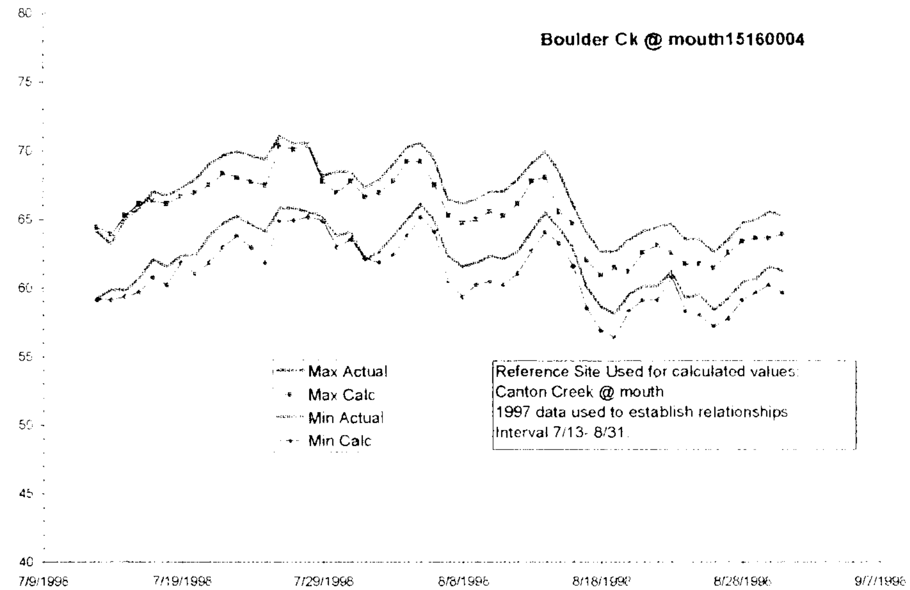


Cedar Creek at Mouth

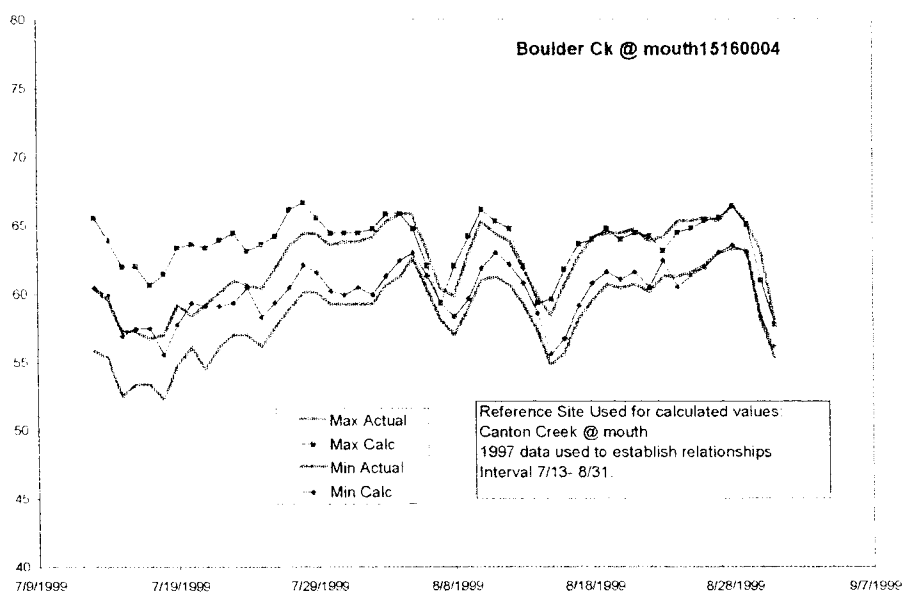


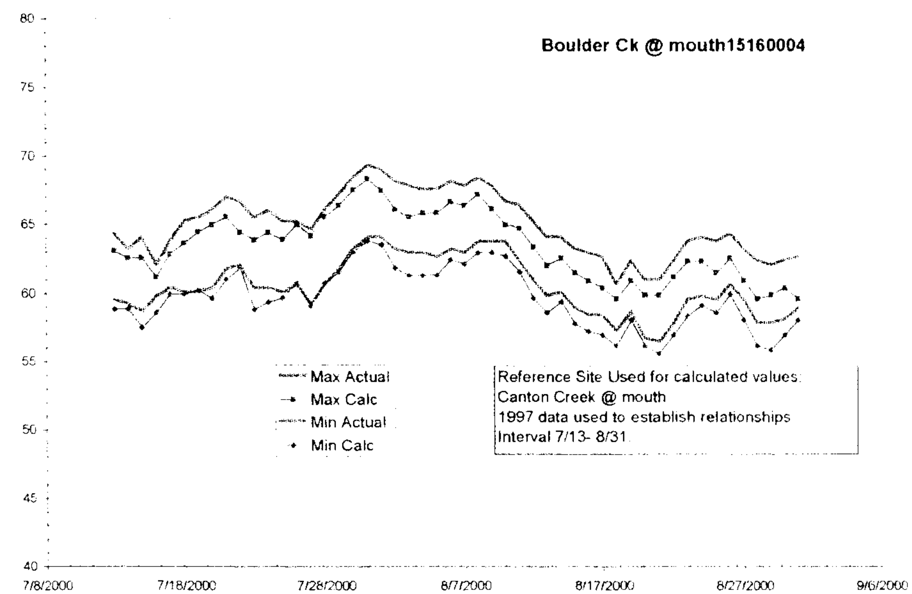


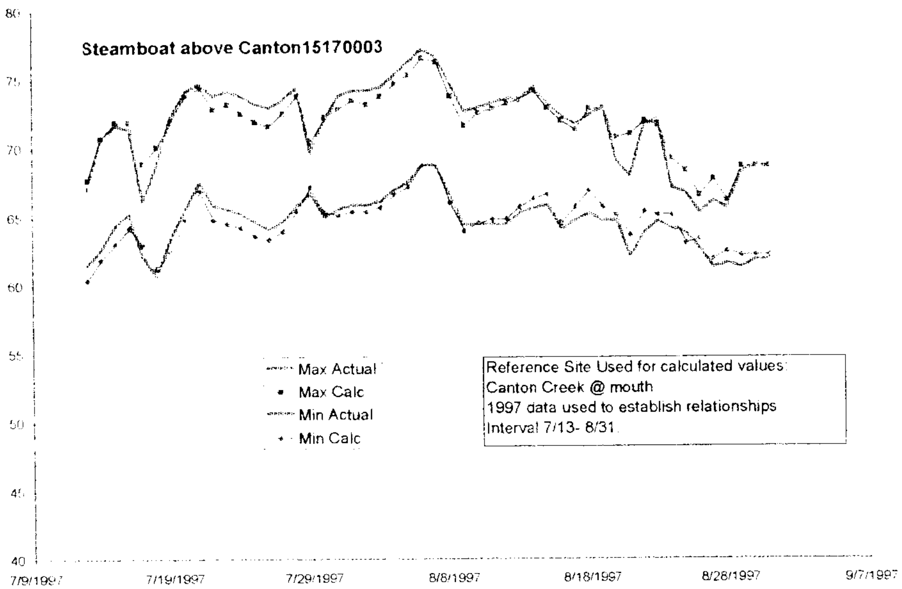


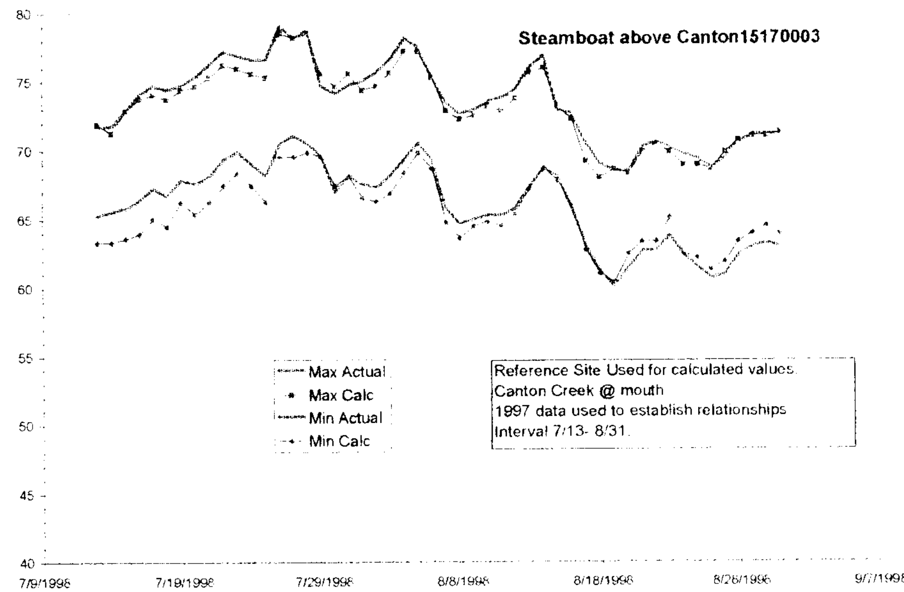


Boulder at mouth

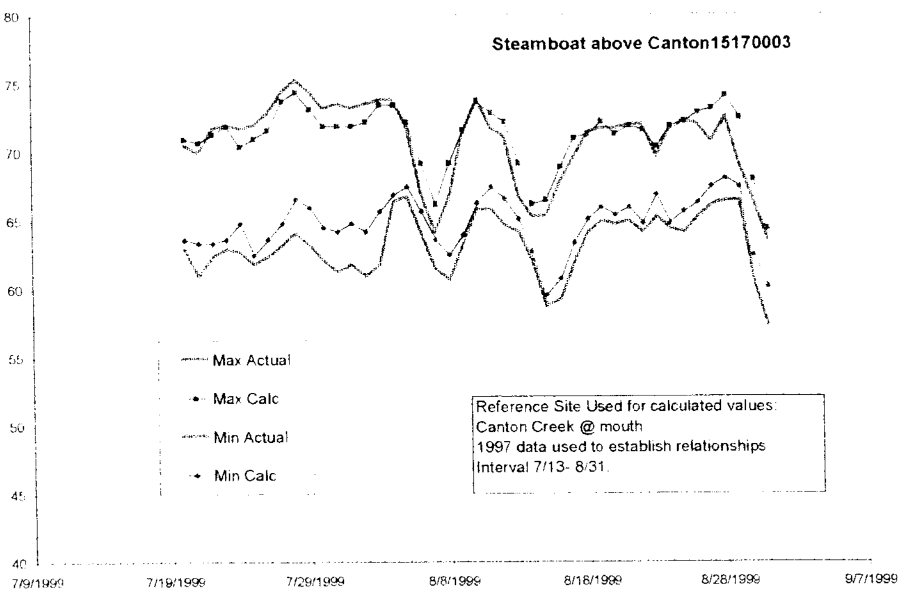


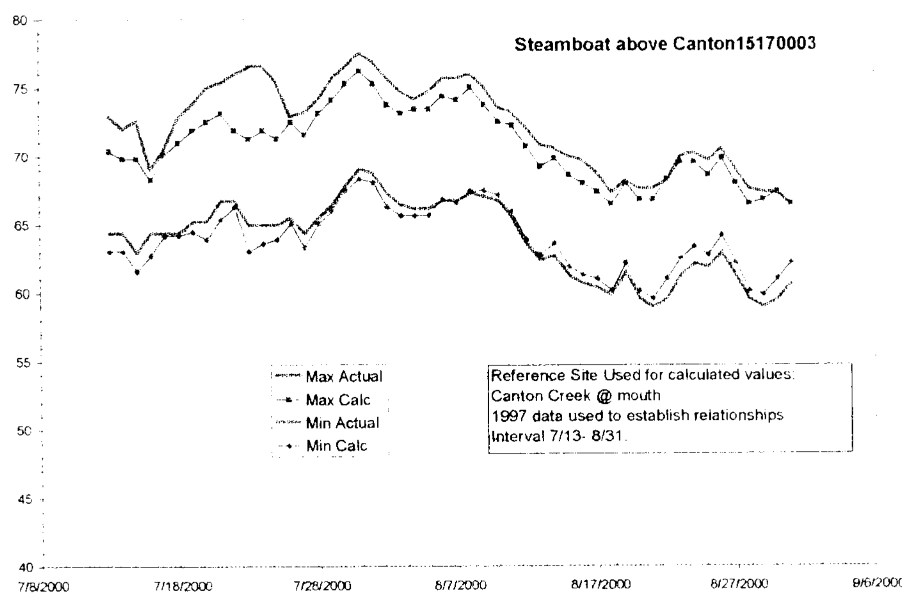






Steamboat above Canton





Appendix E Current Temperature Data

If these reports are not attached, they may be obtained through the Umpqua Basin Watershed Council or InSight Consultants.

- 1998 Elk Creek (North County) Temperature Study (28 monitoring sites).
- 1999 Calapooya Creek Temperature Study (29 monitoring sites).
- 1999 South Umpqua Temperature Study (excluding Cow Creek) (119 monitoring sites)
- 2000 Cow Creek Temperature Study (excluding W Fork) (89 monitoring sites).
- 2000 Main Umpqua Temperature Study (49 monitoring sites).

Appendix F Notes for TMDLs and Management Plans

A stream temperature management strategy needs to be linked to a TMDL and a management plan. The following material provides some notes that may facilitate the linkage.

TMDL Considerations

Since there is a need to develop a management strategy that is consistent with a TMDL the following notes are included.

Relationship between TMDL and aquatic habitat management.

The key beneficial use associated with stream temperature is cold-water fish. Strictly speaking, a stream temperature TMDL is associated with the water quality of the stream while Habitat Conservation Plans (HCPs) are required by the Endangered Species Act. It has been recognized that there are important advantages of integrating planning efforts to meet both laws (Rea, 1999). At a minimum, try to avoid conflicts between the two plans.

Possible General Strategy - Develop a HCP based on watershed scale analysis and land management practices and integrate the TMDL with supplementary quantitative analysis. Both species/habitat needs and pollution reduction commitments will be explicitly addressed.
The TMDL should be consistent with a HCP for the target species.

The temperature standard and implications

Water quality standards are established for the purpose of protecting the "beneficial" or designated uses of the water of Oregon. Under the federal ***Clean Water Act***, states are to specify the appropriate uses of water and adopt water quality criteria that protect the designated uses. Oregon's water quality standards are codified in the Oregon Administrative Rules OAR Chapter 340, Division 40 (groundwater) and 41 (surface water).

Basic absolute numeric criterion of 64°F (17.8 °C) with management plan.

Purpose: To establish a basic absolute numeric criterion statewide for instream temperature at 64°F (17.8 °C) with the provision for the development and implementation of a basin temperature management plan to control anthropogenic sources when the temperature exceeds this numeric criterion. The criterion would be measured as the average of the daily maximum temperatures over a moving 7-day period.

-Streams exceeding these criteria would have a management plan to reverse their individual contribution to the warming trend.

Absolute numeric criterion of 50 °F (10°C) to protect Oregon Bull Trout.

Bull trout habitat has not been identified in Elk Creek so this criteria does not apply at this time.

Absolute numeric criterion of 55 °F (12.8 °C) for salmonid spawning, egg incubation, and fry emergence.

This criteria applies to the average of the daily maximum temperatures over a moving 7-day period of streams with spawning use and during the spawning season.

The extent that this is an issue in the Elk Creek watershed has not been established. It is expected that as the first criterion is addressed, this one will also be satisfied.

Implementation Mechanism: NPS program plans/ SB1010.

Requirement: BMP to achieve load allocation.

Target Criteria: Criteria appropriate to protect beneficial uses present in the water body. (ODEQ,1995 p5-6)

Table 5-1: Temperature Standard Implementation Matrix

Approach	Criteria	Source	Responsible Agency	Requirements	Options	Implementation Mechanism	Target Criteria
INDIVIDUAL OR BASIN MANAGEMENT APPROACHES	Criteria Currently Being Achieved: Proactive Resource Protection	Point Sources	DEQ	Technology Based Permits	Mitigation	NPDES Permit 401 Certification (Hydroelectric or Fill & Removal)	Criteria Appropriate to Protect Beneficial Uses Present in Waterbody
					Water Quality Based Permits		
					EQC Exemption		
		NPS Forestry	USFS	BMPs	–	Contract Requirements	
			BLM	BMPs		Contract Requirements	
			State Department of Forestry	BMPs	–	Forest Practices Act (SB1125)	
		NPS Agriculture	State Department of Agriculture	BMPs	–	Voluntary Use of Farm Plans	
			BLM/USFS Grazing	BMPs		Grazing Permits	
		NPS Urban	Land Use Agencies	BMPs	–	Land Use Plans (Goals 5 & 6)	
	Criteria ***Not*** Currently Being Achieved: Reactive-Restoration	Point Sources	DEQ	Water Quality Based Permit with Waste Load Allocation	Mitigation	NPDES Permits	Criteria Appropriate to Protect Beneficial Uses Present in Water-Quality Limited Segment, Basin, or Watershed
					Trading		
					EQC Exemption		
				Special Conditions	–	401 Certifications	
		NPS Forestry	USFS (DMA)*	Best Management Practices to Achieve Load Allocation	Trading	NPS Program Plan	
			BLM (DMA)*				
			State Department of Forestry (DMA)*			Forest Practices Act (SB1125)	
		NPS Agriculture	State Department of Agriculture (DMA)*	Best Management Practices to Achieve Load Allocation	Trading	NPS Program Plans SB1010	
		NPS Urban	Urban Agencies** (DMA)*	Best Management Practices to Achieve Load Allocation	Trading	NPS Program Plans	

* DMA – Designated Management Agency.
** Entities Responsible for drainage management.

Some streams may exceed 64 °F.

It is recognized that some Oregon streams probably always exceeded the 64 °F standard and it will not be possible to change the stream to meet the standard (Boyd and Sturdevant, 1997 p 22). However, since the stream temperature is above the recommended range, a management plan is required to assure that the best possible conditions (within reason) exist for the fish related beneficial use.

Elements of Water Quality Management Plan

From DEQ Water Quality Division 11/1/97
The emphasis of this plan is on Stream Temperature Management, as it would apply to the Elk Creek Basin.

Element 1: Condition Assessment and problem Description

Water Quality standard and criteria of concern

7-day average of daily maximum not to exceed 64 °F

Water quality conditions

Most of the basin appears to exceed the standard for a period of time ear year. The temperature regime of the watershed appears to be distinctively higher than that of other watersheds throughout Oregon and Washington. - (Based on several studies that can be cited)

Late summer stream flows may be atypically lower within this watershed.

Types of pollution causing the problem

The excessive heating or thermal pollution is caused by:

increased in the net amount of heat received by the stream

a reduction in the amount of water being heated by a given quantity of heat.

In the natural environment, solar heating is the ultimate source of heat input. Secondary radiation and heat transfer from the sky and terrestrial objects contribute to the net heat flux.

Other sources include heat from friction of falling objects and flowing water, geothermal sources, and effects associated with natural chemical processes including fire. These sources are generally considered negligible.

The "pollution" in the case of stream heating, is a typically a condition that causes the net amount of heat in a given volume of water to increase. This increase in heat is identified by a increase in the temperature of the water..

The sources of this pollution in terms of:

Location.

Increases in thermal loading can occur anywhere within a watershed. The small headwater streams are typically quite responsive to changes, both positive and negative. The larger systems may change more slowly but the effect will persist longer.

Land management practice, natural cause or other source.

Actions that cause shade reduction. Vegetative removal or any other action that increases the amount of sunlight to a stream can increase the amount of net increase to the water.

Actions that cause channel modification can affect the amount of exposed water surface, the depth of the exposed water, the length of time the water is exposed, the amount of local topographic shading available.

The amount of water available for heating can be influenced by water withdrawals, changes in evaporation, vegetative transpiration, and groundwater inflow and out flow.

The local micro/ macro climate can affect the air temperature, relative humidity and wind speed and direction; all of which can influence stream temperature. The climate may be affected by factors that are not directly associated with the stream channel.

The relative contribution of each source.

All of the sources identified above can have a significant effect on stream temperature. Sensitivity analysis using a stream temperature model can be used to determine the relative contribution of each component.

Element 2: Goals and Objectives

Goal: To manage temperature in the Elk Creek Watershed to assure optimum use by temperature sensitive aquatic species. I.e. Get summer temperature as cool as the system is capable of supporting.

Assign load allocations as a function of distance from the divide.

Identify "hot areas" , assess and develop a specific action plan for them.

Maintain a reference station to assess specific sites.

Include temperature assessment in all site management plans.

Have appropriate temperature mitigation included in the local site plan.

Conduct additional stream monitoring if necessary.

Element 3: Proposed management measures

Site Assessment

Develop assessment guidelines/ procedures

Use simple computer models as needed

Project design

Develop standard methods

Document proven methods

General types of projects would include some or all of:

Shade enhancement

Flow management

Channel condition enhancement

Project implementation

Element 4: Timeline for Implementation

Project will be tied to other management plans required for landowners. Implementation could start in 2000? Well established by 2005?

Element 5: Identification of Responsible Participants

Implementation would be a joint effort by landowners, agencies UBWC and other interested parties.
Specific roles for the agencies would be developed.

Element 6: Reasonable Assurance of Implementation

A key to completion is the integration and coordination of the effort of all of the participants. This document would have a central role in establishing this integration and coordination.

Element 7: Monitoring and Evaluation

Monitoring would be included in the project plans to determine effectiveness of project.
A plan would be developed to periodically revisit some of the characterization sites to determine overall trend.

Element 8: Public Involvement

The UBWC would coordinate meetings and technical support.
Specific outreach would be made to affected landowners.

Element 9: Maintenance of effort over time

Since this plan integrates the local site plans, it is expected that local standard practices will evolve to sustain the new watershed condition.

Element 10: Discussion of Costs

To be developed...