3.6 Temperature Loading Analysis

3.6.1 Water Quality Targets and Guidelines

The purpose of TMDL development is to meet applicable water quality standards. The SR-HC TMDL is a bi-state effort; therefore the most stringent of each state's water quality standards have been identified as targets for this TMDL. In this way the attainment of these targets will ensure that the water quality requirements of both states will be met.

The entire SR-HC TMDL reach (from RM 409 to RM 188) is listed for temperature on the state 303(d) lists. The water quality standards and guidance values identified for temperature in the SR-HC TMDL are numeric criteria specific to the designated beneficial uses of *cold water aquatic life* and *salmonid spawning and rearing* when and where these uses occur.

The entire SR-HC TMDL reach (from RM 409 to RM 188) has been designated for cold water aquatic life by the State of Idaho. This same segment has been designated for salmonid spawning and rearing by the State of Oregon. Within the beneficial use designation of salmonid spawning and rearing, the State of Oregon can differentiate separately between those areas where salmonid spawning occurs and those areas where salmonid rearing occurs within a watershed. The water quality targets applied to these areas are then determined by this localized designation of use with salmonid rearing targets applied to those areas designated for salmonid rearing and salmonid spawning targets applied to those areas designated for salmonid rearing.

Specific designation of the salmonid spawning and salmonid rearing beneficial uses in the SR-HC TMDL reach are as follows:

Salmonid Spawning. The states of Oregon and Idaho have designated the Downstream Snake River segment (RM 247 to 188) of the SR-HC TMDL reach for salmonid spawning. Both the State of Idaho and the State of Oregon have designated tributaries to the SR-HC TMDL reach for salmonid spawning based on the available data and the current level of understanding of fish species present. Salmonid spawning within these drainage basins is most likely to occur within the tributaries to the SR-HC TMDL reach where flow and substrate conditions are favorable to support such uses. Salmonid spawning is not observed to occur in the Upstream Snake River (RM 409 to 335), Brownlee Reservoir (RM 335 to 285), Oxbow Reservoir (RM 285 to 272.5) or Hells Canyon Reservoir (RM 272.5 to 247) segments of the SR-HC TMDL. The salmonid spawning beneficial use designation and its accompanying water quality targets will apply to those tributaries to the SR-HC TMDL reach so designated, when and where that designated use occurs. As these tributaries are not interstate waters, and salmonid spawning use support is a localized habitat issue, state-specific targets for salmonid spawning will apply to those areas of the tributaries designated for salmonid spawning.

This localized designation of salmonid spawning areas is integral to the approach outlined in the initial sections of this document regarding the open acknowledgement by this TMDL effort that there are distinct spatial and temporal use patterns within the specific segments designated for specific beneficial uses within the SR-HC TMDL reach. Targets must be set to recognize those spatial/temporal use patterns that exist, as well as the needed connectivity within the mosaic of

designated beneficial uses (including critical habitat for sensitive species) throughout the waterbody. This approach provides for full support of existing uses and the restoration of impaired designated uses within that mosaic. In setting specific salmonid rearing and salmonid spawning designations, the SR-HC TMDL also recognizes that this ecosystem is comprised of a variety of aquatic environments that include lentic (still water), lotic (flowing water) and transition areas, each with their own characteristic attributes, habitat types and beneficial uses. In this way the proposed approach can result in a TMDL that is achievable, that will meet criteria, and that will support designated beneficial uses without imposing inappropriate and unreachable water quality targets and implementation expectations.

Salmonid Rearing. The State of Oregon has designated the mainstem Snake River in the SR-HC TMDL reach for salmonid rearing (the State of Idaho designated beneficial use equivalent to *salmonid rearing* is *cold water aquatic life*). The State of Idaho has designated the entire reach for cold water aquatic life. The salmonid rearing/cold water aquatic life beneficial use designation, and the accompanying water quality targets apply to the mainstem Snake River within the SR-HC TMDL reach. As the mainstem SR-HC TMDL reach of the Snake River is an interstate waterway, the more stringent of the two states' standards applies and has been identified as the salmonid rearing/cold water aquatic life target for this TMDL. Temperature targets for the SR-HC TMDL were established based on a comparison between the temperature standards for Idaho and Oregon. A detailed description of the comparison methodology is contained in Appendix C.

The State of Idaho designation of salmonid spawning as a beneficial use for Brownlee Reservoir, Oxbow Reservoir and Hells Canyon Reservoir has been formally removed by state legislative action finalized on March 30, 2001. For the purposes of this TMDL, the current use designations identified by the states have been applied.

3.6.1.1 SALMONID REARING/ COLD WATER AQUATIC LIFE.

The temperature target identified for the protection of salmonid rearing/cold water aquatic life when aquatic species listed under the Federal Endangered Species Act are not present or, if present, a temperature increase would not impair the biological integrity of the Threatened and Endangered population, is: 17.8 ^{o}C (expressed in terms of a 7-day average of the maximum temperature) if and when the site potential is less than 17.8 ^{o}C. If and when the site potential is greater than 17.8 ^{o}C, the target is no more than a 0.14 ^{o}C increase from anthropogenic sources (0.14 ^{o}C is considered less than measurable by ODEQ).

When aquatic species listed under the Endangered Species Act are present and if a temperature increase would impair the biological integrity of the Threatened and Endangered population then the target is no greater than 0.14 ^{o}C increase from anthropogenic sources.

This target is based on Oregon temperature standards, which were found to be more stringent that Idaho cold water aquatic life temperature standards. It includes narrative criteria that acknowledges that "natural surface water temperatures at times exceed the numeric criteria due to naturally high ambient air temperatures, naturally heated discharges, naturally low stream flows or other natural conditions" (OAR 340-41-120 (11)(c)).

Language regarding standard exceedences from naturally occurring sources, similar to that outlined for Oregon State standards above is also contained in the Idaho State Water Quality Standards. At the start of this TMDL process, existing Idaho standards stated that "where natural background conditions from natural surface or ground water sources exceed any applicable water quality criteria...that background level shall become the applicable site-specific water quality criteria" (IDAPA 58.01.02.07.06). A clarification to this statement was added through legislative action during this TMDL process (effective March 15, 2002). Current Idaho State Water Quality Standards state "when natural background conditions exceed any applicable water quality criteria...the applicable water quality criteria shall not apply, instead, pollutant levels shall not exceed the natural background conditions, except that temperature levels may be increased above natural background conditions when allowed under Section 401" (IDAPA 58.01.02.200.09). While the current Idaho State language represents a clarification of the original statement, both recognize the existence of conditions where the presence of natural sources can result in conditions that exceed applicable water quality standards.

Therefore, this approach is supported by both the current Idaho State Water Quality Standards, the Idaho State Water Quality Standards existing at the start of the SR-HC TMDL process, and Oregon State Water Quality Standards.

Although the salmonid rearing/cold water aquatic life designation and the associated targets are applied year-round, the critical time period for salmonid rearing/cold water aquatic life in the SR-HC TMDL reach is from June through September, when elevated water temperatures are most likely to occur. Water temperatures throughout the remainder of the year generally meet the target criteria.

3.6.1.2 SALMONID SPAWNING.

The temperature target identified for the protection of salmonid spawning when aquatic species listed under the Endangered Species Act are not present or, if present, a temperature increase would not impair the biological integrity of the Threatened and Endangered population, is less than or equal to a maximum weekly maximum temperature of 13 ^{o}C (when and where salmonid spawning occurs) if and when the site potential is less than a maximum weekly maximum temperature of 13 ^{o}C (temporary rule, effective by action of the IDEQ board 11-14-03, pending approval by Idaho Legislature 2005, subject to US EPA action). If and when the site potential is greater than a maximum weekly maximum temperature of 13 ^{o}C, the target is no more than a 0.14 ^{o}C increase from anthropogenic sources. (The State of Oregon definition of no measurable increase (0.14 ^{o}C) was used as it is more stringent than the State of Idaho definition of 0.3 ^{o}C.)

When aquatic species listed under the Endangered Species Act are present and if a temperature increase would impair the biological integrity of the Threatened and Endangered population then the target is no greater than 0.14 ^{o}C increase from anthropogenic sources.

The temperature target for salmonid spawning is applicable only when and where salmonid spawning occurs within the SR-HC TMDL reach. This target applies to the Downstream Snake River segment (RM 247 to 188) only, and is specific to those salmonids identified to spawn in this area, namely fall chinook and mountain whitefish. This target is based on Idaho temperature

standards, which were found to be more stringent that Oregon salmonid spawning temperature standards.
Temperature targets for salmonid spawning in the SR-HC TMDL reach apply during critical time periods for salmonid spawning. These targets apply only to that portion of the SR-HC TMDL reach below Hells Canyon Dam (RM 247 to RM 188). Critical time periods for salmonid spawning in the Downstream Snake River segment of the SR-HC TMDL reach are from October 23rd to April 15th for fall chinook, and from November 1st to March 30th for mountain whitefish.

Critical time periods for fall chinook spawning were identified through site-specific data collected by IPCo and USFWS from 1991 through 2001. Fall chinook redds have been identified below Hells Canyon Dam as early as October 9th (IPCo, 2001c, 2001e). However, these early spawners represent less than 1.2 percent of the total number of fall chinook redds documented (Figure 3.6.0). The majority of fall chinook redds created were identified after October 23rd in all years. Of the total number of fall chinook redds counted, approximately 8 percent were present during the week of October 23rd, and approximately 30 percent were present during the week of October 30th. The remaining 70 percent were identified in the following weeks.

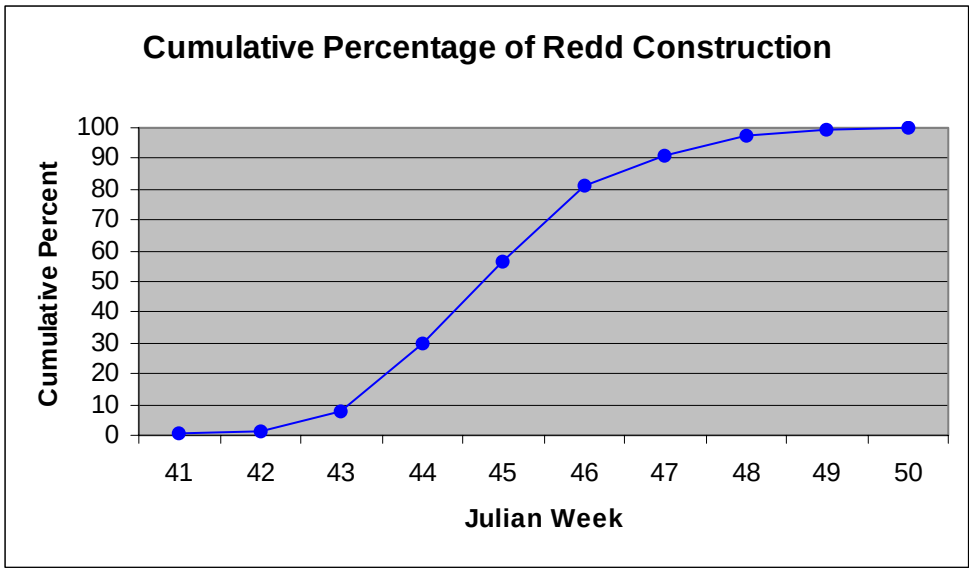


Figure 3.6.0. Cumulative percentage of redd construction for fall chinook observed in the Snake River below Hells Canyon Dam (RM 247) 1991 through 2001. Data collected by IPCo and USFWS (IPCo, 2002).

Given the fact that less than 1.2 percent of the identified fall chinook redds were in place prior to the week of October 23rd, it is the opinion of the DEQs that this week (October 23) represents a valid threshold for the initiation of fall chinook spawning below the Hells Canyon Dam. The fall chinook spawning period, based on this site-specific data, is therefore determined to extend from October 23rd to April 15th. This time period is also protective of the mountain whitefish spawning period (starting 01 November). Chinook spawning does not occur above Hells Canyon Dam, as the dam acts as a barrier to upstream migration.

The spawning and incubation times referenced in this document are based on existing site-specific data. If additional site-specific data on spawning and incubation times or a more complete understanding of critical water temperatures become available following the submission and approval of this TMDL, these data will be evaluated in the context of the iterative TMDL process. If it is determined that the additional data are appropriate to this TMDL, the time frames and/or temperatures identified for spawning and incubation will be updated as necessary to reflect the expanded data set and improved understanding of the SR-HC TMDL reach and related habitat and use-support needs; or a change in state standards for salmonid spawning.

3.6.1.3 Summary of Snake River - Hells Canyon TMDL Water Quality Temperature Targets and Use Designation.

The salmonid rearing/cold water aquatic life temperature target identified for the SR-HC TMDL reach applies to RM 409 to 188. This target is 17.8 ^{o}C (expressed in terms of a 7-day average of the maximum temperature) if and when the site potential is less than 17.8 ^{o}C. If and when the site potential is greater than 17.8 ^{o}C, the target is no more than a 0.14 ^{o}C increase from anthropogenic sources. The critical time period for this target is from June through September.

The salmonid spawning temperature target identified for the SR-HC TMDL reach applies to RM 247 to 188. The target is a maximum weekly maximum temperature of 13 ^{o}C (when and where salmonid spawning occurs) if and when the site potential is less than a maximum weekly maximum temperature of 13 ^{o}C. If and when the site potential is greater than a maximum weekly maximum temperature of 13 ^{o}C, the target is no more than a 0.14 ^{o}C increase from anthropogenic sources. This target applies only when and where salmonid spawning occurs and is specific to those salmonids identified to spawn in the designated segment (RM 247 to 188), namely fall chinook October 23rd through April 15th and mountain whitefish (November 1st through March 30th).

These targets apply when aquatic species listed under the Endangered Species Act are not present or, if present, a temperature increase would not impair the biological integrity of the Threatened and Endangered population. When aquatic species listed under the Endangered Species Act are present <u>and</u> if a temperature increase would impair the biological integrity of the Threatened and Endangered population then the target is no greater than 0.14 ^{o}C increase from anthropogenic sources.

Note: The temperature analysis set forth in this TMDL does not specifically address attainment of Oregon's criterion for protection of Threatened and Endangered Species. Oregon will address this in the Section 401 certification analysis for the Hells Canyon Complex.

3.6.1.4 Changes to State of Idaho Water Quality Standards.

As stated above, language regarding standard exceedences from naturally occurring sources is contained in the Idaho State Standards. Previously, Idaho standards stated that "where natural background conditions from natural surface or ground water sources exceed any applicable water quality criteria...that background level shall become the applicable site-specific water quality criteria" (IDAPA 58.01.02.07.06 (2000)). This language has been interpreted to require a rule-making change to establish natural background as a site-specific standard. A change to this

language has been completed by the State of Idaho to clarify that "when natural background conditions exceed any applicable water quality criteria...the applicable water quality criteria shall not apply, instead, pollutant levels shall not exceed the natural background conditions, except that temperature levels may be increased above natural background conditions when allowed under Section 401" (IDAPA 58.01.02.200.09 (2002)). This change was approved by the IDEQ Board and the Idaho State Legislature, effective 15 March 2002.

3.6.1.5 PACIFIC NORTHWEST TEMPERATURE CRITERIA GUIDANCE PROJECT.

In addition to the proposed change to the Idaho standards, a much broader effort is currently underway to formulate regional temperature guidance for the Pacific Northwest. This effort, with participation from US EPA, USFWS, NMFS, the states of Idaho, Oregon and Washington, and Tribes, had been initiated to recognize and incorporate some of the natural variations in water temperature occurring throughout the region in temperature standards for the Pacific Northwest.

The goal of this project is to develop regional temperature criteria guidance that meets the biological requirements of native salmonid species for survival and recovery pursuant to ESA, provides for the restoration and maintenance of surface water temperature to support and protect native salmonids pursuant to the CWA, and meets the salmon rebuilding needs of federal trust responsibilities with treaty tribes. It is also a goal of this project that the guidance produced will recognize the natural temperature potential and limitations of water bodies. This guidance is also expected to be fashioned in a manner that will allow it to be effectively incorporated by states and tribes in water quality standards programs (US EPA, 2002).

Once this guidance is finalized, it is expected that the States and Tribes in the Pacific Northwest will use the new criteria guidance to revise their temperature standards, if necessary, and that US EPA, USFWS and NMFS will use the new criteria guidance to evaluate state and tribal standard revisions (US EPA, 2002).

These ongoing processes to effect changes to water temperature standards in the SR-HC TMDL reach will be monitored throughout this TMDL effort. If these processes result in changes to state or federal water quality criteria, such changes may be incorporated as appropriate into the SR-HC TMDL through the long-term, iterative nature of the TMDL process.

3.6.2 Designated Beneficial Use Impairment

The designated beneficial uses within the SR-HC TMDL reach determined to be most at risk from elevated water temperature were those associated with aquatic life. Both direct and indirect impacts to aquatic life are possible due to elevated water temperatures.

Direct negative effects of elevated water temperature include lower body weight, poor oxygen exchange and reduced reproductive capacity in aquatic species. Extreme high water temperatures can result in death if they persist for an extended length of time. Juvenile fish are more sensitive to temperature variations and duration than adult fish, and can experience negative impacts at lower water temperatures than adult fish.

Indirect effects associated with elevated water temperature include low dissolved oxygen concentrations due to the growth of algae in the upper water column (diurnal), and increased decomposition rate for organic materials in the lower water column. Elevated water temperatures can also lead to improved growth and decomposition conditions for aquatic nuisance growth such as algae. Appendix C contains more detailed information specific to temperature tolerances of fish species found in the SR-HC TMDL reach.

No specific data is available showing direct effects to fish or other aquatic life due to elevated water temperature in the SR-HC TMDL reach. However, information is available that show differences in fish populations relative to the availability of cool water refugia within the SR-HC TMDL system. These data, collected by IPCo fish biologists (IPCo, 2001g) show a convincing trend in population support where cold water refugia are available during periods of elevated water temperature within the mainstem Snake River. A more detailed discussion of this information is included in the following sections of this document.

Given this understanding, impairment of the salmonid rearing/cold water aquatic life designated beneficial use occurs in the Upstream Snake River segment (RM 409 to 335) where population and species diversity are limited. The salmonid rearing/cold water aquatic life designated beneficial use is supported in the other segments due to the availability of cold water refugia.

Data collected by IPCo and USFWS indicate that fall chinook spawning is occurring under existing conditions throughout the 100-mile reach of the Snake River from below Hells Canyon Dam (RM 245) downstream to Asotin WA (RM 145). While the SR-HC TMDL extends only to the confluence of the Salmon River, the entire 100 miles of the Snake River from Hells Canyon Dam downstream to Asotin, WA currently supports (to some extent) salmonid spawning activity.

Data available for the Downstream Snake River segment (RM 247 to 188) show that the salmonid spawning temperature targets are exceeded in the late fall of some years. Fall chinook have been documented to spawn in the Snake River between Hells Canyon Dam and Asotin, WA as discussed above. The majority of spawning activity occurs from mid-October through the first week of December. Currently, the peak of spawning in the river downstream of Hells Canyon Dam occurs when daily mean and maximum water temperatures are between 12 ^{o}C and l6 ^{o}C.

Data currently available on fall chinook spawning (IPCo, 2002, attachment 13 and 14) does not show impairment due to elevated water temperatures occurring in the late fall. Additionally, studies undertaken by IPCo suggest that warmer fall and winter water temperatures can cause accelerated hatching and fry development. The accelerated hatching and fry development may provide a survival benefit to out-migrating juvenile fall chinook. However, these data, and their interpretation, are preliminary and further study will help to further clarify the support status of fall chinook in this section of the SR-HC TMDL reach. Water temperature data (IPCo, 2002) collected downstream of the SR-HC TMDL reach show that the Snake River downstream of river mile 188 meets the SR-HC TMDL salmonid spawning targets during this time period (October/November).

It is recognized that water temperature is only one component of salmonid spawning habitat requirements. The ability to maintain stable flows during the spawning period provides benefits to salmonid spawning. Stable flows provide redd protection and minimize de-watering during the incubation period.

3.6.3 Sources

Elevated water temperature increases in the SR-HC TMDL reach are the result of a combination of sources. Both natural and anthropogenic sources of temperature are present in the SR-HC TMDL drainage. Anthropogenic sources of temperature loading to this reach include both point and nonpoint sources in the form of point source discharges, agricultural and stormwater drains, and tributary inflows.

3.6.3.1 NATURAL SOURCES.

Natural heat exchange through elevated air temperatures and direct solar radiation on the water surface play a major role in summer water temperatures. Both the mainstem Snake River and the inflowing tributaries drain basins located in hot, dry climates (See Figure 2.3 for average daily air temperatures in the SR-HC TMDL reach). These river systems are characteristically wide and relatively slow moving in the lower portions of their respective watersheds as compared to the upper watersheds. Native vegetation in all but the headwaters of most drainages is relatively low growing and sparse and therefore provides little shading on the wider, downstream sections of these river systems. These environmental factors play a dominant role in water temperatures in the SR-HC TMDL reach.

Aerial photos taken of the mainstem Snake River in 1909 from a hot air balloon show relatively little vegetative cover on the banks of the Snake River or the tributaries (See Photo 3.6.0). One of these photos has been included on the following pages; others are available through the Oregon Historical Society (Portland, Oregon). All the photos show approximately the same low, rolling, sparsely vegetated terrain extending down to the Snake River. All show that what trees are present (mostly what appear to be juniper) are small and somewhat limited in distribution. A few, more leafy trees are visible along some of the river and tributary banks, but they are all very small in comparison to the size of the mainstem river channel. The photos clearly show the lack of ability of this vegetation to shade the mainstem Snake River, or the tributaries. They also serve to demonstrate the open nature of the river system to solar radiation and atmospheric temperature influences. These photos were obviously not taken prior to the advent of white settlers in the basin, and are not intended to represent the pre-anthropogenic condition of the Snake River, but they do help to establish an understanding of historic site vegetation in the early 1900’s, prior to extensive settlement of the area or substantial impoundment of the Snake River itself. It is recognized that migration west along the Oregon Trail, starting in the 1840's, and settlement, ranching and farming along the Snake River in the late 1800's had a substantial impact on the original vegetation bordering the Snake River and its tributaries. By 1909 the Snake River area had been grazed for a period of anywhere from decades to over half a century.

3.6.3.2 ANTHROPOGENIC SOURCES.

As discussed in detail in previous sections, the Snake River is a highly regulated river. Estimates indicate that nearly half the annual discharge is stored and diverted for irrigation upstream of the

Hells Canyon Complex of dams (usable storage capacity above Hells Canyon is ~10 million acre-feet, average annual runoff at Weiser, ID of 13.25 million acre-feet). With such a highly regulated system it is difficult to determine what are natural conditions for temperature, or precisely how altered current conditions are from natural conditions.

Photo 3.6.0 Aerial photograph (taken from a hot air balloon) of the Snake River near Vale, Oregon showing local vegetation in 1909. Photo courtesy of the Oregon Historical Society.

Photo 3.6.0 (cont.) Aerial photograph (taken from a hot air balloon) of the Snake River near Vale, Oregon showing local vegetation in 1909. Photo courtesy of the Oregon Historical Society.

Because of its length, temperature changes in the headwaters of the Snake River cause little if any detectable change in temperature downstream, yet flow alteration due to extensive flow regulation within the Snake River system has resulted in spring flows at Weiser, Idaho that are from 20 to 30 percent lower, and late summer/early fall flows that are typically 40 percent greater than before flow regulation began (Table 2.1.0). This increase in summer flows potentially acts to decrease naturally induced heating due to meteorological effects.

Additionally, nearly all the water in the Snake River is diverted for irrigation above Milner Dam (RM 639) from July through September, often longer. Below Milner Dam the Snake River is replenished by springs fed by subsurface recharge and ground water, rapidly gaining 5,000 to 6,000 cfs in water averaging 11 ^{o}C to 13 °C, and from extensive surface water return flows with water temperatures that are potentially higher than those of the groundwater springs. During summer months the water warms rapidly as it traverses the desert canyon it has cut through Idaho's Snake River Plain. Water temperatures between 22°C and 25°C are commonly observed at RM 345, ten miles above the headwaters of Brownlee Reservoir. These water temperatures are not much different than those currently found in the Salmon River near its mouth, as shown in Figure 3.6.1.

Unlike the Snake River, discharge of the Salmon River is effectively unregulated. (While there are a few small dams in some headwater tributaries, total storage capacity is less than 0.1 percent of the Salmon's average annual runoff). Large portions of its watershed are in wilderness or roadless areas and the watershed is very sparsely populated. These factors combine to make the Salmon River, while not pristine, the most natural river of its size anywhere in the lower 48 states. It follows that its existing water temperatures are close to natural as well.

Figure 3.6.1 a shows water temperatures observed in the Salmon River just above its confluence with the Snake River for 1991 through 1999. Long-term average summer water-temperatures in the Snake River above the Salmon River, and in the Salmon River itself, show differences of less than one degree, as illustrated in Figure 3.6.1 b. The July average water temperature over a decade of monitoring was 20.0 °C in the Snake River above the Salmon River inflow (RM 188) and 19.5 °C in the Salmon River. The August average water temperature for this same time period was 21.7°C in the Snake River above the Salmon River inflow and 21.1°C in the Salmon River (personal communication, Ralph Myers, Idaho Power Company, August 2002). Snake River water temperatures below Hells Canyon Dam are closer to those measured in the Salmon River than those measured upstream of Brownlee Dam (at RM 345) from January through September.

Permitted point source discharges to the SR-HC TMDL reach include four municipal and two industrial discharges to the Upstream Snake River segment (RM 409 to 335). The combined flow from all six of these point sources averages 10.5 cfs annually (less than 1/1000 of the total mainstem flow). This flow is further reduced during the summer growing season, as the City of Ontario discharge is land applied during that time period. Three additional permitted point sources discharge to the remaining downstream segments below Brownlee Reservoir. They are all related to the operation of the Hells Canyon Complex dams and have relatively minor flow contributions (54 cfs maximum permitted flow combined, approximately 0.3 percent than of the total mainstem flow).

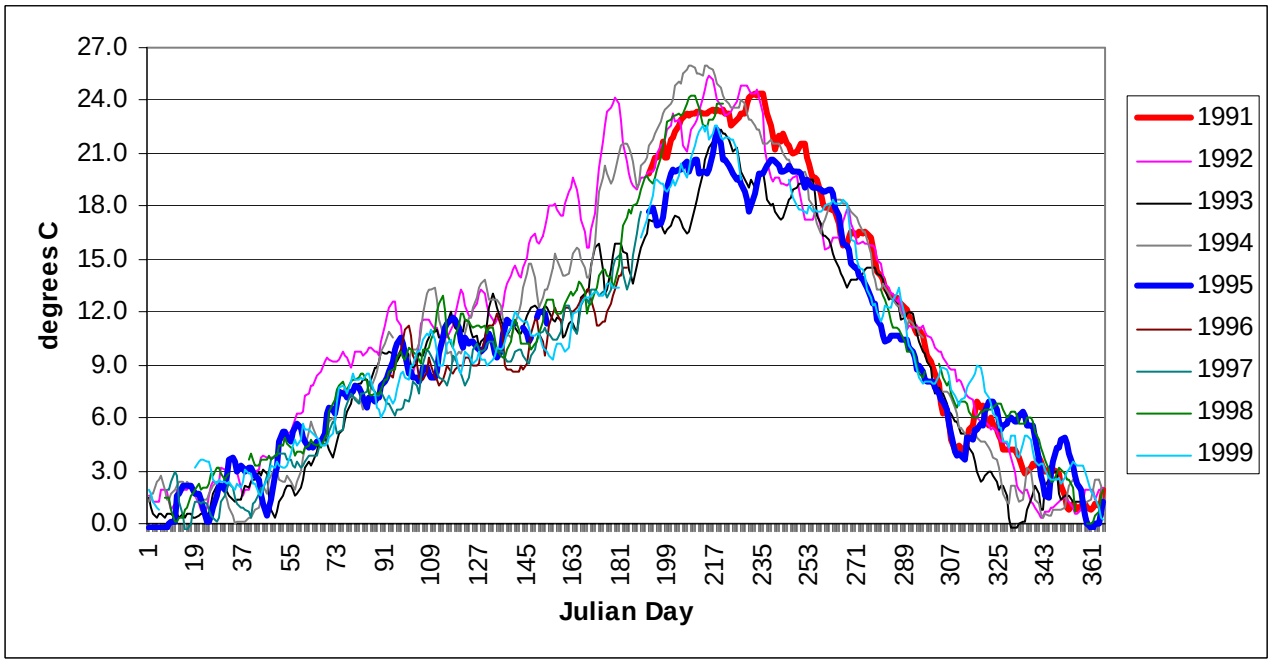


Figure 3.6.1 a. Water temperatures observed in the Salmon River near the confluence with the Snake River at Snake River mile 188. (1991 represents a low water year, 1995 represents a medium water year.)

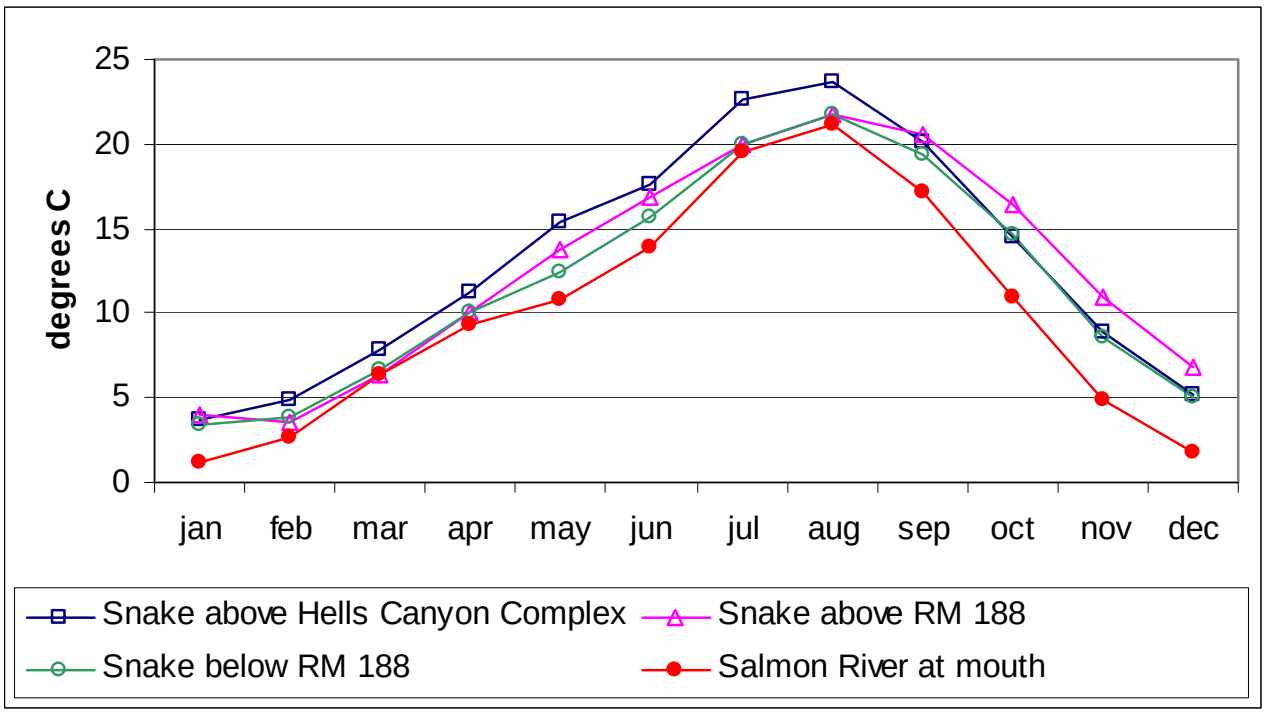


Figure 3.6.1 b. Long-term monthly mean water temperatures observed in the Snake and Salmon Rivers. (The Salmon River flows into the Snake at RM 188.)

Nonpoint sources of anthropogenic temperature increase include agricultural and stormwater drains, and tributary inflows. Agricultural, stormwater and other ungaged drains that discharge directly to the Snake River are estimated to contribute a combined flow of approximately 1,200 cfs annually (less than 8% of the total mainstem flow). Agricultural drain flows are highly seasonal in nature with the highest flow values occurring during the growing season (April to October) when irrigation is in use and very low flows, predominantly driven by precipitation or melt-off, occurring in the winter. The one exception to this trend is the conveyance of snowmelt flows in some drainages in the early spring when flows may exceed those observed during the irrigation season for short periods of time. Calculated agricultural return flows in the Upstream Snake River segment (RM 409 to 335) in the form of surface water range from 635 cfs to 764 cfs during June, July, August and September (USBR, 2001).

Tributary inflows to the SR-HC TMDL reach (including the mainstem Snake River above RM 409) total approximately 16,000 cfs annually, and approximately 14,000 cfs during the months of June, July, August and September (median water year). The tributaries to the SR-HC TMDL reach (including the mainstem Snake River above RM 409) represent the majority of the total mainstem flow. Tributary inflows are also seasonal in nature, as shown in Figure 2.8. The temperature of inflowing tributary waters is a combination of natural and anthropogenic temperature sources within the separate tributary drainages. Tributary water temperatures are seasonal in nature and generally do not deviate substantially from mainstem water temperatures during the critical months of June, July, August and September.

In addition to the above sources, ungaged flows, both ground and surface water, also represent temperature sources to the SR-HC TMDL. The annual water balance in median water years shows an average 6 percent difference (overall difference ranged from 1% to 12% depending on the specific water year) between the measured and estimated inflow and the measured instream flow. The water balance for June, July, August and September in median water years shows an average 9.7 percent difference (overall difference ranged from 5% to 14% depending on the specific month and water year) between the measured inflow and the measured instream flow. This ungaged gain/loss is due to a combination of ungaged inflows and diversions, ungaged overland runoff, ground water inflows, seepage losses, and gauge and estimation error.

3.6.3.3 Additional Considerations

It is recognized by this TMDL that temperature is a highly variable pollutant and therefore needs to be addressed differently from other, conservative pollutants. These considerations and the approaches taken to identify and address these issues are discussed in the following sections.

3.6.4 Data Available for the Snake River - Hells Canyon TMDL Reach

A fairly robust data set for water temperature was available to the SR-HC TMDL effort. Temperature data has been collected over the time period from 1954 to current for both mainstem Snake River and tributary sites. Historic data gathered prior to the construction and completion of the Hells Canyon Complex have been utilized to identify pre-impoundment (Hells Canyon Complex) water temperatures. They do not represent an unregulated or un-impounded system as diversions and upstream and tributary impoundments were in place in many areas when these data were collected. They do, however, lend a better understanding of the conditions

that existed in the SR-HC TMDL reach prior to the completion of the Hells Canyon Complex of dams. These data are displayed in Tables 2.3.22 and 2.3.30 and in Figures 2.3.19 and 2.3.24 in the preceding sections of this document.

Current data, collected from 1991 through 2000 is also available. Although the available data sets are not consistent in coverage, and do not always include co-monitored flow values, they are helpful in an evaluation of water temperature trends within the system. Distribution of the recent water temperature data available is shown in Table 3.6.1. A total data set is available in Appendix E.

Table 3.6.1. Distribution of recent water temperature data available for the Snake River - Hells Canyon TMDL (1990 through 2000).

Sample Site	Distribution and Duration of Temperature data available
Snake River near Murphy (RM 460 to 450)	Daily min, max, mean 03/1996 to 04/1997 06/1997 to 02/1998 04/1998 to 04/1999 10/1999 to 01/2000 04/2000 to 09/2000 11/2000 to 12/2000
Owyhee River Mouth (RM 396.7)	Daily min, max, mean 07/1996 to 08/1999 07/2000 to 08/2000 (From hourly temperature readings)
Boise River Mouth (RM 396.4)	Daily min, max, mean 11/1995 to 07/1996 05/1997 to 09/1997 11/1998 to 12/1998 01/1999 to 09/1999
Snake River at Nyssa (RM 385)	Daily mean – 04/1990 to 04/1991 Daily min, max, mean 03/1996 to 04/1999 01/2000 to 09/2000 12/2000
Malheur River Mouth (RM 368.5)	Daily min, max, mean 07/1996 to 08/1999 07/2000 to 08/2000 (From hourly temperature readings)
Payette River Mouth (RM 365.6)	Daily min, max, mean 08/1997 to 09/1997 07/1998 to 08/1998 05/1999 to 09/1999
Snake River near Weiser (RM 351 to 355)	Daily min, max, mean 03/1996 to 09/1999 01/2000 to 07/2000 10/2000 to 12/2000 RM 345, daily max, mean, min 01/1991 to 12/2001
Weiser River Mouth (RM 351.6)	Daily min, max, mean 08/1997 to 09/1997 06/1998 to 09/1998 05/2000 to 09/2000
Snake River at Porters Island (RM 340)	Daily mean – 04/1990 to 04/1991
Drains	Instantaneous measurements

Sample Site	Distribution and Duration of Temperature data available
	01/1975 to 12/1975 08/1977 05/1978 to 12/1978 01/1979 to 11/1979 01/1980 to 09/1980 (all dates not available for all drains, flow not available for all dates or drains)
Brownlee Reservoir (RM 335 to 285)	Mixed – depth and surface, not daily 03/1992 to 12/1992 03/1995 to 12/1995 03/1997 to 12/1997 03/1999 to 12/1999 Brownlee Dam outflow, daily max, mean, min 01/1991 to 12/2001
Oxbow Reservoir (RM 285 to 272.5)	Mixed – depth and surface, not daily 03/1995 to 11/1995 03/1997 to 11/1997 Oxbow Dam outflow, daily max, mean, min 01/1991 to 12/2001
Hells Canyon Reservoir (RM 272.5 to 247)	Mixed – depth and surface, not daily 01/1995 to 12/1975 01/1997 to 12/1979 Hells Canyon Dam outflow, daily max, mean, min 01/1991 to 12/2001
Downstream Snake River Segment (RM 247 to 188)	Mixed 01 to 12/1975 to 1989, not daily (all dates not available for all years) RM 239 to 192, daily max, mean, min 01/1991 to 12/2001

Data in this table are from US EPA STORET, 1998a; IPCo, 1999a, 2000a, 2000c and USGS, 1999.

3.6.5 Existing Conditions and Observed Water Temperatures

Figure 3.6.2 a shows the daily maximum water temperatures at several locations in the SR-HC TMDL reach. Data displayed is from 1999 and 2000 (relatively average water years). For the sake of comparison, similar data from 1990 and 1991 (relatively low water years) has been plotted for those locations for which it is available. As evidenced by the following plots, the absolute magnitude of change is specific to the data plotted, but the overall trends are consistent from year to year. The temperature of water inflowing from the upstream Snake River at RM 409, and the water temperature at all monitored locations within the SR-HC TMDL reach is often substantially warmer than the salmonid rearing/cold water aquatic life criterion during the summer months, especially July and August. By contrast, the water released from Brownlee, Oxbow and Hells Canyon dams is substantially cooler and does not show as great or extensive a level of exceedence.

3.6.5.1 UPSTREAM SNAKE RIVER SEGMENT.

As water moves downstream within the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach, it gradually becomes warmer, and its temperature fluctuates more widely over time. Direct measurement of water temperature in the Snake River inflowing at RM 409 is not available. Measurements taken at Murphy, Idaho (RM 453.5) located upstream of the

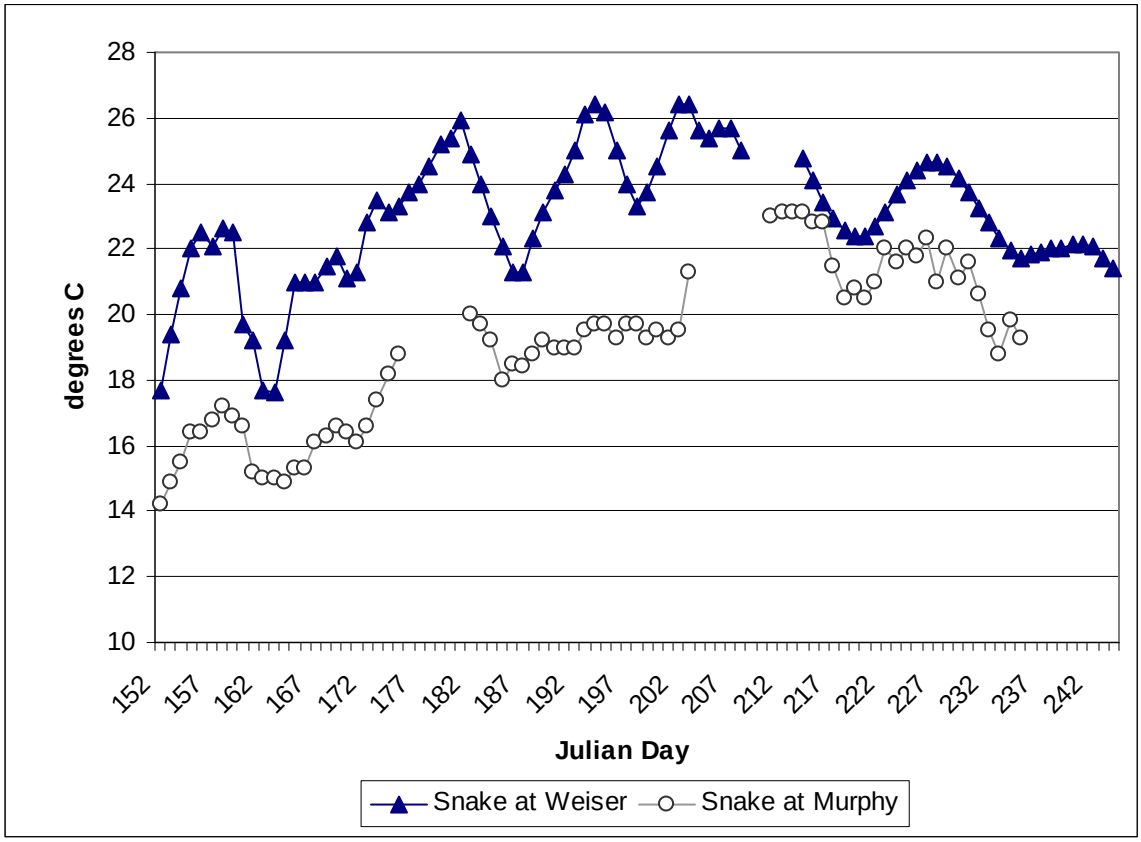


Figure 3.6.2 a – average water year. Daily maximum water temperatures observed in the Upstream Snake River segment (RM 409 to 335) of the Snake River - Hells Canyon TMDL reach, June 01 through August 30 1999-2000. (Precipitation in 1999 and 2000 was approximately 118% of the 30-year average.)

Idaho/Oregon border, show that the mainstem Snake River meets water quality criteria established for the support of salmonid rearing/cold water aquatic life from the first of September through the middle of June. Water temperatures at this site are above 17.8 ^{o}C from late June through late September (Julian days 177 to 265) in an average water year. In a dry water year this time period increases to include nearly the entire month of June.

Water temperatures rise gradually through the months of May and June, commonly peaking near 23 ^{o}C at the beginning of August and then decrease steadily through the month, reaching temperatures below the target by early September. Figure 3.6.2 a shows water temperatures throughout the summer for an average and a dry year in the Upstream Snake River segment (RM 409 to 335). Water temperatures above the 17.8 ^{o}C occur from early July through the end of August (Julian days 182 to 243). Given the above information, the critical time period for salmonid rearing/cold water aquatic life in the SR-HC TMDL reach includes the months of June, July, August and September. These values are tabulated in Table 3.6.2.

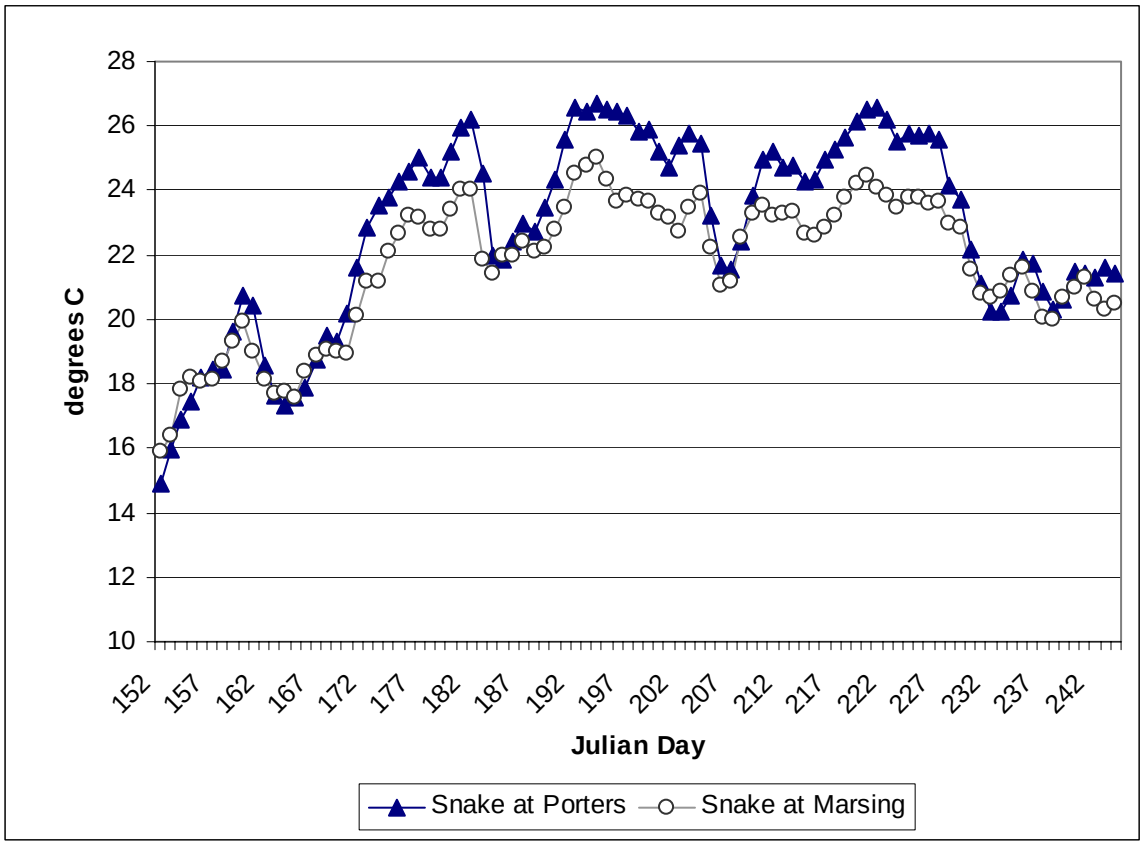


Figure 3.6.2 a – low water year. Daily maximum water temperatures observed in the Upstream Snake River segment (RM 409 to 335) of the Snake River - Hells Canyon TMDL reach, June 01 through August 30 1990 to 1991. (Precipitation in 1990 and 1991 was approximately 54% of the 30-year average.)

The trend observed in the mainstem Snake River near Murphy, Idaho (RM 453.5) is repeated in data collected downstream near Weiser, Idaho (RM 351). Temperatures observed in the mainstem Snake River near Weiser, Idaho (RM 351) show that the mainstem Snake River meets the water quality targets established for the support of salmonid rearing/cold water aquatic life from the first of October through the end of May. Routine, nearly continuous exceedences of the 17.8 ^{o}C target value are observed in the months of June, July, and August (Julian days 152 to 242) in both average and dry water years. Consistent daily maximum water temperature data is not available for September but the trend in water temperature evident at the end of August would project that exceedences would potentially occur through most of September (Julian days 243 to 274). Water temperatures in this section of the river rise gradually through the month of May, commonly peaking near 26 ^{o}C near the middle of July and then decrease through August and September, reaching temperatures below the 17.8 ^{o}C target in October.

In general, in an average water year, water temperatures measured in the mainstem Snake River near Weiser are approximately 5 ^{o}C higher than those observed near Murphy during early to mid-summer (4.8 ^{o}C in June, 4.9 ^{o}C in July). During the month of August, this difference narrows to approximately 2.2 ^{o}C as mainstem water temperatures begin to decrease within the Snake River system.

Table 3.6.2. Time periods of temperature target and standard exceedence for the Upstream Snake River segment (RM 409 to 335) of the Snake River - Hells Canyon TMDL reach.

	Target or standard value	Days at or below the target value	Days consistently greater than target value
Snake River at Murphy			
SR-HC TMDL salmonid rearing/cold water aquatic life target (State of Oregon salmonid rearing standard)	17.8 ^{o}C 7-day daily maximum average water temperature	01 Sept to 22 June (244 to 173)	23 June to 31 Aug (174 to 243)
State of Idaho cold water aquatic life temperature standard	22 ^{o}C instantaneous temperature	17 Aug to 29 July (229 to 210) 05 Aug to 09 Aug (217 to 221)	30 July to 04 Aug (211 to 216) 10 Aug to 16 Aug (222 to 228)
State of Idaho cold water aquatic life temperature standard	19 ^{o}C maximum daily average water temperature	01 Sept to 30 June (244 to 181)	01 July to 31 Aug (182 to 243)
Snake River at Weiser			
SR-HC TMDL salmonid rearing/cold water aquatic life target (State of Oregon salmonid rearing standard)	17.8 ^{o}C 7-day daily maximum average water temperature	02 Oct to 31 May est. (275 to 151)	01 June to 01 Oct est. (152 to 274)
State of Idaho cold water aquatic life temperature standard	22 ^{o}C instantaneous temperature	31 Aug to 03 June (243 to 154) 09 June to 20 June (160 to 171) 05 July to 06 July (186 to 187) 23 Aug to 25 Aug (235 to 237)	04 June to 08 June (155 to 159) 21 June to 04 July (172 to 185) 07 July to 22 Aug (188 to 234) 26 Aug to 30 Aug (238 to 242)
State of Idaho cold water aquatic life temperature standard	19 ^{o}C maximum daily average water temperature	11 June to 12 June (162 to 163) 16 Sept to 01 June (259 to 152)	02 June to 10 June (153 to 162) 13 June to 15 Sept est. (164 to 258)

Julian days are given in parentheses below the calendar dates

In general, in a dry water year, much smaller differences upstream to downstream are observed in water temperatures measured in the mainstem Snake River. Water temperatures measured near Porters Island (downstream of Weiser) are approximately 1 ^{o}C higher than those observed near Marsing (downstream of Murphy) during the early to mid-summer (0.8 ^{o}C in June, 1.5 ^{o}C in July). During the month of August, this difference narrows to approximately 1.1 ^{o}C as mainstem water temperatures begin to decrease within the Snake River system.

3.6.5.2 Brownlee Reservoir Segment.

Temperatures recorded historically (1957) at the Brownlee Dam-site prior to construction show that the average daily maximum water temperature in the river was 18.6 ^{o}C during June, 22.1 ^{o}C during July, 21.2 ^{o}C during August and 18.3 ^{o}C during September. Mean daily average water temperatures for this year showed that the water temperature exceeded 17.8 ^{o}C for the June through September time period and exceeded 19 ^{o}C during the months of July and August. During the month of July, daily maximum water temperatures averaged greater than 22 ^{o}C

(Table 2.3.21 and Figure 2.3.23). While these data do not represent pristine conditions (there were impoundments upstream at this time), they demonstrate quite conclusively that elevated water temperatures (above target values) do not occur solely as the result of the Hells Canyon Complex of impoundments within the SR-HC TMDL reach.

As identified in the previous discussion, water flowing into Brownlee Reservoir from the Upstream Snake River segment (RM 409 to 335) is often warmer than the salmonid rearing/cold water aquatic life maximum criterion during the summer months. Within the reservoir, the surface waters continue to warm as they move downstream, while deeper waters cool. A report on Brownlee Reservoir authored by IPCo in 1999 (IPCo, 1999d) states that Brownlee Reservoir consistently experiences thermal stratification during summer months, with the thermocline forming near the elevation of approximately 1948 ft (~37 m below the surface elevation at full pool) and extending approximately 25 miles upstream of the dam (Figure 3.6.2 b). The reservoir is typically stratified from March until November.

Surface waters in the reservoir are often warmer than the salmonid rearing/cold water aquatic life maximum criterion during the summer months. The temperature of hypolimnion waters is generally less than 10 ^{o}C, while surface water temperatures can reach above 26 ^{o}C. The strongest thermal stratification occurs during the months of July and August. Cooling starts to occur in surface waters in September, leading to a gradual breakdown of stratification in November.

Data collected by IPCo in 1992, 1995 and 1997 (Figure 3.6.2 b) show that maximum surface water temperatures generally range from 20 ^{o}C to 23 ^{o}C in early July to 23 ^{o}C to 26 ^{o}C in August. The Brownlee Reservoir Model Report (IPCo, 1999d) states that a maximum surface water temperature of 29 ^{o}C was recorded near Brownlee Dam. Minimum surface water temperatures observed in the report (surface to a depth of 50 feet) ranged from 18 ^{o}C to 20 ^{o}C in early July and 20 ^{o}C to 22 ^{o}C in August in 1992 and 1995. Surface waters exceeded 24 ^{o}C in August.

In 1995, a reasonably average year, instantaneous measurements of surface water temperature (<1 m below the surface) averaged 13.5 ^{o}C during May, 18.4 ^{o}C during June, 24.0 ^{o}C during July, 23.7 ^{o}C during August, 20.3 ^{o}C during September and 17.1 ^{o}C during October. Instantaneous water temperature data collected at a depth of 15 m (45 feet) averaged 12.2 ^{o}C during May, 17.3 ^{o}C during June, 20.5 ^{o}C during July, 21.7 ^{o}C during August, 20.6 ^{o}C during September and 16.3 ^{o}C during October. Similar data, collected by the Boise City Public Works in 1999 (BCPW, 2001), show surface water temperatures that ranged from 19 ^{o}C to 25 ^{o}C in July, and 22 ^{o}C to 26 ^{o}C in August. Temperatures near the metalimnion ranged from 19 ^{o}C to 23 ^{o}C in July and from 22 ^{o}C to 23 ^{o}C in August. Deep (hypolimnetic) water temperatures ranged from 12 ^{o}C to 15 ^{o}C in July and from 12 ^{o}C to 14 ^{o}C in August over the same time period.

The stratification of the reservoir and the resulting water temperature ranges are dependent on the operation of the reservoir as a mechanism for flood control. The Brownlee Reservoir Model Report (IPCo, 1999d) compares 1992 data to 1997 data to illustrate this difference (Figure 3.6.2, 1992 and 1997). In 1992, relatively low precipitation levels necessitated little drawdown for flood control purposes, while above average precipitation levels in 1997 necessitated substantial drawdowns. During the summer of 1997, the report states that the volume of water in the reservoir below 10 ^{o}C was nearly nonexistent due to heating from shallow depths and delayed

Figure 3.6.2 b – 1992 Temperature isopleths for Brownlee Reservoir for June, July and August of 1992 (a dry water year). (Data collected and plotted by Idaho Power Company.)

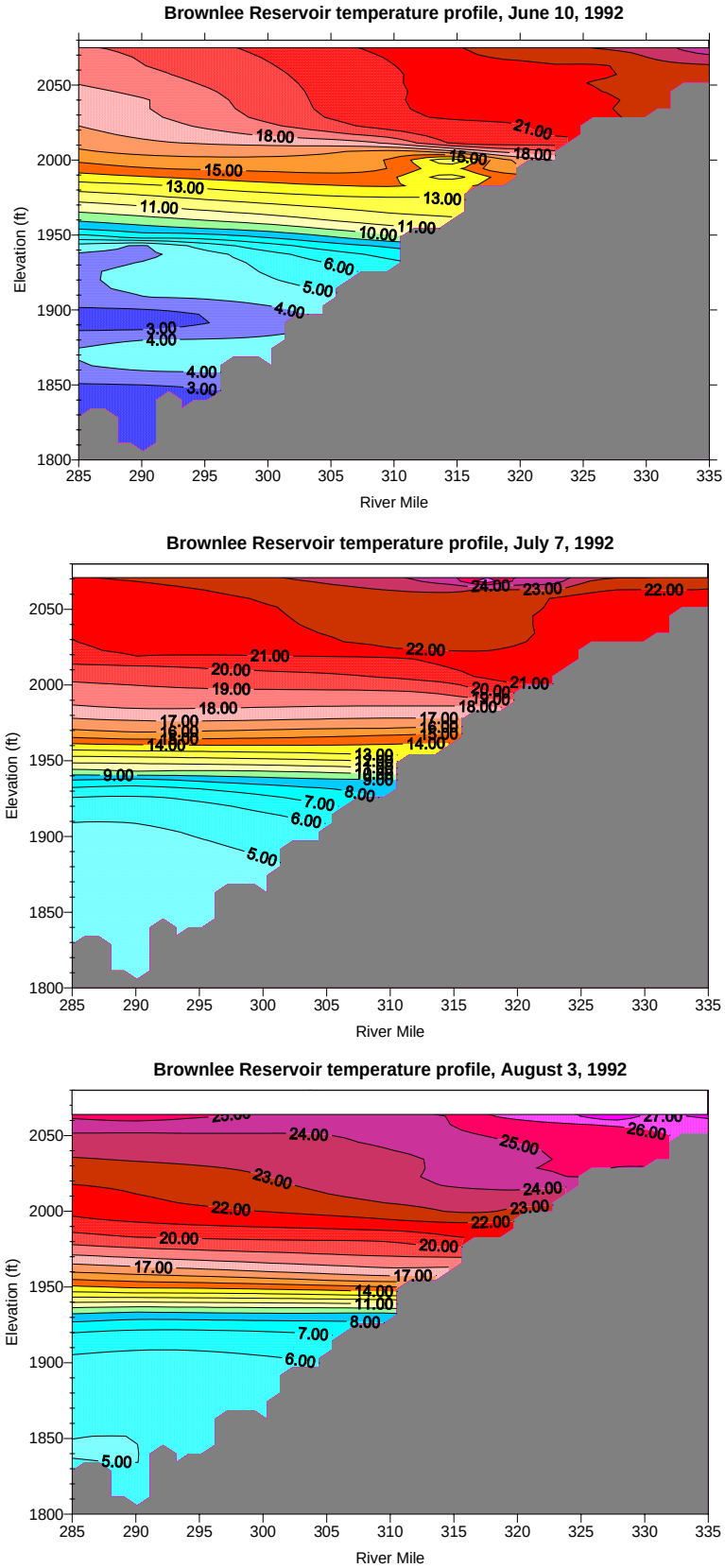
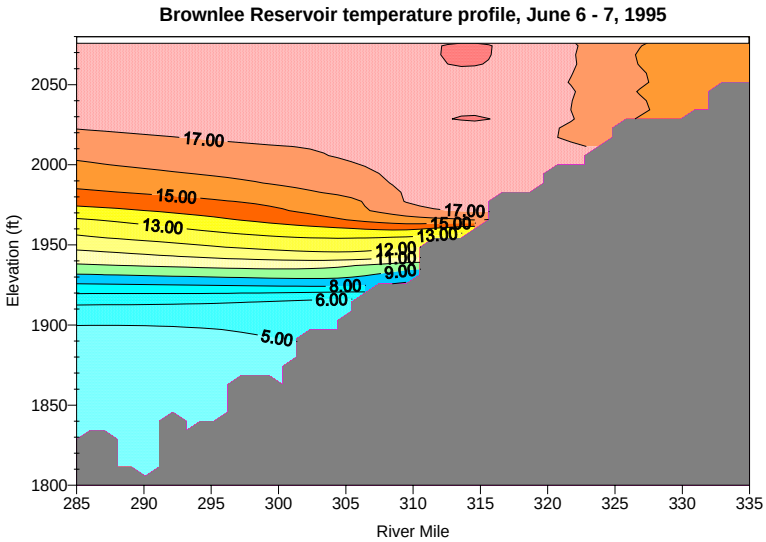
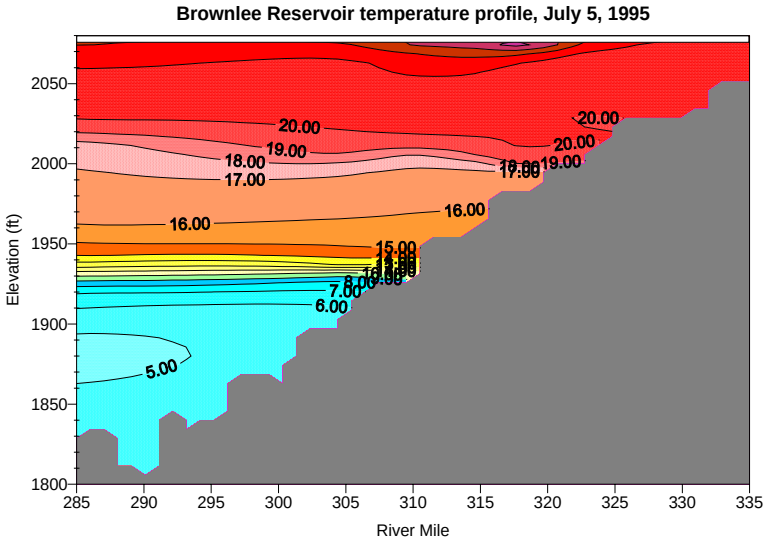


Figure 3.6.2 b – 1995 Temperature isopleths for Brownlee Reservoir for June, July and August of 1992 (an average water year). (Data collected and plotted by Idaho Power Company.)





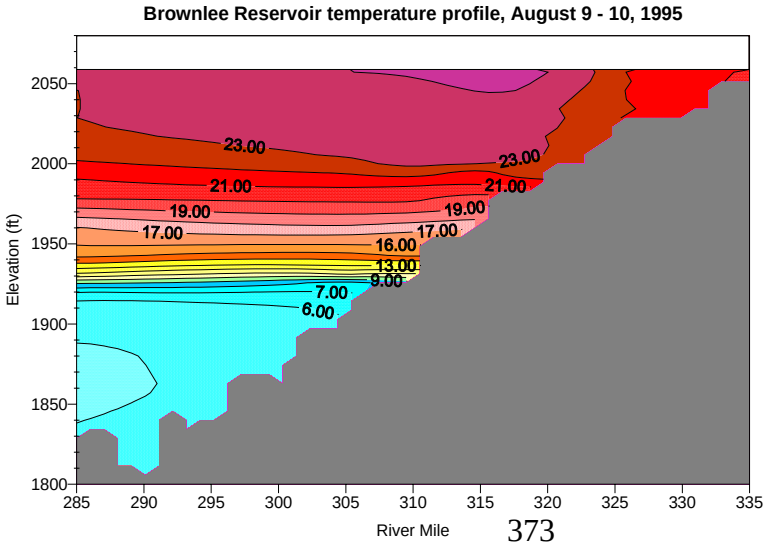
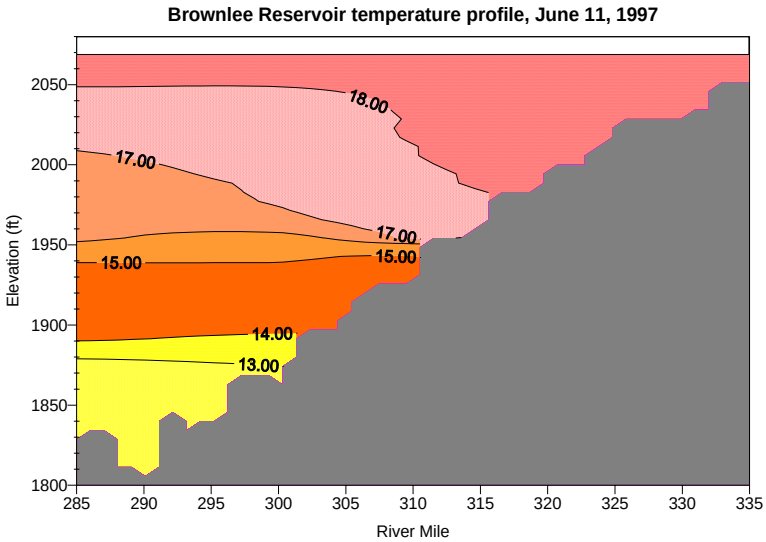
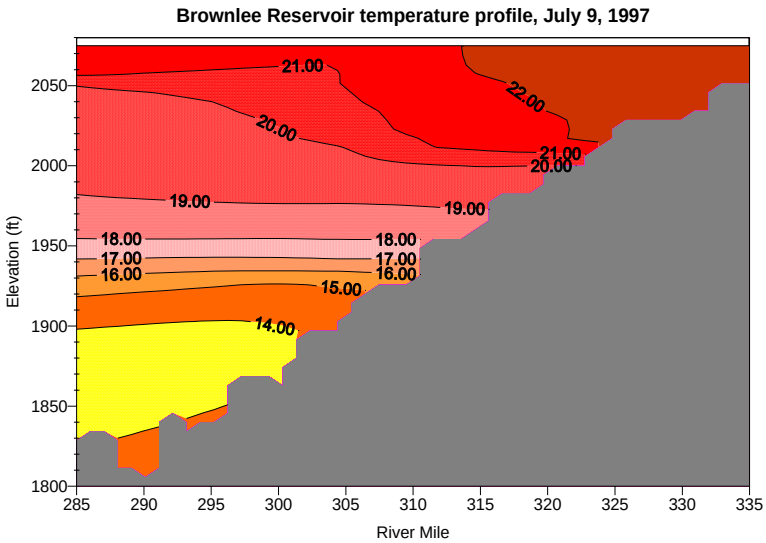
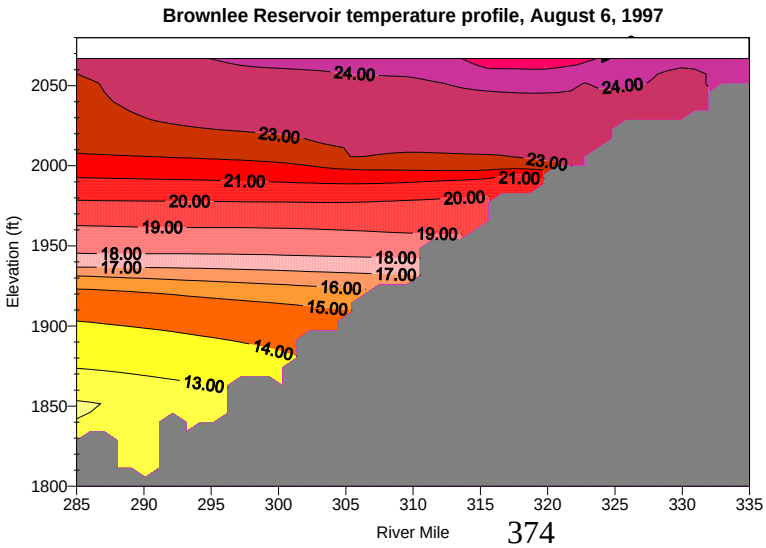


Figure 3.6.2 b – 1997 Temperature isopleths for Brownlee Reservoir for June, July and August of 1992 (a high water year). (Data collected and plotted by Idaho Power Company.)







storage. Water temperatures at the thermocline in July of 1992 were approximately 11 ^{o}C, in July of 1997 the temperature was approximately 17 ^{o}C. Similarly, hypolimnion temperatures for the two years were 5 ^{o}C and 13 ^{o}C, respectively. Substantial drawdown within the reservoir system results in higher overall water temperatures due to more effective heating within the shallower reservoir depths, and less storage of cold, snow-melt runoff water. Figure 3.6.2 b, from the Brownlee Reservoir Water Quality and Model Development Report (IPCo, 1999d) illustrates the temperature variability within the reservoir and the influence of drawdown timing and magnitude on water temperatures during the summer months.

The greater surface area of Brownlee Reservoir allows more solar and atmospheric influence on temperature within the surface water layers. However, increasing depth and channel width act to cool the majority of the water volume below the inflow temperature. While water at the surface in Brownlee Reservoir is observed to exceed the salmonid rearing/cold water aquatic life maximum criterion during the summer months, water in deeper layers of the reservoir is substantially cooler and does not show as great or extensive a level of exceedence.

3.6.5.3 OXBOW RESERVOIR SEGMENT.

Temperatures recorded historically (1954 to 1957) at the Oxbow Dam-site prior to construction (Table 2.3.30) show that the average daily maximum water temperature in the river was greater than 17.8 ^{o}C from June through September for all four years. The trend observed here shows a pattern very similar to that observed at the Brownlee Reservoir Dam-site prior to construction. While these data do not represent pristine conditions (there were impoundments upstream at this time), they demonstrate quite conclusively that the elevated water temperatures (above target values) currently observed do not occur solely as the result of the Hells Canyon Complex of impoundments within the SR-HC TMDL reach.

Oxbow Reservoir is a moderately sized, run-of-river reservoir, and water passes through very quickly (approximately 1.4 days). As shown by the temperatures in the metalimnetic waters of Brownlee Reservoir, water flowing into Oxbow Reservoir is often cooler than the river inflow to Brownlee Reservoir. The majority of the water flowing into Oxbow Reservoir is released from the outlet of Brownlee Dam. Water released from the outlet of the dam is from the lower water column of Brownlee Reservoir and therefore remains cooler during summer months than surface water layers. Water temperature data available to this TMDL effort for the downstream portion of Oxbow Reservoir are very limited, and most were collected in the mid to late 1970's.

In the absence of a complete, reservoir-wide data set, this TMDL effort recognizes that most of the water entering Oxbow Reservoir is from the outlet of Brownlee Dam (Figure 3.6.2 c). The temperature of water introduced into Oxbow is generally cooler than that of the surface waters upstream of Brownlee Dam. Temperature ranges and depth related trends are expected to mimic those observed in Brownlee Reservoir. As Oxbow is a small, run-of-river reservoir, water passes through very quickly, and an increase in water temperature is more likely to be observed at the downstream end of the reservoir as a result of atmospheric conditions than at the immediate outlet of the dam.

The small data set available for downstream portions of Oxbow Reservoir contains only instantaneous measurements of surface water temperature, not daily maximum temperatures and

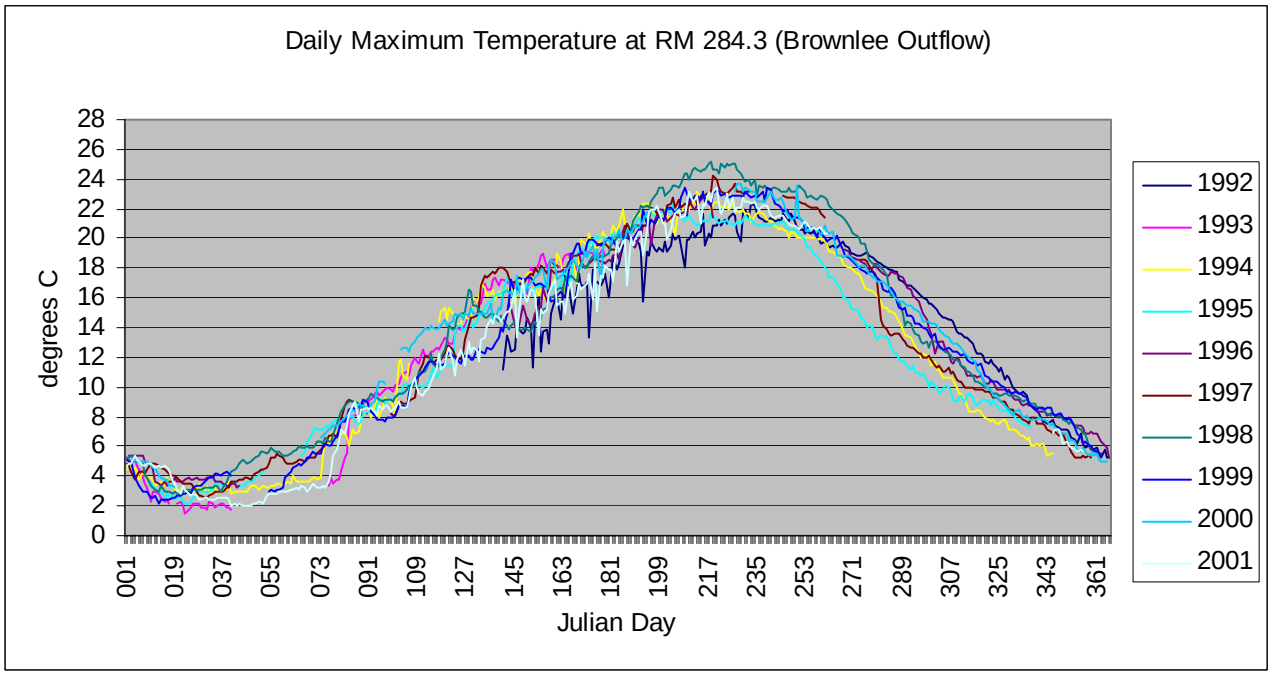


Figure 3.6.2 c Water temperatures observed at the outflow of Brownlee Reservoir in the Oxbow Reservoir segment (RM 285 to 272.5) of the Snake River - Hells Canyon TMDL reach.

therefore cannot be used to determine whether or not an exceedence of water quality standards or target values has occurred. However, the limited data available show that surface water near the dam (at RM 272.3) in Oxbow Reservoir is at slightly warmer temperatures than those measured at the outlet of Brownlee Dam in the early summer (approximately 2 ^{o}C during the month of June). This difference decreases later in the summer when the water entering Oxbow from Brownlee Reservoir upstream is warmer (0.5 ^{o}C increase). Water temperature overall increases during summer months. Instantaneous surface water temperature data collected at RM 284.3 are routinely above 17.8 ^{o}C from July through September (Julian days 182 through 273). The fact that the majority of water discharging into Oxbow Reservoir exhibited water temperatures above 17.8 ^{o}C indicate that surface water temperatures in downstream portions of Oxbow Reservoir were, most likely, also above 17.8 ^{o}C during this same time frame.

Similar to the trends observed in Brownlee Reservoir, increasing depth and channel width in Oxbow Reservoir act to minimize the effect of natural sources of warming in the majority of the water volume.

3.6.5.4 HELLS CANYON RESERVOIR SEGMENT.

Surface water temperature data is not available for downstream portions of Hells Canyon Reservoir. The majority of the water entering Hells Canyon Reservoir is from the outlet of Oxbow Dam (Figure 3.6.2 d), and is somewhat cooler than that of surface waters upstream of Oxbow Dam.

Hells Canyon Reservoir is a moderately sized, run-of-river reservoir, and water passes through very quickly (approximately 4 days). An increase in surface water temperature is more likely to

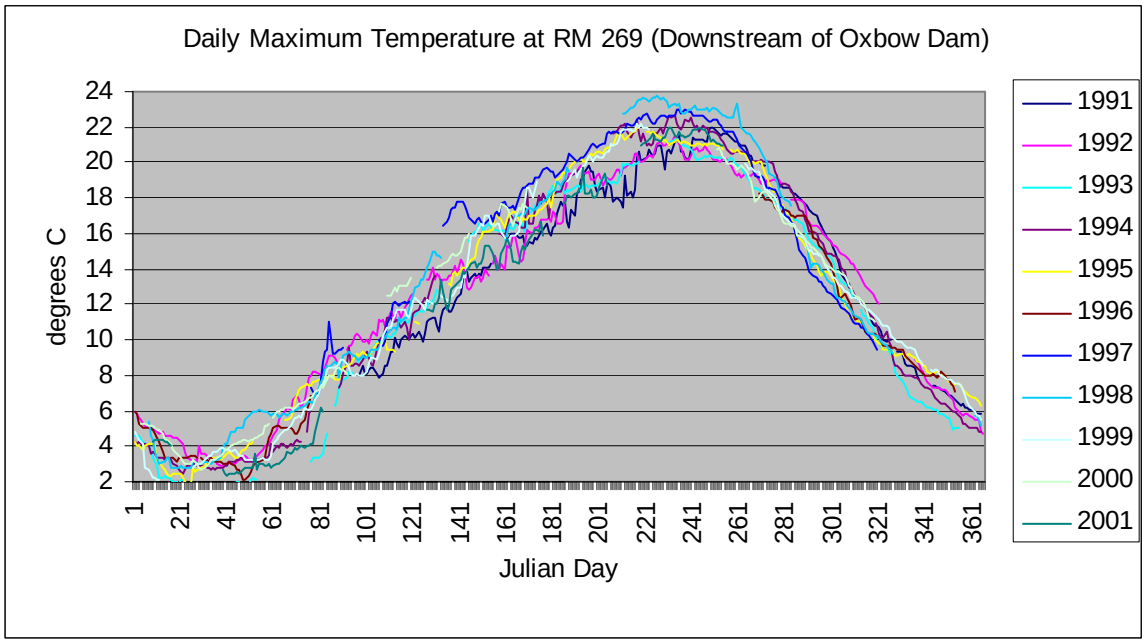


Figure 3.6.2 d. Water temperatures observed downstream of the outflow of Oxbow Reservoir (RM 269) in the Hells Canyon Reservoir segment (RM 272.5 to 247) of the Snake River - Hells Canyon TMDL reach.

be observed at the downstream end of the reservoir as a result of atmospheric conditions than at the immediate outlet of the dam. Data collected from downstream of the outlet of Oxbow Dam (RM 269) between 1991 and 2001 show water temperatures above 17.8 ^{o}C during the months of July, August and September (Julian days 182 through 273). The fact that the majority of water discharging into Hells Canyon Reservoir exhibited water temperatures above 17.8 ^{o}C indicate that surface water temperatures in downstream portions of Hells Canyon Reservoir were, most likely, also above 17.8 ^{o}C during this same time frame.

Similar to the trends observed in the upstream reservoirs (Brownlee and Oxbow), increasing depth and channel width in Hells Canyon Reservoir act to minimize the effect of natural sources of warming in the majority of the water volume.

3.6.5.5 Downstream Snake River Segment.

Water moving through the outlet of Hells Canyon Dam represents the dominant source of flow to the Downstream Snake River segment (RM 247 to 188). Water temperature data available for the Downstream Snake River segment includes three years of monthly average temperatures from June 1955 through June 1958 at RM 203 below the Hells Canyon dam, and 10 years (1991 through 2001) of daily minimum, mean and maximum water temperature data provided by IPCo for various sites within the Downstream Snake River segment (RM 247 to 188). Water temperatures measured immediately downstream from the outlet to Hells Canyon Dam (Figure 3.6.2 e) show exceedences of the 17.8 ^{o}C target in July, August, and September (Julian days 182 through 273). Water temperatures further downstream of the outlet of Hells Canyon Dam (Figure 3.6.2 f), show summer high temperatures above 17.8 ^{o}C for most of June, July, August and September (Julian days 152 through 273).

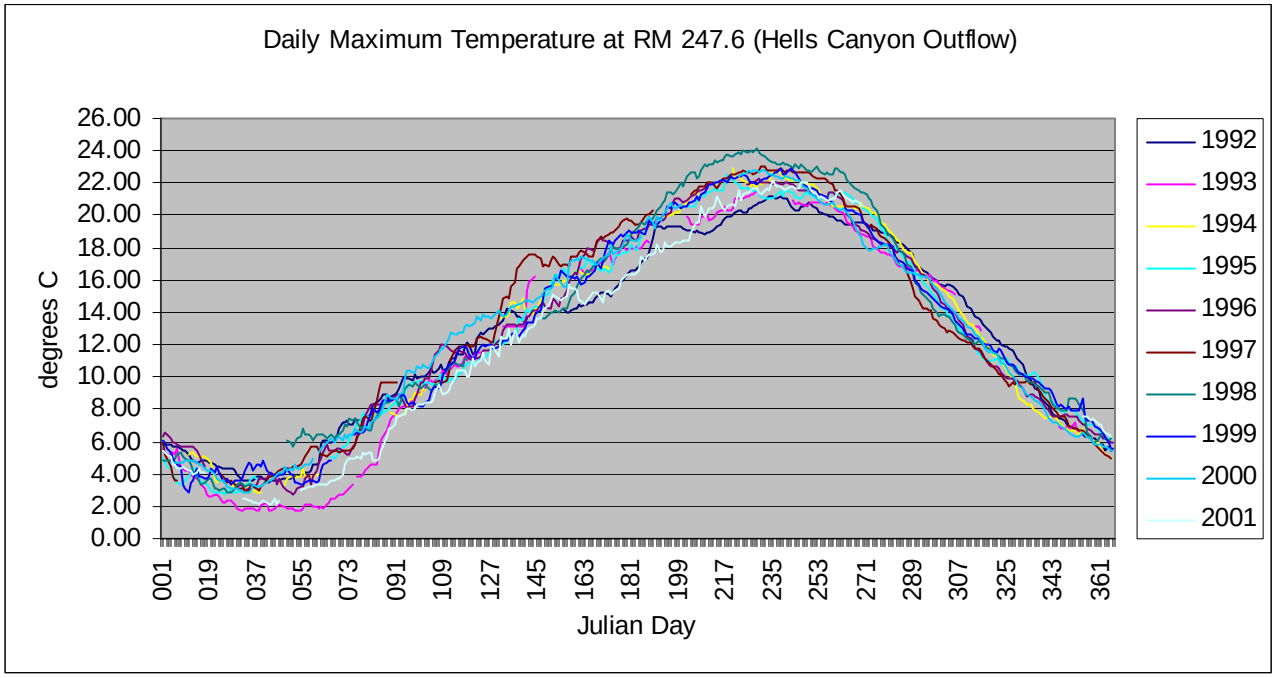


Figure 3.6.2 e. Water temperatures for the Downstream Snake River segment (RM 247 to 188) of the Snake River - Hells Canyon TMDL reach near Hells Canyon Dam.

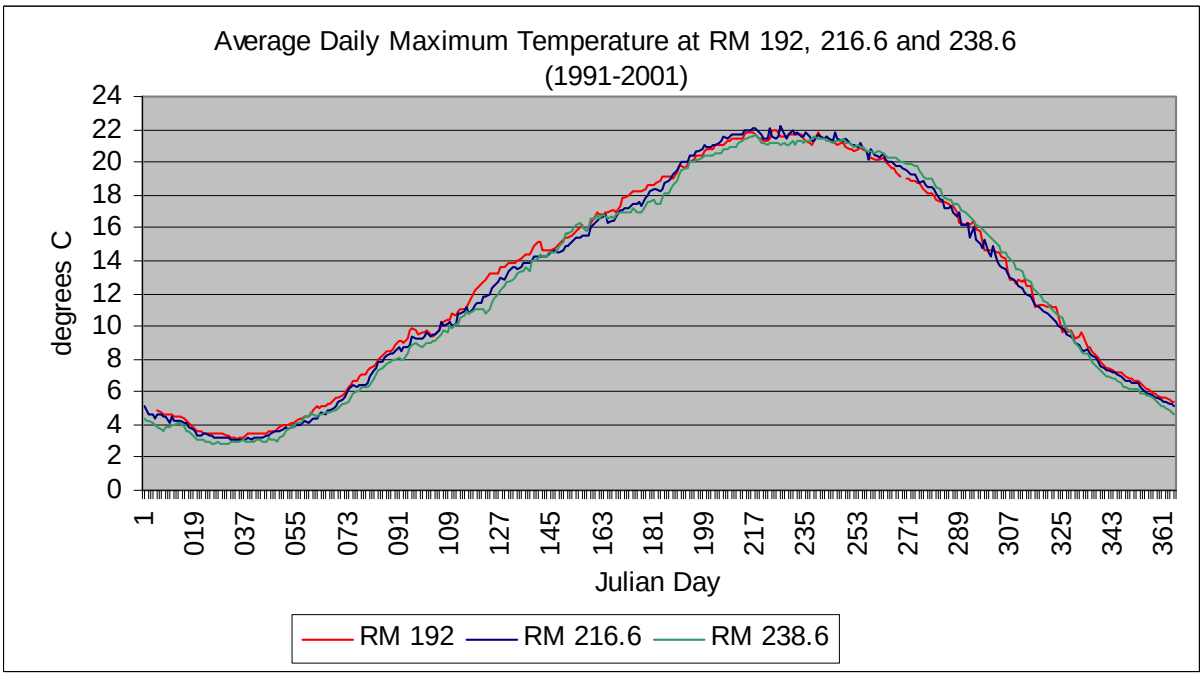


Figure 3.6.2 f. Water temperatures for the Downstream Snake River segment (RM 247 to 188) of the Snake River - Hells Canyon TMDL reach.

Average conditions over the 10 year time period available, as plotted in Figure 3.6.2 f, show only minor temperature change occurring between the outlet of Hells Canyon Dam (RM 247) and the inflow of the Salmon River (RM 188). A more discernable, general trend in water temperature can be observed over the course of a single year as in Figure 3.6.2 g, where fall water temperatures leaving Hells Canyon Dam are slightly warmer than those downstream.

During the early summer months (20 June to 03 August, Julian day 170 to 215), as water moves downstream, temperatures at RM 192 are observed to be slightly warmer (by approximately 0.4 ^{o}C maximum in 1995) or very similar to water temperatures near the outlet of Hells Canyon Dam (RM 239). The opposite trend is observed in the later summer months (08 August to 01 October, Julian day 220 to 274) when temperatures at RM 192 are slightly cooler than water temperatures near the outlet of Hells Canyon Dam (RM 239) (by approximately 0.7 ^{o}C maximum in 1995). Water temperatures observed at RM 192 are essentially the same as those observed at RM 239 during the mid-summer months (Julian days 194 to 220). However, the magnitude of the observed changes is very small and may represent less of an overall temperature change than the diurnal variations observed for this reach of the river.

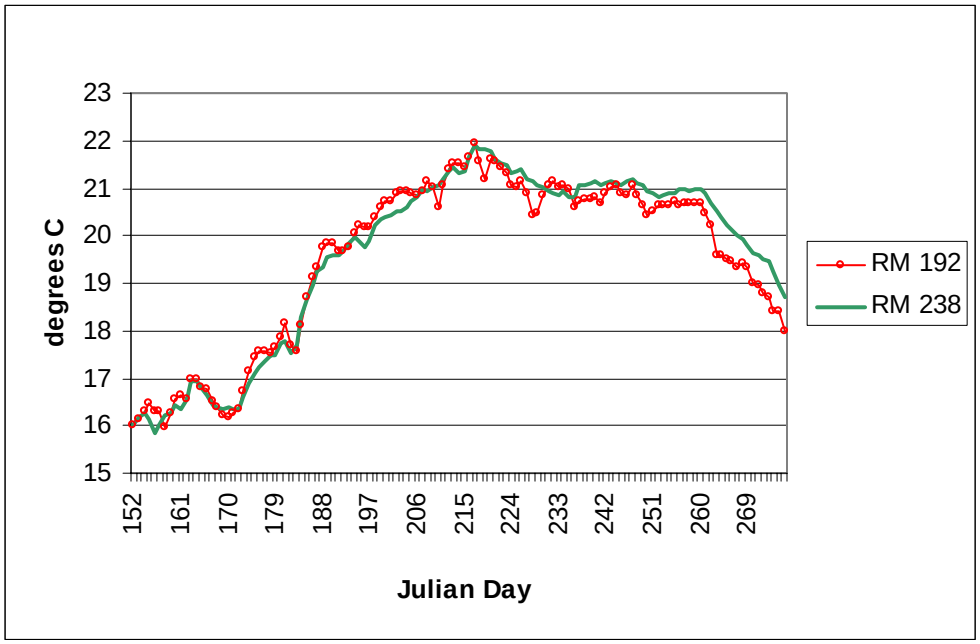


Figure 3.6.2 g. Water temperatures near the outflow of Hells Canyon Dam (RM 238) and above the inflow of the Salmon River (RM 192) measured June through September of 1995.

Water temperatures in the Downstream Snake River segment (RM 247 to 188) are shown in Figure 3.6.2 h for the 1950s, pre-construction of the Hells Canyon Complex and the 1990s, post-construction. Pre-construction water temperature data is available for RM 203, (approximately 44 miles downstream of the Hells Canyon Dam-site) for water years 1955 through 1958 as monthly averages. Water years 1955 and 1959 are slightly below average (75% and 73% of the 50-year average respectively), 1958 is close to an average water year (102% of the 50-year average), and 1956 and 1957 are slightly above average water years (116% and 113% of the 50-year average respectively). These data are not intended to represent natural temperature

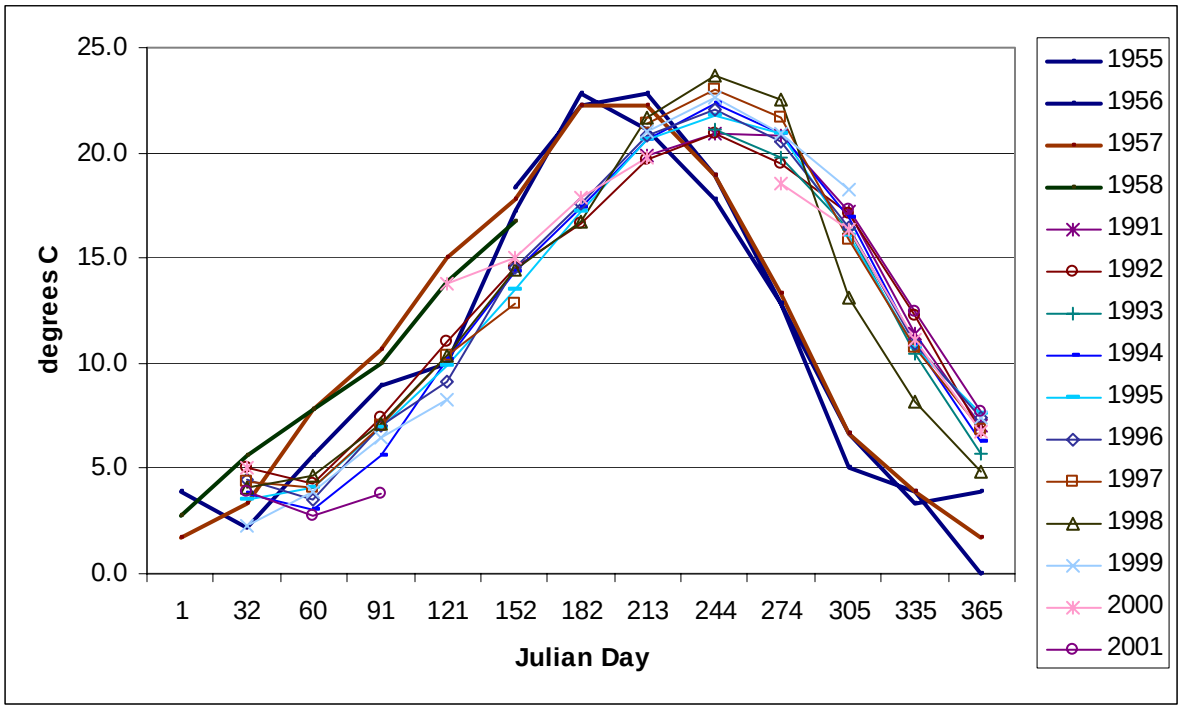


Figure 3.6.2 h. Comparison of the monthly average of daily maximum water temperatures below Hells Canyon Dam pre-construction (RM 203) and post-construction (RM 202).

conditions as a substantial level of diversion and impoundment was occurring upstream when the data were collected.

Post-construction water temperature data is available for RM 202 (1991 through 2001) that covers a range of water years including 1995, a close to average water year (94% of the 50-year average), 1996, a high water year (131% of the 50-year average), and 1991, a low water year (55% of the 50-year average). Data was provided as daily maxima, minima and mean water temperatures (IPCo, 2002). Daily mean water temperatures were averaged to monthly means to provide consistency in this comparison (Figure 3.6.2 h). The water temperature data available for this segment show that monthly average water temperatures are in excess of the 17.8 ^{o}C salmonid rearing/cold water aquatic life target from mid-June through mid-September, Julian days 170 through 265 for pre-construction data (approximately 90 days total). Post-construction data show exceedences occur between the first week of July and mid-October, Julian day 182 through 295 (approximately 113 days total). However, the overall shape of the curve observed on the downsloping side of the post-construction plots does not appear different from the pre-construction plots, only the timing is changed. Additionally, while these periods of exceedence are temporally shifted by approximately two weeks, they are of very similar duration.

The 1950s data pre-dates completion of the three Hells Canyon Complex dams. Data from 1991 through 2001 are representative of post-construction conditions. In both cases, exceedences of the 17.8 ^{o}C salmonid rearing/cold water aquatic life target occurred. This comparison demonstrates quite clearly that changes in water temperature specific to the impoundments in the SR-HC TMDL reach are related to how the water is processed through the Hells Canyon

Photo 3.6.1. Snake River at approximately RM 250, near the Hells Canyon Dam site, circa 1939 to 1940. This photo was proposed to be used for a state stamp. Photo from the collection of Dr. Lyle M. Stanford.

Complex. The impoundments themselves do not act as heat sources, but rather act to delay temperature changes within the mainstem Snake River downstream. The water temperature curve described by the post-construction data shows a shifted temporal distribution where water temperatures following construction of the Hells Canyon Complex reservoirs are slightly warmer for longer in the fall and cooler for longer in the spring. Upstream sources of elevated water temperature, many potentially in place prior to the completion of the Hells Canyon Complex, are the primary source of increased water temperature within the SR-HC TMDL reach.

Overall, the data available for the Downstream Snake River segment (RM 247 to 188) show that average monthly summer water temperatures in this segment were higher prior to the construction of the Hells Canyon Complex reservoirs. The Hells Canyon Complex reservoirs act to cool the overall summer water temperature below those observed in the Snake River upstream of Brownlee Reservoir (Figure 3.6.2 i). Data collected 1991 through 2001, above Brownlee Reservoir at RM 345 and below Hells Canyon Dam at RM 247 show that cooling

occurs throughout the spring and summer months relative to inflow water temperatures. The average magnitude of cooling observed during July and August (Julian days 182 through 250) is approximately 4 ^{o}C. This trend is not as dominant during the later fall months of September or October (Julian days 253 through 304) due to the temporal lag in water temperatures discussed earlier. The data plotted in Figure 3.6.2 i represent a wide range of water years; 1995 was a relatively average water year (94% of the 50-year average annual flow), 1996 and 1997 were high water years (131% and 170% of the 50-year average annual flow respectively), and 1991 was a relatively low water year (55% of the 50-year average annual flow).

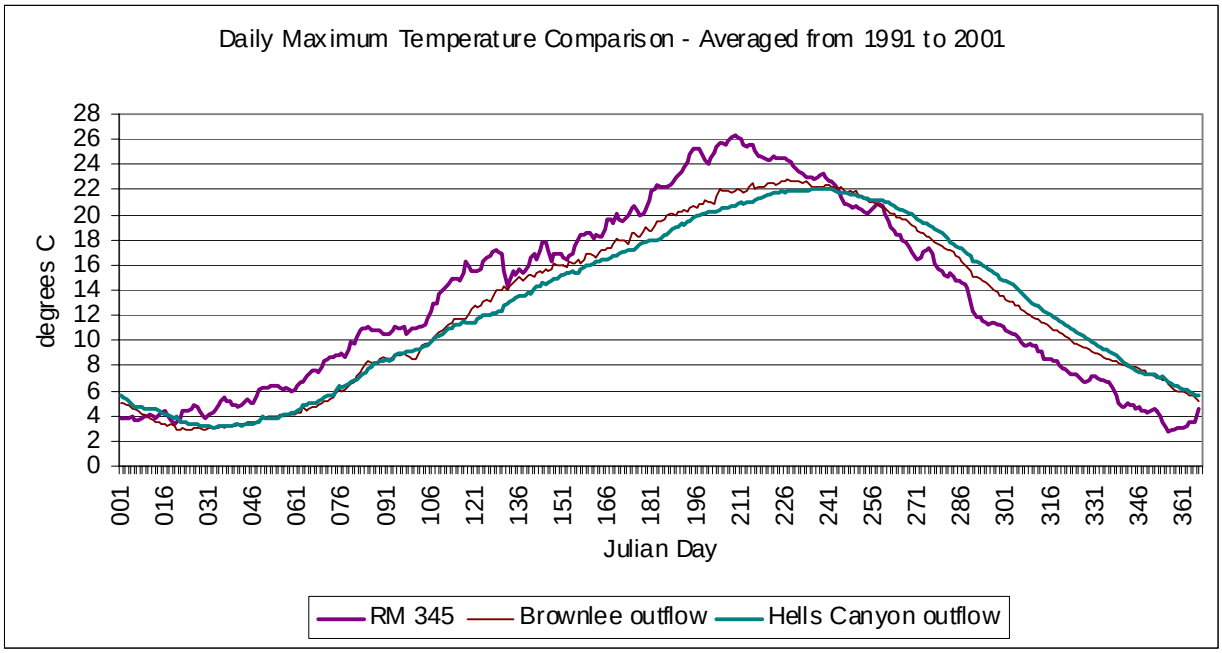


Figure 3.6.2 i. Differences in daily maximum surface water temperatures observed between the Upstream Snake River segment (measured downstream of Weiser, Idaho (RM 345)) and the Downstream Snake River segment (measured below the Hells Canyon Dam site (RM 247)).

It should be recognized that the Snake River above RM 345, and the tributary inflows to the SR-HC TMDL reach reflect the effects of substantial diversion and impoundment upstream and therefore are not representative of natural temperature or flow conditions for this system.

The Imnaha River flows into the Snake River at RM 191. Temperature data available from 1995 and 1996 for the Imnaha show daily maximum water temperatures that average 18.8 ^{o}C during July, 20.7 ^{o}C during August and 17.1 ^{o}C during September, Julian days 182 through 273 (Figure 3.6.3). Exceedences of the 17.8 ^{o}C salmonid rearing/cold water aquatic life target occur during July, August and part of September (Julian days 196 through 256).

3.6.5.6 THREATENED AND ENDANGERED SPECIES AND SALMONID SPAWNING.

A number of species listed as threatened or endangered under the Federal Endangered Species Act (ESA), are known to inhabit the SR-HC TMDL reach. The SR-HC TMDL reach provides habitat for the Idaho spring snail (*Pyrgulopsis idahoensis,* formerly *Fontelicella idahoensis*), identified in the region between RM 422 and 393 and between RM 372 and 366; and the Bliss

Photo 3.6.2. The mouth of the Imnaha River (RM 191), circa 1939 to 1940. Photo shows boatmen collecting mail from a receptacle anchored on the shoreline. Photo from the collection of Dr. Lyle M. Stanford.

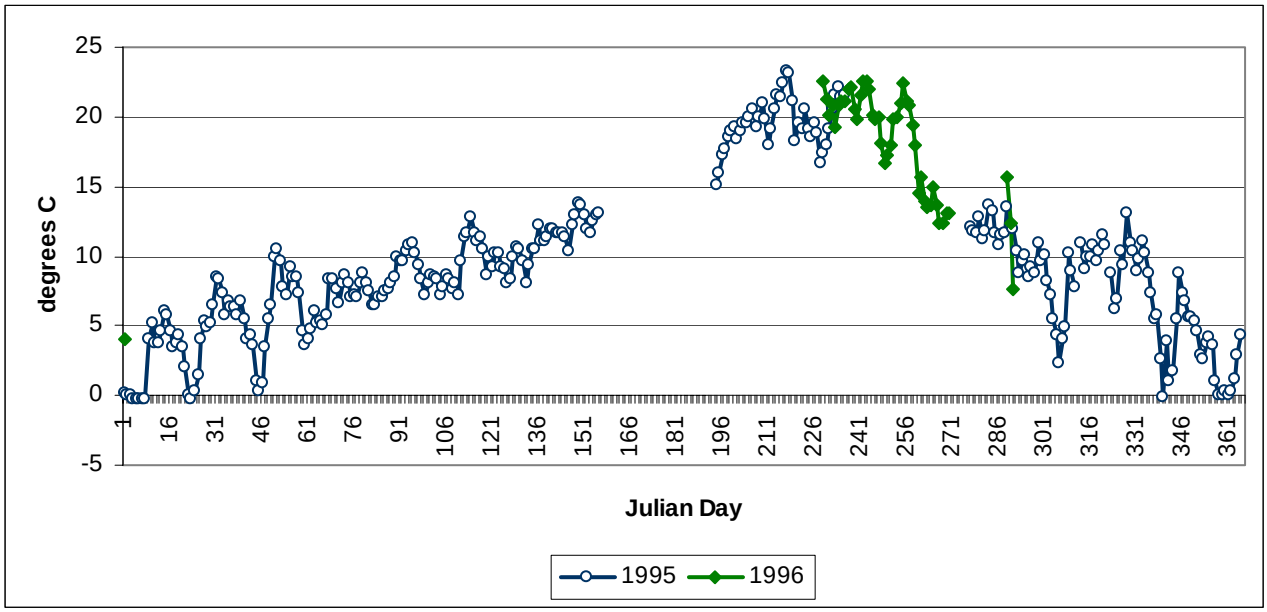


Figure 3.6.3. Water temperatures measured in the Imnaha River during 1995 and 1996.

Rapids snail (*Taylorconcha serpenticola*), identified in the region between RM 228 and 225 and in several areas of the Snake River upstream of the SR-HC TMDL reach. Both of these snail species are listed as threatened under the ESA, both are listed as requiring cold, clear, well oxygenated water for full support. Adult bull trout (*Salvelinus confluentus*), known to utilize the reservoir segments, are listed as threatened under the ESA. The SR-HC TMDL reach and some inflowing tributaries below Hells Canyon Dam also provide habitat for the Snake River fall (*Oncorhynchus tshawytscha*) and spring/summer chinook (*Oncorhynchus tshawytscha*), as well as steelhead (*Oncorhynchus mykiss*), all of which are listed as threatened under the ESA. A more complete description of these species, their status and their habitat needs is outlined in the Subbasin Assessment (Section 2.2.2.3).

All of the species listed above as threatened or endangered rely on good water quality for survival. Some species are sensitive to elevated water temperatures.

3.6.5.7 SALMONID SPAWNING AND REARING

Waters are designated for salmonid spawning and rearing in the Downstream Snake River segment (RM 247 to 188) of the SR-HC TMDL reach. Waters so designated are required to exhibit appropriate levels of water column dissolved oxygen, intergravel dissolved oxygen, temperature, pH, ammonia, toxics, and turbidity for full support of fish during the spawning, incubation and rearing periods for those salmonid species inhabiting the designated waters. General time periods for spawning and incubation of the salmonid species identified to use the Downstream Snake River segment (RM 247 to 188) are:

- Chinook salmon (fall) October 23 through April 15 (Julian day 296 to 105)*
- Mountain Whitefish Nov 01 through March 30 (Julian day 305 to 89)*

* represents spawning and incubation times identified as specific to the SR-HC TMDL reach.

A complete table of fish species in the SR-HC TMDL reach is available in section 3.6.9.2 of this document.

3.6.5.8 INFLUENCE OF IMPOUNDMENTS ON DOWNSTREAM WATER TEMPERATURES RELATIVE TO SALMONID REARING/CLOD WATER AQUATIC LIFE AND SALMONID SPAWNING

Water temperatures in the Downstream Snake River segment (RM 247 to 188) are shown in Figure 3.6.2 h for the 1950s, pre-construction of the Hells Canyon Complex and the 1990s, post-construction. Pre-construction water temperature data is available for RM 203, (approximately 44 miles downstream of the Hells Canyon Dam-site) for water years 1955 through 1958 as monthly averages representing a variety of low, average and high water years. Post-construction water temperature data is available for RM 202 (1991 through 2001) and also covers a range of water years. Daily mean water temperatures from 1991 through 2001 were averaged to monthly means to provide consistency.

Data available for the pre-impoundment time period (1955 through 1958) are monthly mean water temperature values and therefore cannot be used to determine if the 13 ^{o}C maximum weekly maximum target value was exceeded. A general evaluation of pre-impoundment data shows that monthly averages above 13 ^{o}C occurred at the beginning of the salmonid spawning period identified by this TMDL and extended for approximately 2 weeks.

A general evaluation of this data shows that monthly averages above 13 ^{o}C did not occur within this data set during the fall chinook spawning period (Julian day 296 to 105). Please note, Figure 3.6.4 a shows daily mean water temperature data, and Figure 3.6.2 h shows monthly average daily maximum water temperature data for post-construction (current) conditions.

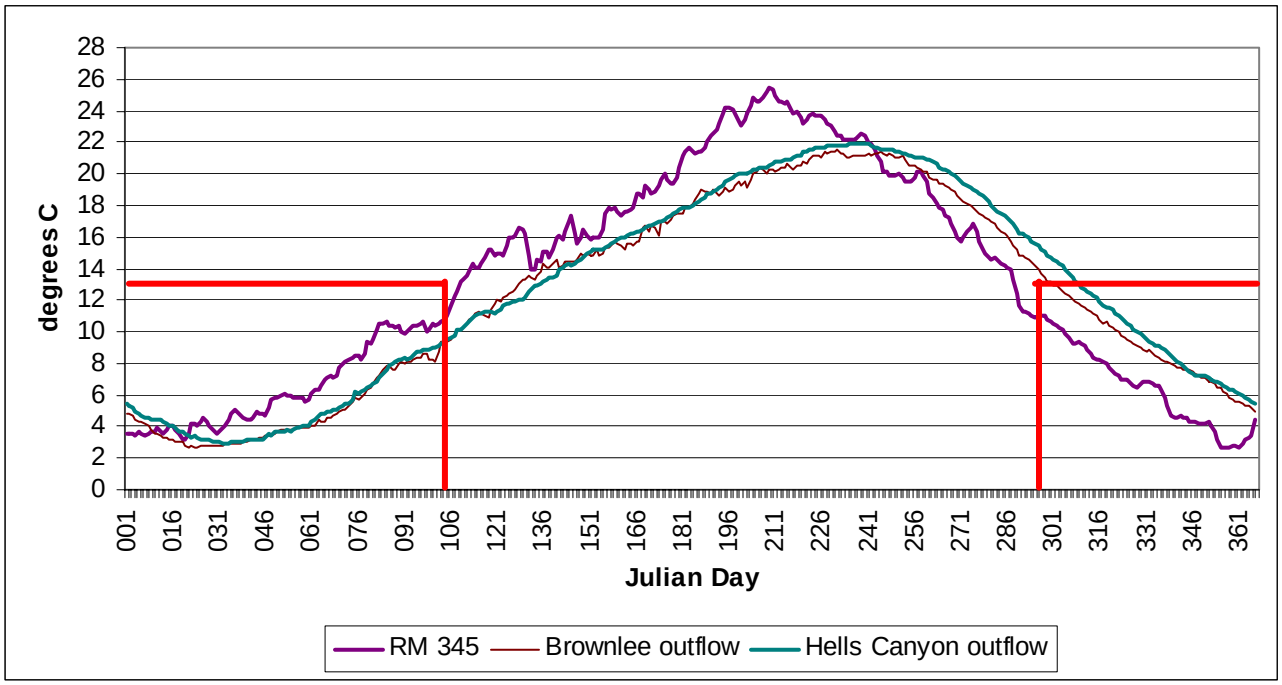


Figure 3.6.4 a. Post-construction daily mean water temperature data for the Snake River above and below the Hells Canyon Complex dams. (Salmonid spawning periods (boxes) for the Snake River below Hells Canyon Dam are displayed specific to fall chinook in this reach.)

The data displayed in Figure 3.6.2 h and Figure 3.6.4 a indicate several points. First, the effect of the Hells Canyon Complex of dams on water temperatures is one of cooling during much of the year, particularly through the time of peak summer temperatures. Secondly, an effect of the Hells Canyon Complex reservoirs has been to delay cooling of stored water in the fall relative to upstream water temperatures. Warm summer temperatures in water inflowing to Brownlee Reservoir, coupled with the storage capacity of the impoundment are factors in the timing and magnitude of this delayed cooling effect downstream of Hells Canyon Dam.

Finally, both the summer cooling and the delayed fall cooling effect appears largely attributable to Brownlee Reservoir as indicated by the narrow difference between the average outflow water temperature from Brownlee Dam as compared to the average outflow water temperature of Hells Canyon Dam (Figure 3.6.4 a). Brownlee Dam (RM 285) is the farthest upstream of the Hells Canyon Complex dams. It backs up the only significant storage reservoir of the three. By comparing water temperatures measured at RM 345 to those below Hells Canyon Dam at RM 247, the effect of the Hells Canyon Complex, primarily Brownlee Reservoir, on downstream Snake River water temperatures can be observed.

3.6.5.9 SITE POTENTIAL ASSESSMENT

To more accurately assess the influence of the Hells Canyon Complex on water temperatures in the Downstream Snake River segment (RM 247 to 188) of the SR-HC TMDL reach, an approach using thermal "site potential" has been employed. For the purposes of this TMDL, site potential is defined as the temperature that is predicted to have occurred without the influence of the Hells Canyon Complex dams and other direct sources of heat to the mainstem itself, but with the current altered hydrological regime, climate, and tributary inputs. Use of site potential relates to provisions in the water quality standards of the states of Idaho and Oregon, which allow for natural conditions when such conditions result in water temperatures, which exceed numeric criteria. These water quality standards further prescribe a small allowable increase in water temperatures when natural conditions, ergo "site potential", are above numeric criteria or target thresholds.

For the purpose of modeling mainstem Snake River site potential, tributary inflows were modeled at their current (recent) condition irrespective of their specific temperatures in relation to water quality criteria. The assumptions made in relation to modeled temperature influences for the mainstem Snake River should be applied only as appropriate within this assessment. Caution must be used when interpreting and applying the results of this temperature model analysis more broadly to other systems, particularly the tributaries. While the major heat contributions to large rivers may be predominantly due to natural atmospheric inputs, this is not likely to be the case for smaller streams and rivers, including most of the tributaries to this TMDL reach. As such, it is expected that a more comprehensive evaluation of temperature loading to tributary systems will be conducted when TMDLs for the tributaries are prepared. The assumptions made in this TMDL should not be applied to the tributary-specific TMDLs. It is likely that a more detailed analysis of the tributaries will indicate that temperature reductions are needed in the tributaries and upstream of this TMDL segment in order to fully attain water quality standards.

Since modeling to date has determined that water temperatures in the mainstem would still exceed criteria under site potential, the goal of the TMDL is to not exceed the small incremental increase in water temperature allowed by applicable water quality rules in such circumstances. Mathematical notation for this change in water temperature is delta T (ΔT). This TMDL seeks to limit the incremental effect of heat loads to that which does not cause violation of the temperature target (Oregon's 0.14 °C allowable increase, the most limiting criterion). Water temperatures measured at RM 345 were used as site potential for the downstream temperature assessment. It should be noted that while water temperatures at RM 345 should not be interpreted as "natural conditions", this approach acts to remove the effect of the Hells Canyon Complex on estimation of site potential further downstream.

Data available (1996 to 2001) show that mainstem water temperatures at RM 345 (Figure 3.6.4 b) exceed criteria at times under the site potential scenario, though for a shorter period of time than observed at the outflow of Hells Canyon Dam (Figure 3.6.4 a).

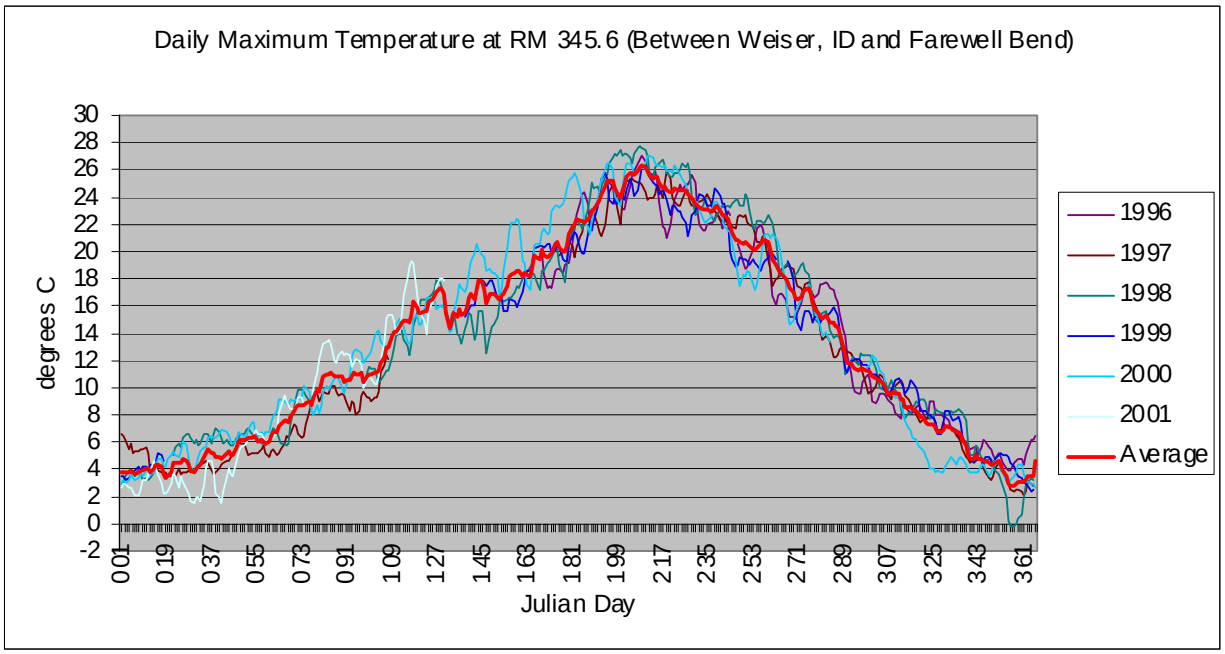


Figure 3.6.4 b. Daily maximum water temperature data for the Snake River at RM 345, 10 miles upstream from the headwaters of Brownlee Reservoir.

If existing water temperatures at RM 345 are in fact a high estimate of natural conditions this would cause a slightly higher estimate of site potential downstream, and would in turn result in a conservative estimate of load reductions needed below Hells Canyon Dam to limit the change in temperature.

3.6.6 Determination of Temperature Loading

As discussed previously, there are a variety of sources that influence water temperature in the SR-HC TMDL reach. These sources may act to increase or decrease water temperature within the mainstem Snake River. They include inflowing tributaries and drains, ground water and industrial discharges. In addition to these sources, it is well recognized that in hot arid climates such as that in which the SR-HC TMDL reach is located, natural atmospheric heat sources will also have a noticeable influence on water temperatures.

Tributaries, drains and industrial discharges can act as heating, neutral or cooling influences on the mainstem depending on their temperature relative to that of the Snake River. The influence of these inflowing waters can be measured in-river if the resulting difference is of sufficient magnitude, or can be calculated using known temperature and flow volume/dilution relationships.

Ground water inflows can also be heating, neutral or cooling influences on the mainstem depending on their temperature relative to the Snake River. Geothermal waters would generally be heating influences. Ground water from aquifer or irrigation sources is generally a cooling or a neutral source during the summer months.

3.6.6.1 TEMPERATURE INPUT CALCULATION MECHANISMS.

An assessment of temperature sources to the SR-HC TMDL reach has been incorporated as part of this TMDL process. Industrial discharge influences were evaluated through direct discharge volume measurements, available discharge temperature data and estimation based on best professional judgement where data were not available.

Temperature influences from tributary, drain, ground water and natural atmospheric sources were also evaluated. Due to the variability and interconnected nature of surface and ground water systems, a calculational model was used to evaluate the influences of these inflows on water temperature in the mainstem Snake River. A spreadsheet water temperature model reported by Sharpe (1980) was used to calculate the change in water temperature in the mainstem Snake River due to tributary, drain and ground water inflows. The magnitude of the temperature influence exerted on the mainstem by tributary, drain and ground water inflows was calculated directly using the model. Model output was then compared to the measured temperature change within the system. The magnitude of natural atmospheric temperature influences and non-quantifiable influences was determined by difference. The difference between the instream temperatures produced by modeled inflow values and the measured water temperature was assumed to be the combination of the net natural atmospheric heat input and these non-quantifiable influences (these influences are discussed in more detail in Section 3.6.8.3).

Consecutive, daily water temperature and flow data were critical to this modeling effort. Consecutive daily maximum average water temperature and flow data were available for the major tributaries in the Upstream Snake River segment (RM 409 to 335) for summer months in 1999 or summer months in 2000. Few tributaries had data for both years (See Table 3.6.1). The data set included water temperature and flow measurements for all tributary and mainstem sites. Where data was available, data was compiled for the same day and year. In cases where data was unavailable, correlations between overlapping data sets were derived using direct linear interpolation and applied to the appropriate day and year for the compiled data set. Because they represent the most complete data set available, and the most current conditions, 1999 and 2000 data were selected for use in this exercise.

Within these two years of collected data, the most complete set for the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach contained data from June, July and August. June data, while relatively complete, required some estimation of temperature values based on linear interpolation from 1996 and therefore was not as robust as data available for July and August, which did not require as much estimation. However, July and August represent the months in which the greatest and most consistent elevation of water temperature is observed to occur. These two months therefore represent the basis of this analysis. June generally shows temperature exceedences occurring consistently at the latter end of the month, and September data generally shows the majority of temperature exceedences occurring at the beginning of the month. In those instances where flow data was unavailable (the Malheur and Owyhee Rivers and drains) calculated data from USBR was utilized (USBR, 2001) and from previous monitoring efforts (IPCo, 2000c; US EPA 1974 to 1995).

Consecutive, daily water temperature and flow information was not available for the Burnt or Powder rivers. The understanding of temperature influences to the Upstream Snake River

segment (RM 409 to 335) was therefore applied with accommodation for increases in total surface area to the extent possible.

Precipitation levels from 1999 and 2000 are reasonably close to average conditions. The 1999 and 2000 data therefore represent median conditions for the SR-HC TMDL system, thus characterization of these conditions for relative temperature influences would be expected to apply the majority of the time. In-river, low flow years would be expected to exhibit higher levels of natural atmospheric-induced heating due to lower flow volume and decreased water depth in the mainstem, while high water years would be expected to show less natural atmospheric-induced heating due to greater flow volume and water depth.

Temperature loads from agricultural drains discharging to the SR-HC TMDL reach were determined using available temperature data. Neither water temperature nor flow data were plentiful; however, data were collected between 1975 and 1980, most as part of US EPA studies (US EPA STORET data, 1998). Temperature data for monitored drains were available for June, July and August of 1975 and August of 1977. Collected data show water temperatures that average 19.5 ^{o}C in June, 21.4 ^{o}C in July, 22.8 ^{o}C in August, and 17.6 ^{o}C in September. The data were not collected on a consistent time schedule, and do not necessarily represent maximum daily averages. These data are instantaneous measurements only; therefore, average water temperatures were used as the best estimate of overall drain temperatures. The available temperature data set did not include consistent flow data.

For the purposes of this exercise, available flow information was utilized. In some cases, flows were estimated using general flow descriptions supplied by the US EPA study (1974 and 1975), in other cases, return flow information by drainage area supplied by the USBR (USBR, 2001) was utilized. Care was taken to preserve the highest possible level of accuracy in these calculations, however, due to the level of uncertainty associated with water temperature and flow determinations for the agricultural drains, these values should be viewed as best estimates only. If drain-specific data become available during the implementation of this TMDL they should be used in place of these estimates.

Only limited data are available on ground water inflows to the Snake River. However, a substantial amount of information is available on the temperature of ground water in the Snake River Basin. These data were utilized to estimate average ground water temperatures in the SR-HC TMDL reach (USGS, 1999; IDEQ, 2000c; IDWR, 2000). Data available from ground water (well) records in the SR-HC TMDL watershed were evaluated. Wells less than 75 feet deep were selected as being most representative of ground water inflows to the Snake River in the SR-HC TMDL reach. Of the well records available in this area, 780 were 75 feet deep or less. The majority of the wells identified for this evaluation were located on the Idaho side of the river. Many well records were available for the Oregon side of the river but the majority of these was over 75 feet in depth and thus did not meet the depth requirement for this assessment. Temperature values obtained for the selected wells ranged from 8 ^{o}C to 21.5 ^{o}C but most (85%) were well correlated with a fairly narrow temperature range (13 ^{o}C to 16 ^{o}C). The mean ground water temperature was calculated to be 14.7 ^{o}C (median = 14.5 ^{o}C). In order to estimate ground water temperatures conservatively, a 95th percentile temperature value of 17.5 ^{o}C was used in

place of the mean ground water temperature value of 14.7 ^{o}C. A complete set of all well data utilized is available in Appendix E.

The temperature model was applied using the available daily water temperature and flow volumes from all measured tributaries and drains. Ground water influences were calculated using the 17.5 ^{o}C temperature identified and the flow multiplied by the linear distance between gauges for the purposes of this calculational model.

Flow within the SR-HC TMDL reach was quantified using gauged measurements where possible and calculated flows where gauged measurements were not available. This was most critical for the Owyhee and Malheur rivers where gauged flows near the mouth were not always available. Flows for these systems were calculated using gauge data from upstream locations and calculating downstream increases based on estimated diversion and return flows within the system.

Ungauged gain/loss measurements within the reach were calculated from flow data evaluated over the time periods to which the modeling effort was applied. The overall reach "gain/loss" measurements identified using the water balance calculated for the loading analysis process were compared to those calculated by the USBR (USBR, 2001). The USBR quantified 1991 and 1992 (relatively low water years) and 1997 and 1998 (relatively high water years).

Daily water temperature and flow data used were collected from 1999 and 2000 (reasonably average water years). While there is no direct overlap between these data sets, the reach gain/loss values calculated for 1999 and 2000 are an approximate average of the low and high water year values, which is logical. For the purposes of this modeling effort, the ungaged flow difference was assumed to be related to a mixture of ungaged ground and surface water input, and was assumed to enter the river evenly on a per mile basis between the two gauges.

The maximum ungaged gains in flow from 1999 and 2000 were selected as conservative overall estimates of ungaged flows. These values were then evaluated as if the entire volume were from ground water inflows (representing a maximum cooling influence) and as if the entire volume were from surface water inflows (a maximum heating influence). To allow the determination of a relative range of temperature variation from ground and surface water inflows, ungaged flows were applied evenly over the stretches for which they were measured by dividing the total gained flow by the length of the segment in miles.

Using this modeled approach, the overall influence of surface and ground water inflows was evaluated. A comparison was then made to calculate the difference between the modeled and measured water temperatures. This difference was assumed to be the combination of the net natural atmospheric heat input and these non-quantifiable influences on water temperatures within the SR-HC TMDL reach.

An example calculation of the average mainstem water temperature after mixing is outlined below.

$$Tm = [(Q*T) + (Qi*Ti)] / (Q + Qi)$$

Where:
Q = mainstem river flow, cfs
T = mainstem river temperature, ^{o}C
Qi = tributary flow, cfs
Ti = tributary temperature, ^{o}C
Tm = average mainstem temperature after mixing, ^{o}C

Example day: 30 July, from RM 453.5 to RM 396.7, based on daily maximum average water temperatures. (NOTE: for the sake of simplification, only major inflows were used in this example)

A	Per mile ungaged flow	=	6 cfs
B	Ground water temperature	=	17.5 ^{o}C
C	Snake River flow at RM 409	=	6,880 cfs
D	River temperature at RM 409	=	23.0 ^{o}C
E	Owyhee River flow	=	123 cfs
F	Owyhee River temperature	=	20.9 cfs
G	Boise River flow	=	1100 cfs
H	Boise River temperature	=	23.6 ^{o}C

Temperature after the Boise River is mixed into the Snake River:

(((C*D)+(E*F)+(G*H))+((A*12.3)*B)) / (C+E+G) +(A*12.3))

(Note that the per-mile ground water flow, 6 cfs, is multiplied by 12.3 miles, the total flow is then multiplied by 17.5 ^{o}C.)

- If only tributary and drain inflows are assessed, the mixed (modeled) water temperature in the mainstem = 23.05 ^{o}C
- If tributary and drain inflows are assessed, in combination with ungaged flows assumed to be 100 percent ground water, the mixed (modeled) water temperature in the mainstem = 23.0 ^{o}C
- If tributary and drain inflows are assessed, in combination with ungaged flows assumed to be 100 percent surface water inflows, the mixed (modeled) water temperature in the mainstem = 23.12 ^{o}C

The measured mainstem water temperature at the downstream end of this reach = 25.5 ^{o}C

In this example, if all of the ungaged flow is assigned to ground water inflows, the model shows that the mainstem water temperature is essentially unchanged over this section of the SR-HC TMDL reach. (Inflow temp was measured at 23 ^{o}C, and outflow temperature is calculated to equal 23 ^{o}C.) If all of the ungaged flow is assigned to surface water inflows (using an averaged temperature of 21.5 ^{o}C from measured drain data), the model shows that the mainstem water temperature increases by 0.12 ^{o}C over this section of the SR-HC TMDL reach.

The measured water temperature changed by 2.5 ^{o}C over the same section, increasing from 23 ^{o}C to 25.5 ^{o}C. The calculated temperature influence from tributary and drain inflows accounted for 0.05 ^{o}C of this change. Ungaged ground and/or surface water inflows in this same section accounted for between -0.05 ^{o}C (where all ungaged flow was assumed to be ground water inflow) and 0.07 ^{o}C (where all ungaged flow was assumed to be surface inflow). Assuming an even mixture of ground and ungaged surface water inflows, this temperature change is calculated to be 0.01 ^{o}C. The total modeled temperature change resulting from tributary, drain and ungaged inflows (assuming a 50/50 mixture of ground and surface water) is 0.06 ^{o}C (0.05 ^{o}C + 0.01 ^{o}C = 0.06 ^{o}C). Natural atmospheric and non-quantifiable temperature influences based on an equal mixture of ungaged inflows and the measured tributary and drain inflows are responsible for the remaining warming, equal to 2.44 ^{o}C (2.5 ^{o}C – 0.06 ^{o}C = 2.44 ^{o}C). Tributary, drain and ground water influences accounted for 2.4 percent of the heating that occurred, the combination of natural atmospheric and non-quantifiable influences accounted for 97.6 percent of the warming.

The mechanism for determining the relative contribution of temperature sources outlined in this example was applied to the SR-HC TMDL reach. The following discussion details the assumptions made and results obtained from this analysis.

3.6.6.2 ASSUMPTIONS.

Several assumptions were made in order to allow the calculation of temperature changes in mainstem Snake River water temperatures as a result of inflowing surface and ground water, and natural atmospheric temperature influences. The assumptions made are discussed below.

Temperature Variation.

The calculational model used only daily maximum water temperatures. There is no accommodation for cooling from lower nighttime air temperatures, or for cooling due to weather or heat loss throughout the system as water moves downstream. These factors result in an overestimation of the downstream influence of both mainstem water temperature increases and inflowing sources.

Mixing.

The temperature modeling analysis assumed uniform mixing of both surface and ground water inflows to the mainstem river. This analysis does not attempt to quantify variability of water temperatures laterally or through the depth of the river in the Upstream Snake River and Downstream Snake River segments. Temperature differences at varying depths within the reservoir segments were identified in a semi-quantitative fashion as discussed below. Temperatures within the reservoirs were assumed to be laterally uniform.

Water Temperatures in Tributaries.

Natural atmospheric temperatures are expected to influence water temperatures in tributaries to the Snake River. This influence may occur to a greater or lesser degree than that calculated for the mainstem Snake River depending on water depth, flow volume, and other factors. However, the magnitude of this influence was not directly assessed for the tributaries in this evaluation. All inflow temperatures were assessed as occurring at the point of discharge to the Snake River.

Water Temperatures in Tributaries without Monitoring.

Minor tributary and drain influences were calculated where flow and water temperature data were available. Where flow and water temperature data were not available, these inputs were assumed to be included in the "ungaged" inflow/outflow calculation.

Natural Temperature Loading.

Natural atmospheric temperature sources can be divided into two general categories: (1) Direct solar radiance, where sunlight striking the water results in a transfer of energy from the light waves to heat in the water, and (2) Direct heat conduction from the air itself. This calculational model does not differentiate between these two mechanisms, but rather seeks to identify the total atmospheric input that occurs from both processes simultaneously.

3.6.6.3 POINT SOURCE TEMPERATURES.

Six NPDES permitted discharges are identified in the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL (Table 3.6.3). Two of these point sources are industrial discharges, four are municipal discharges. Only two of the NPDES permits for this segment have identified temperature discharge limits. There are three additional NPDES permitted point sources in the SR-HC TMDL reach; all are related to the operation of the Hells Canyon Complex dams (Brownlee, Oxbow and Hells Canyon). These discharges are composed of cooling water from the turbines in Brownlee, Oxbow and Hells Canyon dams. Discharge mixes directly with the outflow of the dams.

Table 3.6.3. Point source discharge volume and water temperature information for the Snake River - Hells Canyon TMDL reach.

Point Source	Discharge Volume (average)	Permitted Discharge Temperature
City of Nyssa	0.33 MGD	none
Amalgamated Sugar	Seepage ponds	< 32 ^{o}C
City of Fruitland	0.23 MGD	none
Heinz Frozen Foods	2.5 MGD	none
City of Ontario	1.9 MGD*	none
City of Weiser	1.8 MGD	none
Brownlee Dam	10 MGD	Not to exceed 79 ^{o}F
Oxbow Dam	11 MGD (max)	Not to exceed background + 10 ^{o}F
Hells Canyon Dam	9 MGD (max)	Not to exceed background + 10 ^{o}F

* land application during the critical season

Discharge volumes are available for all point source discharges. Temperature data however, is very limited. Where both discharge temperature and volume data were available, this information was used directly in the calculations. Where water temperature data was not available, as in the case of the Upstream Snake River segment (RM 409 to 335) wastewater treatment plant discharges, the maximum water temperature observed in smaller tributaries was applied.

Wastewater treatment plant discharge data available from other drainage basins show that discharge temperatures are commonly lower than those observed in the tributaries. The estimate applied in this modeling effort is therefore most probably and over estimate of the total increase

in temperature contributed by the permitted point sources. This value was retained in the calculation effort as it represents a conservative (worst case scenario) overall.

The point source discharges represent no-measurable-increase in the water temperature of the mainstem Snake River within the SR-HC TMDL reach. (No-measurable-increase is defined by the State of Oregon as 0.25 ^{o}F (0.14 ^{o}C), and by the State of Idaho as 0.3 ^{o}C.) The point source discharges are calculated to contribute less than 0.012 ^{o}F (0.0066 ^{o}C) increase in mainstem water temperature in the Upstream Snake River segment (RM 409 to 335).

3.6.6.4 GROUND WATER.

Ground water influences were addressed in two ways to provide a relative range of effect:

1. In the first scenario, all of the flow unaccounted for in the water balance on a segment-specific basis was assumed to be ground water inflow. This volume was distributed evenly by distance along the length of the segment. This scenario represents the greatest possible ground water influence on a segment, given the data available. Because ground water is generally cooler than the surface water during the months for which natural atmospheric temperature influences were evaluated, this scenario represents the "coolest" conditions as calculated by the temperature model.
2. In the second scenario, none of the flow unaccounted for in the water balance on a segment-specific basis was assumed to be ground water. All ungaged inflow was assumed to be surface water. The temperature assigned to this ungaged flow was calculated as the average temperature of the measured drains in the segment. This scenario represents the least effect ground water may have on the mainstem Snake River water temperature. Because surface water is generally similar in temperature to the mainstem flow, or warmer, this scenario represents the "warmest" conditions as calculated by the temperature model.

This two part scenario provides a relative range for interpretation of the potential variability in calculated values. The actual conditions probably fall somewhere between the extremes represented by these two scenarios. This evaluation also provided information on the relative influence of ground water inflows on water temperatures in the mainstem Snake River. During the summer months of July and August, the greatest ground water influence calculated here is shown to average 0.33 ^{o}C of cooling.

3.6.7 Temperature Loading Analysis

Water temperature data from 1999 to 2000 was selected for use in this calculational modeling effort because it represented the best coverage for the SR-HC TMDL reach overall. The fact that this data also represents a reasonably average water year was very fortunate. Had the best coverage been available on a water year representing extreme conditions, a greater level of estimation and associated level of error would have been necessary to define generally occurring conditions.

The critical months of June, July and August were the focus of this evaluation. June shows the initial increase from spring to summer temperatures, and July and August represent those months where the greatest temperature exceedences occur. September could not be evaluated, as a

complete data set was not available for most of the major tributaries. However, a similar, opposite trend in water temperature as observed in June is assumed to apply (i.e. Water temperature was observed to increase gradually over the first two weeks of June, with the majority of exceedences occurring the last two weeks of the month. A reverse of this trend is assumed to occur in September with the majority of water temperature exceedences occurring the first two weeks of the month, observed to decrease gradually over the last two weeks of the month.)

As in the example above, the level of increase in water temperature was evaluated based on tributary and drain inflows. Ungaged flow was assessed in two ways: assuming that all of the flow was the result of ground water inflows, and (2) assuming that all of the flow was the result of surface water inflows. Both of these scenarios were assessed separately and a separate equal mixture was also evaluated. The calculated output from the water temperature model is shown in Table 3.6.4.

Table 3.6.4. Calculated model output for temperature influences in the Upstream Snake River segment (RM 409 to 335) of the Snake River - Hells Canyon TMDL reach. (GW = ground water, SW = surface water)

JUNE	100% GW Temp change	100% GW Percent change	100% SW Temp change	100% SW Percent change	50/50 mix Temp change	50/50 mix Percent change	Range (+/-)
Modeled Tributary Influence	0.297 ^{o}C	7.1%	0.297 ^{o}C	7.1%	0.297 ^{o}C	7.1%	
Modeled Drain Influence	0.022 ^{o}C	0.5%	0.022 ^{o}C	0.5%	0.022 ^{o}C	0.5%	
Modeled Ungaged Flow Influence	-0.143 ^{o}C	-3.4%	0.034 ^{o}C	0.8%	-0.055 ^{o}C	-1.3%	0.177 ^{o}C
Modeled Point Source Influence	0.007 ^{o}C	0.2%	0.007 ^{o}C	0.2%	0.007 ^{o}C	0.2%	
Total Modeled Temperature Change	0.183 ^{o}C	4.4%	0.360 ^{o}C	8.6%	0.271 ^{o}C	6.5%	0.177 ^{o}C
Total Measured Temperature Change	4.2 ^{o}C		4.2 ^{o}C		4.2 ^{o}C		
Natural Atmospheric and Non-Quantifiable Influence	4.02 ^{o}C	95.7%	3.84 ^{o}C	91.4%	3.93 ^{o}C	93.6%	0.177 ^{o}C

JULY	100% GW Temp change	100% GW percent change	100% SW Temp change	100% SW percent change	50/50 mix Temp change	50/50 mix percent change	Range (+/-)
Modeled Tributary Influence	0.785 °C	15.1%	0.785 °C	15.1%	0.785 °C	15.1%	
Modeled Drain Influence	-0.030 °C	-0.6%	-0.030 °C	-0.6%	-0.030 °C	-0.6%	
Modeled Ungaged Flow Influence	-0.500 °C	-9.6%	-0.031 °C	-0.6%	-0.266 °C	-5.1%	0.469 °C
Modeled Point Source Influence	0.006 °C	0.1%	0.006 °C	0.1%	0.006 °C	0.1%	
Total Modeled Temperature Change	0.261 °C	5.0%	0.730 °C	14.0%	0.495 °C	9.5%	0.469 °C
Total Measured Temperature Change	5.2 °C		5.2 °C		5.2 °C		
Natural Atmospheric and Non-Quantifiable Influence	4.9 °C	95.0%	4.47 °C	86.0%	4.71 °C	90.5%	0.469 °C

AUGUST	100% GW Temp change	100% GW percent change	100% SW Temp change	100% SW percent change	50/50 mix Temp change	50/50 mix percent change	Range (+/-)
Modeled Tributary Influence	0.449 °C	12.8%	0.449 °C	12.8%	0.449 °C	12.8%	
Modeled Drain Influence	0.004 °C	0.1%	0.004 °C	0.1%	0.004 °C	0.1%	
Modeled Ungaged Flow Influence	-0.350 °C	-10%	0.004 °C	0.1%	-0.173 °C	-4.9%	0.354 °C
Modeled Point Source Influence	0.007 °C	0.2%	0.007 °C	0.2%	0.007 °C	0.2%	
Total Modeled Temperature Change	0.110 °C	3.1%	0.464 °C	13.3%	0.287 °C	8.2%	0.354 °C
Total Measured Temperature Change	3.5 °C		3.5 °C		3.5 °C		

AUGUST	100% GW Temp change	100% GW percent change	100% SW Temp change	100% SW percent change	50/50 mix Temp change	50/50 mix percent change	Range (+/-)
Natural Atmospheric and Non-Quantifiable Influence	3.39 °C	96.9%	3.04 °C	86.9%	3.21 °C	91.7%	0.354 °C

3.6.8 Loading Analysis Results

The relative change in mainstem water temperature in the Upstream Snake River segment (RM 409 to 335) from modeled tributary, drain and point source influence is shown for June, July and August (Table 3.6.4).

Modeled total tributary temperature influences range from 0.297 °C to 0.785 °C. The calculated temperature influences are higher in July, when the highest air and water temperatures are observed, and lowest in June when water and air temperatures start out relatively cool and then increase sharply as summer progresses. Calculated temperature influences in August are midway between those for June and July, and represent the slower cooling trend observed in the fall. Total tributary temperature influences account for an average of 12 percent of the temperature change in the mainstem river. July shows the highest relative percent contribution with 15.1 percent (monthly average).

Modeled temperature influences from the drains are also greatest in the month of July, where they represent 0.6 percent of the total temperature change modeled. During both June and August, the drains show a small positive temperature influence on mainstem temperatures (0.022 °C and 0.004 °C respectively), while in July they exert a cooling influence (-0.030 °C). This may be an outcome of shading from maturing plant growth in irrigated areas or an artifact of using averaged drain data in the calculation, as daily maximum water temperature data is unavailable. Averaged data do not allow differences in water temperature due to variations in sampling time and weather to be accounted for. Therefore, drain data taken in early morning hours may show cooler water temperatures due to the fact that most drains are fairly small and shallow and would respond to atmospheric temperature changes more rapidly than the mainstem Snake or major tributaries. However, both heating and cooling influences calculated for the drains are small compared to the overall temperature changes measured and should not be a dominant factor in determining the relative heat source balance.

Modeled point source temperature influences on the mainstem are very small, and relatively constant, ranging from 0.006 °C to 0.007 °C. The overall relative temperature change calculated for point sources averaged 0.17 percent. As stated previously, this is an overestimation of the total point source temperature influence, and is applied as a conservative value.

The relative change in mainstem water temperature calculated for the ungaged flows is shown for the two scenarios outlined, influence assuming that the total ungaged flow is ground water (maximum cooling effect) and the influence assuming that the total ungaged flow is surface water (maximum warming effect). In the first scenario, where all ungaged flow is assumed to be

ground water, the ungaged inflows consistently represented a cooling influence during the critical time period. These flows resulted in the greatest cooling influence occurring in July (-0.500 ^{o}C overall) when the relative difference between ground and surface water temperatures is the greatest and would have the most effect. The smallest calculated cooling influence occurred in June (-0.143 ^{o}C) when the relative difference between ground and surface water temperatures is the least and the temperature change from ground water would be minimized by cooler instream water temperatures before mixing. August showed a value midway between those for June and July (-0.350 ^{o}C), and again represents the slower cooling trend of surface waters observed in the fall. The relative temperature change calculated for this scenario ranged from 3.4 percent to 10 percent and was consistently a cooling influence on mainstem water temperatures.

The second scenario showed a somewhat different outcome, as would be expected. In this scenario the total ungaged flow is assumed to be surface water. The temperature of the ungaged flow was assigned to be that of the measured drains. Little precipitation falls in the SR-HC TMDL reach during June, July and August. It was assumed that if the ungaged flow were associated with surface runoff, the majority of this flow would be from unmeasured agricultural and storm drains. Therefore, a similar temperature range should apply. In this evaluation, the ungaged inflows mimicked the temperature influence from the drains, exerting a relatively modest warming influence on the mainstem water temperature during June and August (0.034 ^{o}C and 0.004 ^{o}C respectively), and a relatively modest cooling influence in July (-0.031 ^{o}C). The relative temperature change calculated for this scenario ranged from 0.1 percent (warming) to 0.6 percent (cooling).

The overall range in the two scenarios was calculated to be 0.177 ^{o}C in June, 0.469 ^{o}C in July and 0.354 ^{o}C in August. While this exercise is helpful in determining a relative operating range for further interpretation, neither of the two scenarios modeled have a high probability of occurring within the SR-HC TMDL reach. A more realistic estimate of actual temperature influences from ungaged flows is a combination of ground and surface water inflows. As the range for possible conditions is well defined by the above discussion, an equal distribution of ground and surface water inflows was used to characterize the ungaged flow.

An equal (50:50) distribution was selected for further modeling based on the return flow calculations of the USBR and best current understanding of the SR-HC TMDL reach during summer months. This modeled scenario resulted in calculated values halfway between the two scenarios modeled previously. Cooling influences were consistently projected for this scenario, but were smaller in magnitude than those projected for the total ground water modeling. The temperature influence from the ungaged flow exerted a relatively modest cooling influence on the mainstem water temperature during June and August (-0.055 ^{o}C and -0.173 ^{o}C respectively), and a moderately higher cooling influence in July (-0.266 ^{o}C). The relative temperature change calculated for this scenario ranged from 1.3 percent to 5.1 percent (cooling).

Using the equal distribution scenario, the sum of all modeled temperature influences in the Upstream Snake River segment (RM 409 to 335) equaled 0.271 ^{o}C in June, 0.495 ^{o}C in July and 0.287 ^{o}C in August. The vast majority of the modeled differences are from the tributary influences. The measured difference in water temperature equaled 4.2 ^{o}C in June, 5.2 ^{o}C in July

and 3.5 ^{o}C in August. The modeled values represent less than 10 percent of the measured change in water temperature within the Upstream Snake River segment (6.5%, 9.5% and 8.2% respectively). July showed the highest relative temperature influence from modeled inflows.

The calculated combination of the net natural atmospheric heat input and these non-quantifiable influences on the Upstream Snake River segment equals 93.6 percent of the total increase in June, 90.5 percent of the total temperature increase in July, and 91.8 percent of the total temperature increase in August. These calculations indicate that the dominant source of temperature increase in the mainstem Snake River is attributable to natural atmospheric inputs and non-quantifiable influences (discussed in detail in Section 3.6.8.3).

3.6.8.1 Determination of Tributary-Based Anthropogenic Temperature Loading

As stated previously, tributary inflows were modeled using water temperatures measured at the inflow to the Snake River. No tributary-specific modeling was undertaken to distinguish the relative influence of natural atmospheric inputs and non-quantifiable influences to these systems. However, tributary systems flowing into the mainstem Snake River in the SR-HC TMDL reach encounter the same hot, arid climate as they leave higher elevations and make their way across the valley floor to their inflow to the Snake River.

Flow volume and channel depth are smaller for all tributaries flowing into the Snake River, than those existing within the mainstem Snake River, therefore, natural atmospheric conditions have the probability to exert a larger influence on these systems than on the mainstem Snake River. Given these circumstances, and the modeled information on natural atmospheric influences and non-quantifiable influences on the mainstem Snake River, a general differentiation of these sources and quantifiable anthropogenic temperature sources for tributary inflows was undertaken.

In estimating the magnitude of natural atmospheric and non-quantifiable temperature influences to the inflowing tributary systems, the overall relative temperature influence determined for the mainstem Snake River was applied. As outlined previously, given the lower flow volumes and shallower depths of the inflowing tributaries as compared to the mainstem Snake River, the relative natural atmospheric influence on the tributaries would generally be greater than that determined for the mainstem river. For the purposes of this calculation, the relative influence of drains and point sources was assumed to be entirely (100%) anthropogenic. The calculated influence of ungaged flows was acknowledged to be a cooling influence on the system, but was not included in the calculations due to the level uncertainty involved. The relative percent natural atmospheric and non-quantifiable influence from the Snake River mainstem was only applied to the tributary inflows. Therefore, this application of Snake River values represents a conservative estimate of the natural atmospheric and non-quantifiable influences within the SR-HC TMDL reach. Table 3.6.5 shows the calculated changes in tributary temperature influences relative to anthropogenic loading.

The total anthropogenic temperature load to the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach as calculated by this method equals 0.048 ^{o}C in June (1.1% of the total measured load), 0.026 ^{o}C in July (0.5% of the total measured load) and 0.048 ^{o}C in August

Table 3.6.5 Estimated Relative Temperature Influence of Anthropogenic Sources to the Snake River – Hells Canyon TMDL Reach

	June (model total)	June (calculated anthropogenic influence)	July (model total)	July (calculated anthropogenic influence)	August (model total)	August (calculated anthropogenic influence)	Average Calculated Anthropogenic Influence
Anthropogenic influences on water temperature in the Upstream Snake River Segment of the Snake River – Hells Canyon TMDL listed in this table were calculated using the relative percent anthropogenic influence calculated for the mainstem Snake River							
Modeled Tributary Influence	0.297 °C	0.019 °C	0.785 °C	0.050 °C	0.449 °C	0.037 °C	0.035 °C
Modeled Drain Influence	0.022 °C	0.022 °C	-0.030 °C	-0.030 °C	0.004 °C	0.004 °C	0.001 °C
Modeled Ungaged Flow Influence*	cooling	cooling	cooling	cooling	cooling	cooling	cooling
Modeled Point Source Influence	0.007 °C	0.007 °C	0.006 °C	0.006 °C	0.007 °C	0.007 °C	0.007 °C
Total Calculated Anthropogenic Influence		0.048 °C		0.026 °C		0.048 °C	0.043 °C
Measured Temperature Change		4.2 °C		5.2 °C		3.5 °C	4.3 °C
Percent of Total Measured Temperature Change from Calculated Anthropogenic Influences		1.1%		0.5%		1.5%	1.0%
Percent of Temperature Increase Calculated as Atmospheric (Background) Influences		98.9%		99.5%		98.5%	99.0%

* These values assume a 50/50 mixture of ground and surface water for ungaged flows.

(1.5% of the total measured load). The average calculated anthropogenic loading is 0.043 ^{o}C (1.0% of the total measured load).

The State of Oregon has defined "no-measurable-increase" as less than 0.25 ^{o}F (0.14 ^{o}C). The State of Idaho has recently approved a definition of "no-measurable-increase" as 0.3 ^{o}C. The US EPA has defined "no-measurable-increase" as 0.3 ^{o}C in association with joint efforts to identify water quality standards for the Colville Tribe. These definitions are not arbitrary units assigned for measurement purposes only, but rather carry an inferred interpretation that changes in water temperature must be at levels greater than this amount to be biologically significant to aquatic life. For the purposes of this TMDL, the State of Oregon definition of 0.14 ^{o}C has been applied as the most conservative definition of no-measurable-increase. This value is less than one half of the amount identified by the US EPA, and that defined by the State of Idaho.

Using the methodology outlined previously, the calculated change in water temperature in the Snake River in the SR-HC TMDL reach due to measurable anthropogenic influences during the critical time period is well below the defined no-measurable-increase value of 0.14 ^{o}C. Even if a 100 percent margin of error was assumed, and the calculated anthropogenic loadings were doubled, they would still fall well below the defined no-measurable-increase limit of 0.14 ^{o}C.

Therefore, the findings of this TMDL effort indicate that natural atmospheric sources and non-quantifiable influences on temperature are the dominant source of elevated water temperatures in the mainstem Snake River. This indicates that, in the case of salmonid rearing/cold water aquatic life targets, site potential is above the 17.8 ^{o}C therefore, the target is no more than 0.14 ^{o}C increase from anthropogenic sources. (Salmonid spawning is discussed in the following sections.)

Stream temperature change is an expression of heat exchange between a stream and its environment. This dynamic exchange process can only be evaluated when the individual components of the heat exchange process are either known or estimated. This information is required to accurately predict the temperature of the river, and its response to the surrounding environment. The accuracy of the prediction correspondingly depends on the accuracy of the data or estimates used in the analysis.

The analysis provided in this TMDL did not include any evaluation of the heat exchange processes within the river system. Instead, it was assumed for the purpose of the analysis, that all heat exchange processes or heat inputs outside of the discretely measured sources are natural or non-quantifiable and the result of "natural atmospheric and non-quantifiable influences." Using this assumption, the TMDL utilized a mixing zone evaluation (model) to predict the relative impacts of pollutant loads from external sources (i.e., tributaries, point source discharge, groundwater and other ungaged flows).

It should be recognized however, because of the underlying assumptions used, that the level of analysis to evaluate the magnitude of natural atmospheric or non-quantifiable influences within this TMDL is rough. Moreover, while the assumption that all other sources of heat inputs are "natural or non-quantifiable" may be correct, there is only limited information in this TMDL to

support this conclusion. It will be necessary to collect more data and conduct additional analyses to determine the accuracy of this assumption.

Accordingly, caution must be applied when interpreting and applying the results of this temperature model analysis more broadly to other systems, particularly the tributaries. While the major heat contributions to large rivers may be due to natural atmospheric inputs, this is not likely to be the case for smaller streams and rivers, including most of the tributaries to this TMDL reach. As such, it is expected that a more comprehensive evaluation of the temperature loading to tributary systems will be conducted when TMDLs for the tributaries are prepared. The assumptions made in this TMDL should not be applied to those TMDLs. Furthermore, it should be clearly understood that the assessment in this TMDL only evaluates the impact of current tributary temperatures on the Snake River and makes no attempt to analyze compliance with water quality standards in the tributaries themselves.

Site potential as used in this analysis is based upon a cursory or general review of the watershed. A more intense review might determine that, in some areas, riparian conditions are at less than site potential due to anthropogenic causes. It is likely that a more detailed analysis of the tributaries will indicate that temperature reductions are needed in the tributaries and upstream of this TMDL segment in order to fully attain water quality standards. The information developed and the conclusions reached in the tributary and upstream processes will be reviewed and incorporated, as appropriate, into future revisions to this mainstem TMDL.

Thus, for the purposes of clarity, the temperature loading assessment in this TMDL only analyzed the impact of current tributary temperatures on the Snake River and made no direct attempt to collect data and assess quantitatively whether or not the tributaries are currently complying with State water quality standards.

In interpreting and applying the outcome of this temperature assessment, it is critical to bear in mind the assumptions utilized in developing this TMDL. For instance, the TMDL does not attempt to address temperature modifications due to upstream mainstem and tributary sources, impoundments, water withdrawals, channel straightening and diking and removal of streamside vegetation. While these limitations are qualitatively outlined in Section 3.6.8.3, they are not reflected in the quantification to establish the loading capacity and loading allocations in the TMDL. It is important to remember that these alterations can lead to increases in water temperature (at least locally) and thus the TMDL addresses existing site potential conditions as opposed to natural conditions. As such, in addressing water quality management in the Snake River basin, these other factors should be considered.

3.6.8.2 HELLS CANYON COMPLEX AND DOWNSTREAM TEMPERATURE LOADING.

There are few anthropogenic temperature sources in the Hells Canyon Complex. As stated previously, the impoundments do not function as heat sources. Rather, the temperature issue related to the dams is the result of the impoundment and how the water is stored and processed. In addition to the small permitted point source discharges associated with the operation of the dams, the Burnt and Powder rivers represent the source of the majority of anthropogenic inputs to the system as a whole.

Within Brownlee Reservoir, there are no permitted point sources discharges. Agricultural land use around the reservoir is very limited and no major drain flows have been identified. Therefore, the Burnt and Powder rivers represent the most likely source of non-atmospheric temperature influences to the reservoir segment. Data are not available to evaluate the water temperature influences from the Burnt and Powder Rivers, however, an evaluation of the Upstream Snake River segment (RM 409 to 335), where the majority of the instream flow was from tributaries, showed that water temperature influences from anthropogenic sources were below the defined no-measurable-increase level of 0.14 ^{o}C. It is unlikely therefore, that the Burnt and Powder rivers, which collectively equal less than 4 percent of the total inflow to Brownlee Reservoir, would exert sufficient warming to create a measurable water temperature increase. Other tributaries to Brownlee Reservoir, such as Brownlee Creek, contain minimal anthropogenic sources and are therefore not estimated to increase water temperatures measurably. They are, in fact, known to be a source of cooling inflows to the reservoir.

While surface water temperatures exceed the 17.8 ^{o}C target in Brownlee Reservoir during the critical time period, the lower layers of the reservoir are cooled well below the surface temperatures (See Figures 3.6.2 b and 3.6.4 a). The overall effect for Brownlee Reservoir is that of cooling to the downstream segments. As they are acting in a similar manner and flowing directly from one into another, the reservoir segments as a whole can be assumed to act as cooling influences on the water column. Figure 3.6.4 a shows discharge temperatures from Hells Canyon Dam. When compared to mainstem water temperatures at RM 345, a marked cooling effect can be observed over the critical time period. Given the available data, water exiting Hells Canyon Dam is cooler than that entering the SR-HC TMDL reach near Murphy during the critical time period (June through September).

One permitted point source (cooling water for the turbines at Brownlee Dam) discharges to Oxbow Reservoir. This discharge has been evaluated using the maximum discharge temperature and the maximum flow value recorded in the discharge monitoring reports for this facility. It is likely that this is an overestimate of the actual temperature influence of this facility. Using the calculational model discussed previously with averaged maximum daily water temperatures (data were not available for all days of the month), and calculated average monthly discharge values for Brownlee Dam, the total influence on water temperature within Oxbow Reservoir was calculated to be 0.0175 ^{o}C in June, 0.0102 ^{o}C in July and 0.0105 ^{o}C in August. These calculated values represent the maximum allowable temperature of permitted discharge to the reservoir, but do not necessarily represent the maximum temperature influence due to lack of consistent outflow temperature data. However, they act to give a relative magnitude of temperature influence that is obviously well below the defined measurable increase level of 0.25 ^{o}F (0.14 ^{o}C).

One permitted point source (cooling water for the turbines at Oxbow Dam) discharges to Hells Canyon Reservoir. This discharge has been calculated in the same manner as outlined for Oxbow Reservoir above and is also likely to be an overestimate of the actual temperature influence of this facility. Using the calculational model discussed previously with averaged maximum daily water temperatures (data were not available for all days of the month), and calculated average monthly discharge values for Oxbow Dam, the total influence on water temperature within Hells Canyon Reservoir was calculated to be 0.0066 ^{o}C in June, 0.0058 ^{o}C in July and 0.0096 ^{o}C in August. As in Oxbow Reservoir, these calculated values represent the

maximum allowable temperature of permitted discharge to the reservoir, but do not necessarily represent the maximum temperature influence. However, they provide a relative magnitude of temperature influence that is obviously well below the defined measurable increase level of 0.25 ^{o}F (0.14 ^{o}C).

The Hells Canyon Complex reservoirs act to cool water within the SR-HC TMDL reach. Direct temperature loading and designated beneficial support needs for the reservoir system are discussed in the following sections.

There is one permitted point source that discharges to the Downstream Snake River segment (RM 247 to 188). It is the cooling water for the turbines at Hells Canyon Dam. This discharge has been calculated as outlined previously and the total influence on water temperature within the Downstream Snake River segment was calculated to be 0.0044 ^{o}C in June, 0.0040 ^{o}C in July and 0.0066 ^{o}C in August. As in Oxbow Reservoir, these calculated values represent the maximum allowable temperature of permitted discharge to the reservoir, but do not necessarily represent the maximum temperature influence. However, they provide a relative magnitude of temperature influence that is obviously well below the defined measurable increase level of 0.25 ^{o}F (0.14 ^{o}C).

Given an average flow contribution and average daily maximum water temperatures from 1995, the inflow from the Imnaha River was calculated to influence the water temperature in the mainstem Snake River by a maximum of -0.12 ^{o}C during July, -0.05 ^{o}C during August and -0.06 ^{o}C during September. All calculations showed a cooling effect on the mainstem Snake River.

In the absence of water column data to generate a quantitative assessment of relative temperature loading to the reservoir segments, the data available show that the reservoirs act to cool the overall water volume released to temperatures below those measured in the mainstem Snake River near Weiser, and that the permitted point source influences are below the defined measurable increase level of 0.25 ^{o}F (0.14 ^{o}C).

Water temperature data collected from 1991 through 2001 show that the presence of the Hells Canyon Complex causes a shift in temperatures from those that would occur were the Hells Canyon Complex not in place. While peak summer temperatures are several degrees cooler due to withdrawals from below the reservoir surface, the decline in temperatures in the fall is delayed from that observed immediately upstream of the Hells Canyon Complex. This temperature delay is commonly observed to begin in early September. While the temporal distribution of this temperature shift is due to the delay in flow caused by water moving through the Hells Canyon Complex, the actual heat load (warmer water) is not. The impoundments are not a heat source. Sources of elevated water temperature include natural, unquantifiable and anthropogenic sources upstream of the Hells Canyon Complex and similar sources on inflowing tributaries.

Modeling work completed by IPCo (IPCo, 2002b) has shown that if the water inflowing to Brownlee Reservoir at RM 335 were at or below 17.8 ^{o}C, water leaving the Hells Canyon Complex at Hells Canyon Dam would also be at or below 17.8 ^{o}C, regardless of the temperature shift specific to the Hells Canyon Complex. While the DEQs do not agree that the 17.8 ^{o}C water temperature used in this modeling is an appropriate or attainable condition (as outlined in the

discussion of the calculational model earlier in this document), the modeling does show that the Hells Canyon Complex is not the source of the heat load in the reservoirs and that if upstream conditions were cooler, the water exiting the Hells Canyon Complex would also be cooler. Therefore, it is concluded that the Hells Canyon Complex is not contributing to temperature exceedences specific to the cold water aquatic life/salmonid rearing designated use

However, the IPCo water temperature modeling also shows that even if the inflowing water temperature were less than or equal to 17.8 ^{o}C, the water exiting the Hells Canyon Complex would not meet the salmonid spawning criteria (although by only a small margin) because of the temporal shift created by the Hells Canyon Complex. Data assessment and calculational modeling by the DEQs (as discussed earlier) have identified a similar trend. It is, therefore, concluded that the responsibility for exceeding the salmonid spawning criteria is specific to the presence and operation of the Hells Canyon Complex.

3.6.8.3 Anthropogenic Influences on Temperature not Accounted for in this Analysis

The Pacific Northwest Water Quality Temperature Criteria Guidance Project (US EPA, 2002) identified the four largest sources of increased temperature in the Pacific Northwest to be (1) removal of streamside vegetation, (2) channel straightening or diking, (3) water withdrawals, and (4) dams and impoundments. The fourth item listed, dams and impoundments, has been discussed in the preceding sections. Water temperature data collected from sites within, above and below the Hells Canyon Complex show that the impoundments result in cooler overall maximum water temperatures during the summer months and a slight delay in heating (spring) and cooling (fall) below the Hells Canyon Complex (as discussed in Section 3.6.5.5 and Section 3.6.8.2).

While this analysis makes full use of the data and methodologies appropriate to evaluate temperature influences on the SR-HC TMDL reach, changes in water temperature due to items one through three above are non-quantifiable on a watershed scale. While these influences undoubtedly result in increased water temperatures within the SR-HC TMDL reach, the magnitude of this increase is unknown.

Removal of Streamside Vegetation.

Streamside vegetation on the mainstem and inflowing tributaries acts to reduce heating from solar radiation through shading. This effect is minimal on a site-specific basis, especially in the mainstem Snake River where the channel is very wide compared to the width of the riparian area, however, cumulative effects on smaller tributary systems can result in improved cool water refugia for aquatic species. The removal of this vegetation reduces the potential for shading within the system. While available water temperature data for the SR-HC TMDL are not sufficient to quantify the magnitude of this change, it is projected to result in increased water temperatures on, at minimum, a site-specific scale. Additional, consistent water temperature data would allow the use of more advanced modeling techniques that will aid in the identification of water temperature changes through restoration of streamside vegetation. If identified as an appropriate mechanism for reducing water temperatures, ground surveys to identify areas where streamside vegetation is degraded or non-existent can be undertaken as part of the implementation process. Areas identified as needing treatment could then be re-vegetated and water temperature monitored on a site-specific basis.

Channel Straightening or Diking.

The effects of channel straightening or diking on water temperatures in the SR-HC TMDL reach have not been quantified in this assessment. As with streamside vegetation removal, the influence of this action on water temperatures in both the mainstem and the tributaries can have both site-specific and cumulative effects. The magnitude of this effect is unknown at this time.

Water Withdrawal.

The analysis of relative temperature influences detailed previously does not account for anthropogenic influences due to changes in stream flow from water withdrawal for either the mainstem Snake River or the tributary systems. This analysis does not attempt to quantify the increase in water temperature due to diversion of mainstem Snake River or tributary flow. It is recognized that such diversions lead (during some portions of the growing season) to elevated water temperatures due to removal of instream flow. Water is diverted from the mainstem Snake River and inflowing tributaries as per existing water rights. The resulting reductions in instream flow result in shallower water, more susceptible to atmospheric heating. It is also recognized that such diversions (especially during the summer irrigation season) often act to increase naturally occurring instream flows through late season irrigation recharge and drain flow.

Diversion flows and total river flow (April through October) were calculated for the mainstem Snake River between Murphy and Weiser by the USBR (2001). This information was used to make a comparison of diverted flows and instream flows. Data was available for low (1991) and high (1997) water years. The comparison showed that the total flow (April through October) in the Snake River in 1991 (a low water year) was approximately 2,920,000 acre-feet at Murphy (RM 453.5) and 4,220,000 acre-feet at Weiser (RM 351). The total flow diverted during 1991 was approximately 1,980,000 acre-feet. The diverted flow is equal to 68 percent of the total instream volume at Murphy and 47 percent of the total instream volume at Weiser. The total flow (April through October) in the Snake River in 1997 (a high water year) was approximately 7,150,000 acre-feet at Murphy and 12,060,000 acre-feet at Weiser. The total flow diverted during 1997 was approximately 2,100,000 acre-feet. The diverted flow is equal to 29 percent of the total instream volume at Murphy and 17 percent of the total instream volume at Weiser.

While it is estimated that nearly half of the water diverted from the Snake River in the SR-HC TMDL reach returns to the system, that return is spread out between surface and ground water inflows and the return period is estimated to be close to a year (USBR, 2001). The management and diversion of water within the SR-HC TMDL reach, and upstream of this TMDL reach have a substantial influence on water flow and volume within the SR-HC TMDL reach. In the case of the SR-HC TMDL reach, the volume of water diverted in the dry year (1991) was over one and a half times more than the difference in water volume between 1991 and 1997. (The diverted flow is 1.5 times the difference between a high and a low water year.) This indicates that diverted flows, especially in average or low water years, represent a very substantial portion of the water volume in the river, and thus potentially have a large influence on the water temperature. This effect is not quantified by the temperature evaluation detailed here.

Return flows, in the form of subsurface recharge, are observed to have a cooling effect on surface water temperatures as shown in the previous analysis. A portion of the return flows in the SR-HC TMDL reach is in the form of subsurface recharge and no doubt exerts a cooling

influence on the river. A general evaluation of the potential magnitude of this cooling influence was undertaken as part of the temperature source assessment; however, it provides only a general estimate. These same flows often act to increase late season stream flows over that which would occur naturally without management.

Other Considerations.

Changes in the water table resulting from water management practices have resulted in reduction of riparian or marshy areas along the mainstem Snake River in the SR-HC TMDL reach. Photos showing the Snake River in 1909 (too dark for reproduction) in the archives of the Oregon Historical Society show large marshy areas in the Snake River near the present day site of Ontario, Oregon. The existence of these areas historically in the SR-HC TMDL reach has been discussed repeatedly during the public meetings held as part of the SR-HC TMDL process.

Work currently in progress in the John Day River system has shown that recharge through such marshy areas can result in a substantial cooling influence on water temperatures. Temperature effects resulting from the loss of these types of marshy/riparian areas on the mainstem Snake River and the inflowing tributaries have not been quantified. Data collected from other systems may be generalized to project what the influences on the SR-HC TMDL reach may be, but it is doubtful that SR-HC specific data can be generated to quantify this influence directly.

Additionally, the fact that the Snake River is heavily impounded, together with the return flows from diversions along the SR-HC TMDL reach have resulted in a more stable, static flow pattern within the mainstem. Summer flow volumes in low water years are, without question, greater than those observed before the current level of management was in place.

3.6.8.4 AIR TEMPERATURE.

As stated previously, natural atmospheric temperature sources can be divided into two general categories: (1) Direct solar radiance, where sunlight striking the water results in a transfer of energy from the light waves to heat in the water, and (2) Direct heat conduction from the air itself. As the SR-HC TMDL reach and the mouths of many of the inflowing tributaries are contained in wide, relatively shallow channels where vegetation (current and historic) is sparse, direct solar radiance will result in efficient heat transfer to the system. Additionally, daily high air temperatures over the SR-HC TMDL reach regularly exceed 32 ^{o}C (90 ^{o}F) and often are over 37 ^{o}C (100 ^{o}F). During the majority of the summer months, maximum daily air temperatures routinely exceeded the maximum average daily water temperature in the mainstem river. This condition results in a situation where energy flows from the atmosphere into the river throughout the major portion of the sunlight hours, leading to substantial levels of naturally induced heating.

As natural atmospheric and non-quantifiable influences were shown to be a dominant factor in mainstem and potentially tributary water temperatures, air temperatures were assessed in correlation with water temperature target exceedences. Air temperature data was available for three sites in close proximity to the SR-HC TMDL reach. Data collected at Boise, Idaho, Weiser, Idaho and Brownlee Dam (RM 285) by the Western Regional Climate Center (WRCC) include daily minimum, average, and maximum air conditions. These data were available for 1999 to 2000. Figures 3.6.5 a and b show the average and maximum air temperatures in these locations throughout the summer season.

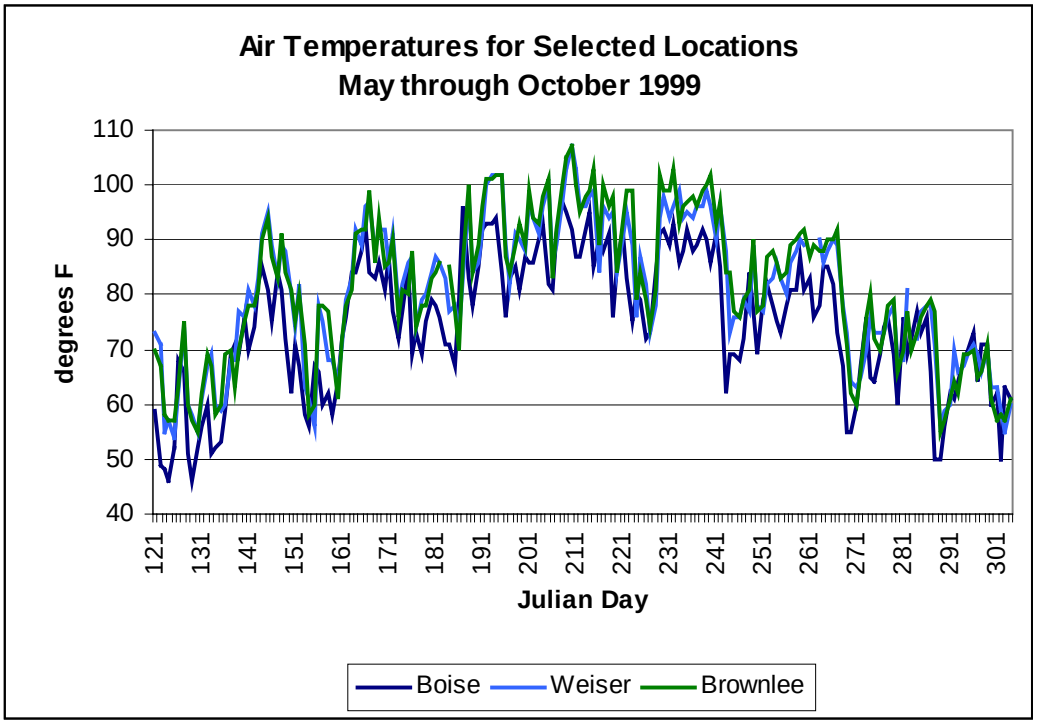


Figure 3.6.5 a. Air temperatures recorded at Boise, Weiser and Brownlee Dam from May through October of 1999.

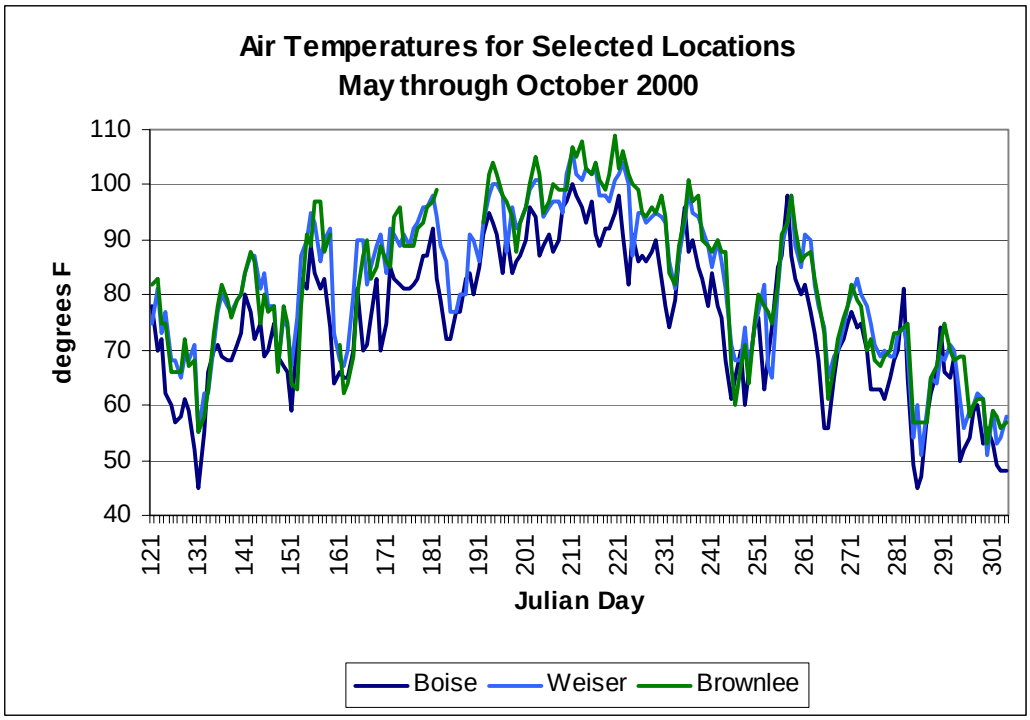


Figure 3.6.5 b. Air temperatures recorded at Boise, Weiser and Brownlee Dam from May through October of 2000.

The pattern of highs and lows in air temperature closely follows that observed in the water temperatures recorded for the same time period.

Air temperatures associated with maximum water temperatures exceeding the salmonid rearing/cold water aquatic life criterion of 17.8 °C are substantially warmer than the air temperatures associated with days on which the maximum water temperatures are less than 17.8 °C. Table 3.6.6 shows the typical daily maximum air temperatures associated with exceedence and non-exceedence water temperatures in the SR-HC TMDL reach.

Air temperature data from the Boise area, when compared with water temperatures in the mainstem Snake River near Murphy, Idaho, RM 453.5 (air temperatures from Murphy were not available), averaged approximately 6.2 °C (11.1 °F) higher on days when maximum water temperatures were greater than 17.8 °C. For air temperatures in the Weiser area this difference was even more pronounced, averaging 12 °C (21.6 °F) higher when water temperatures were greater than 17.8 °C.

Table 3.6.6. Mean daily maximum air temperatures at Boise, Weiser and Brownlee Dam, 1999 to 2000.

Month	Air temperatures when max. water temperatures do not exceed 17.8 °C	Air temperatures when max. water temperatures exceed 17.8 °C
Boise		
June	75.2 °F	84.3 °F
July	None	87.4 °F
August	None	87.2 °F
Mean	**75.2 °F**	**86.3 °F**
Difference	**11.1 °F**	
Weiser		
June	71.0 °F	89.9 °F
July	None	93.4 °F
August	None	94.6 °F
Mean	**71.0 °F**	**92.6 °F**
Difference	**21.6 °F**	
Brownlee Dam		
June	55 °F	64 °F
July	None	92.7 °F
August	None	95 °F
September	None	88 °F
October	65 °F	None
Mean	**60 °F**	**85 °F**
Difference	**25 °F**	

Daily maximum average water temperatures were not available for Brownlee Reservoir. Instantaneous data was used for the purposes of this comparison and showed a similar trend. On days when the available surface water temperature were greater than 17.8 ^{o}C, the corresponding air temperatures were more than 13.9 ^{o}C (25 ^{o}F) higher than those measured on days when water temperatures did not exceed the 17.8 ^{o}C target.

This substantial difference in temperature supports the relatively high level of natural atmospheric and non-quantifiable temperature influence calculated above.

3.6.8.5 TRIBUTARY COOLING EVALUATION.

After analyzing the existing conditions in the SR-HC TMDL reach, the effects of cooling the tributaries to the mainstem Snake River in the SR-HC TMDL reach were examined using the same calculational model described earlier. For this analysis, the water temperatures for all major tributaries to the mainstem Snake River in the SR-HC TMDL reach were gradually reduced to simulate cooling of the inputs to the river. Point sources, agricultural drains and ungaged inflows were kept at the initial values described earlier. The scenario modeling an equal (50:50) distribution of surface and ground water within the ungaged flow was employed in these calculations. This analysis used daily maximum water temperatures for an average water year as they represented the most complete data set available. However, the resulting outputs most likely represent a slight overestimation of the actual cooling necessary, as daily maximum water temperatures do not account for diurnal cooling influences.

The results of this analysis showed that the tributaries would all have to be cooled substantially to ensure that exceedences of the 17.8 ^{o}C seven-day average of daily maximum water temperatures instream in the mainstem Snake River at the Weiser gauge (RM 351) occurred less than 10 percent of the time.

The calculated reductions in daily maximum tributary water temperatures are as follows:

- an average of 7 ^{o}C during the month of June
- an average of 10 ^{o}C during the month of July
- an average of 10 ^{o}C during the month of August

Even when acknowledged to be a slight overestimate of the actual cooling necessary, these results show that the reductions needed in tributary water temperatures are very large, and unlikely to be achievable. The result is not unexpected given that in the initial evaluation performed, natural atmospheric and non-quantifiable temperature influences were identified as the primary factor driving temperature conditions in the mainstem river.

3.6.8.6 CONCLUSIONS.

From the temperature loading assessment discussed above, several conclusions can be drawn:

1. Ground water inflows exert a cooling effect on water temperatures observed within the mainstem Snake River. However, given the assumptions used in this calculation, the magnitude of cooling projected appears to be well within the general error and assumptions associated with this modeling exercise.

2. The overall magnitude of the influence of point sources on mainstem water temperatures within the SR-HC TMDL reach is calculated conservatively at 0.007 ^{o}C. This accounts for less than 0.2 percent of the total temperature load during the critical months of June, July, August and September. (Due to lack of consistent data, September temperature influences were not calculated, but were estimated to occur at a level similar to that observed in June.)

3. The average magnitude of the influence of tributary and drain inflows on mainstem water temperatures within the SR-HC TMDL reach is calculated conservatively at 0.5 ^{o}C. This accounts for approximately 12 percent of the total temperature during the critical months of June, July, August and September. (Due to lack of consistent data, September temperature influences were not calculated, but were estimated to occur at a level similar to that observed in June.). This does not account for natural atmospheric and non-quantifiable temperature influences within tributary systems. If the relative proportion of natural atmospheric and non-quantifiable temperature loading calculated for the mainstem Snake River within the SR-HC TMDL reach is applied to the tributary water temperature influences, the calculated average measurable anthropogenic temperature load to the Upstream Snake River segment (RM 409 to 335) would equal approximately 0.043 ^{o}C.

4. Calculated measurable anthropogenic temperature influences to the mainstem Snake River within the SR-HC TMDL reach are well below the "no-measurable-increase" value defined by the State of Oregon as 0.14 ^{o}C (0.25 ^{o}F).

5. Calculated natural and non-quantifiable temperature influences to the mainstem Snake River within the SR-HC TMDL reach equal over 90 percent of the increase in water temperature for the critical months of June, July, August and September. Natural atmospheric and non-quantifiable inputs are clearly the dominant influence on the water temperature of the river. Air temperature plays an important role in water temperature in the SR-HC TMDL reach.

3.6.9 Temperature and Designated Use Support Status

In correlation with the evaluation of the relative magnitude of temperature sources to the SR-HC TMDL reach discussed above, the existing language in the Oregon and Idaho state standards addressing temperature violations occurring from natural causes, and the ongoing process for improved temperature standards and policy in the Pacific Northwest, this TMDL recognizes the fact that water temperatures above those identified in the appropriate state standards can and do occur within the SR-HC TMDL reach due to natural atmospheric sources. Because of the situation occurring in the SR-HC TMDL reach, careful consideration has been given to the needs of designated aquatic life uses within the reach.

Although there are data that show water temperatures that exceed the temperature target in the reach, there is considerable information (data as well as anecdotal) available that indicates there were water temperatures over this target historically (prior to dam construction), even when aquatic species were present in healthy populations (USFWS, 1957 and 1958). One explanation for this is the occurrence of colder water refugia during periods of high stream temperatures in the bulk of the waterway. Such refugia are known to be present in the form of cold water tributaries in the SR-HC TMDL reach, and may also include springs or other ground water

inflows where localized water temperatures are cooler than those observed for the system as a whole.

A second explanation is that water temperatures have always been elevated in much of the SR-HC TMDL reach and the lower portions of its tributaries due to high summer air temperatures, high solar radiation, and low summer flows. Climatologically, this area is classified as xeric, indicating little precipitation and high summer air temperatures. Native fish species may have adapted to these conditions. Fish species present (both native species and those introduced due to stocking or other management practices) may be capable of surviving and thriving in water temperatures in excess of those defined by the targets identified in this TMDL either with physiological or migration adaptations. Cold water refugia may have been more extensive historically than it is today due to anthropogenic effects in tributaries and the upstream Snake River. It is assumed that a combination of more extensive cold water refugia and an evolutionary temperature tolerance may both have been factors in supporting healthy population levels historically.

Both explanations have validity in this segment of the Snake River. Cold water refugia may have been more extensive historically than it is today due to anthropogenic effects in tributaries, the upstream Snake River and dam construction. It is assumed that a combination of more extensive cold water refugia and an evolutionary temperature tolerance may both have been factors in supporting healthy population levels historically. Both factors are explored further in the application of the creative approach outlined in the general loading analysis portion of this document.

The basic premise for developing the SR-HC TMDL is that the targets for the water body (Snake River mainstem from RM 409 to RM 188) must be set so that the water body will meet water quality standards. The reason water quality standards are established is the protection of designated beneficial uses. The criteria within water quality standards are developed as surrogate measures of beneficial use health/support, and it is assumed that attainment of those criteria will provide for full support of the designated beneficial uses. Therefore, water quality targets within the Snake River-Hells Canyon TMDL must be set so that water quality standards are met in such a manner that the designated beneficial uses are protected.

A second premise of this approach is the acknowledgement that there are distinct spatial and temporal (including seasonal) use patterns of the specific segments by the designated beneficial uses within the Snake River-Hells Canyon aquatic ecosystem. These spatial/temporal use patterns are not always captured in designation of beneficial uses by reach or watershed. Therefore, the Snake River-Hells Canyon TMDL targets and resulting implementation strategies need to recognize those spatial/temporal use patterns that exist, as well as the needed connectivity within the mosaic of designated beneficial uses (including critical habitat for sensitive species) throughout the waterbody. This would provide for full support of existing uses and the restoration of impaired designated uses within that mosaic. The Snake River-Hells Canyon TMDL also recognizes that this ecosystem is comprised of a variety of aquatic environments that include lentic, lotic and transition areas, each with their own characteristic attributes and beneficial uses.

3.6.9.1 COLD WATER REFUGIA.

It has been observed that there is often a natural component to any water body that may represent a source of pollutant loading. Surface water temperatures are observed to exceed water quality criteria within the SR-HC TMDL reach. The dominant cause of these exceedences is natural temperature loading. However, even with these exceedences, the Hells Canyon Complex manages to support viable populations of cold water species such as rainbow and redband trout.

Population Distribution.

Studies completed by IPCo have documented the distribution of salmonid species within the Snake River (Figure 3.6.6). Viable populations of rainbow trout have been documented to occur within the river system from American Falls to Swan Falls. While there is some variation in species composition throughout the studied sections of the mainstem Snake River, noticeably

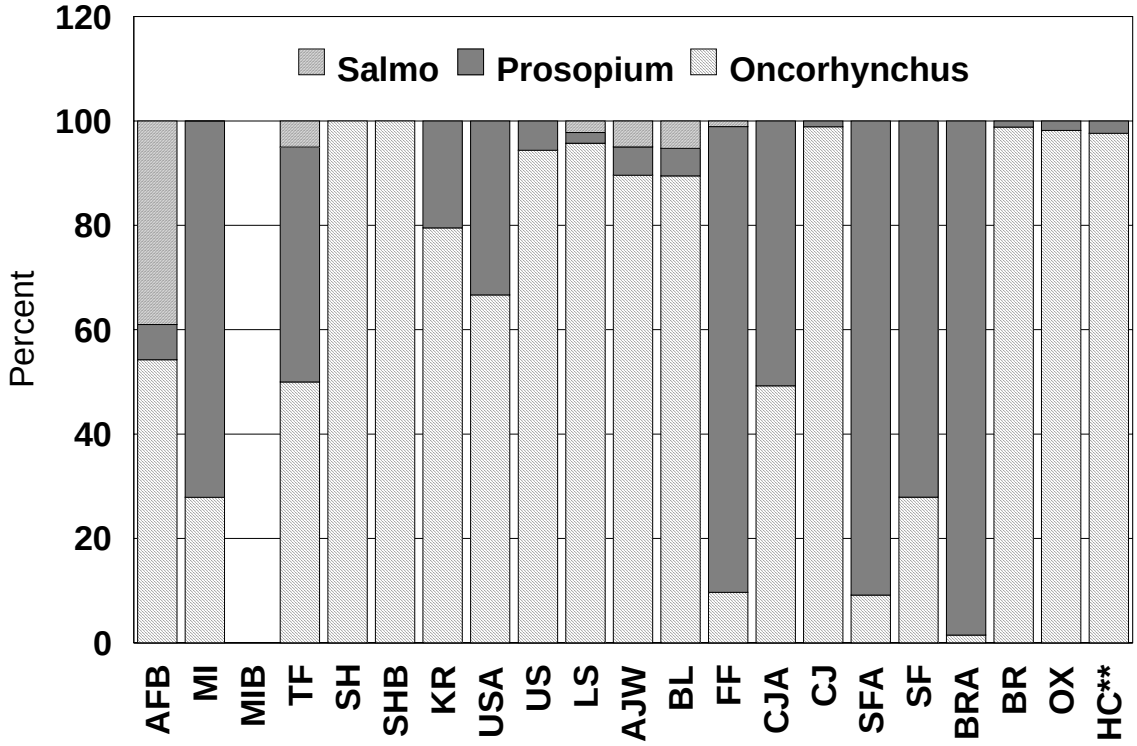


Figure 3.6.6. Percent composition of the family Salmonidae in the Snake River from the tailrace of American Falls Dam to Hells Canyon Dam. The genus *Salvelinus* is also present in small numbers in Hells Canyon Reservoir. Sampling is based on electrofishing spring and fall months periodically from 1991 to 2000. (Data was collected and plots were generated by Idaho Power Company).

The reach codes are as follows: AFB – American Falls Dam Tailrace, MI – Milner Reservoir, MIB – Milner Bypass Reach, TF – Twin Falls Reservoir, SH – Shoshone Falls Reservoir, SHB – Below Shoshone Falls to Pillar Falls, KR – Snake River from Buhl Bridge to Kanaka Rapids, USA – Snake River from Box Canyon to Thousand Springs, US – Upper Salmon Falls Reservoir, LS – Lower Salmon Falls Reservoir, AJW – Snake River from Lower Salmon Falls Dam to the upper end of Bliss Reservoir, BL – Bliss Reservoir, FF – Snake River from Bliss Dam to the upper end of CJ Strike Reservoir, CJ – CJ Strike Reservoir, SFA – CJ Strike Dam to the upper end of Swan Falls Reservoir, SF – Swan Falls Reservoir, BRA – Swan Falls Dam to the upper end of Brownlee Reservoir, BR – Brownlee Reservoir, OX – Oxbow Reservoir, HC – Hells Canyon Reservoir.

smaller relative populations of rainbow trout were observed in the sections of the Snake River from Bliss Dam to the upper end of CJ Strike Reservoir, in Swan Falls Reservoir and in the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach where whitefish dominate. The Upstream Snake River segment of the SR-HC TMDL reach showed the lowest relative rainbow trout populations in the study.

Downstream of the Upstream Snake River segment (RM 409 to 335), populations of rainbow trout rebound as the dominant salmonid species within the Hells Canyon Complex reservoirs. Both stocked and wild trout populations have been tracked in this study. Figure 3.6.7 shows the relative abundance of wild and hatchery rainbow trout in the mainstem Snake River. Although hatchery fish are more abundant, Brownlee, Oxbow and Hells Canyon reservoirs support viable populations of wild fish. Similar wild populations have not been observed in the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach.

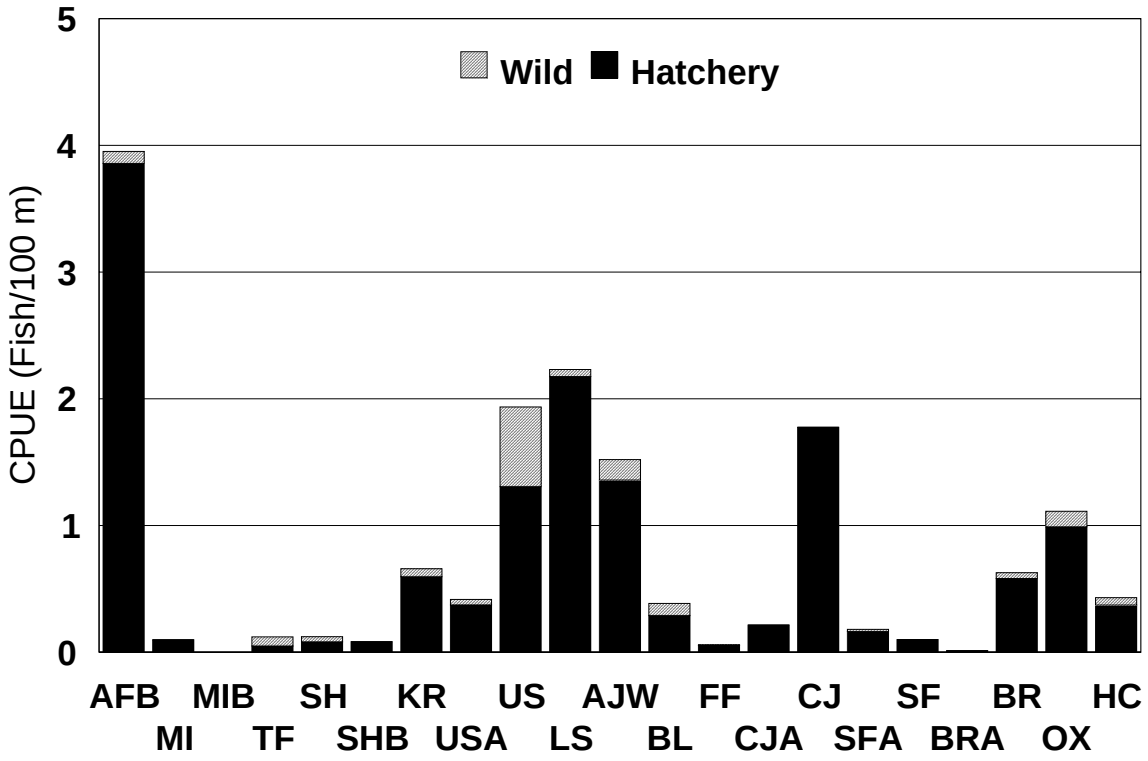


Figure 3.6.7. Relative abundance of wild and hatchery rainbow trout based on catch per unit of effort (CPUE fish/100 m of shoreline) in the Snake River from electrofishing effort in the Snake River from American Falls Dam tailrace to Hells Canyon Dam. Sampling is based on electrofishing spring and fall months periodically from 1991 to 2000. (Data was collected and plots were generated by Idaho Power Company). (The reach codes are defined in Figure 3.6.6)

A breakdown of spatial distribution within most of the SR-HC TMDL reach is displayed in greater detail in Figure 3.6.8. The data illustrated in this figure show hatchery rainbows present in the Snake River near Swan Falls Dam. Wild rainbows have not been documented in this section of the river. No rainbow populations (wild or hatchery) are observed between the area

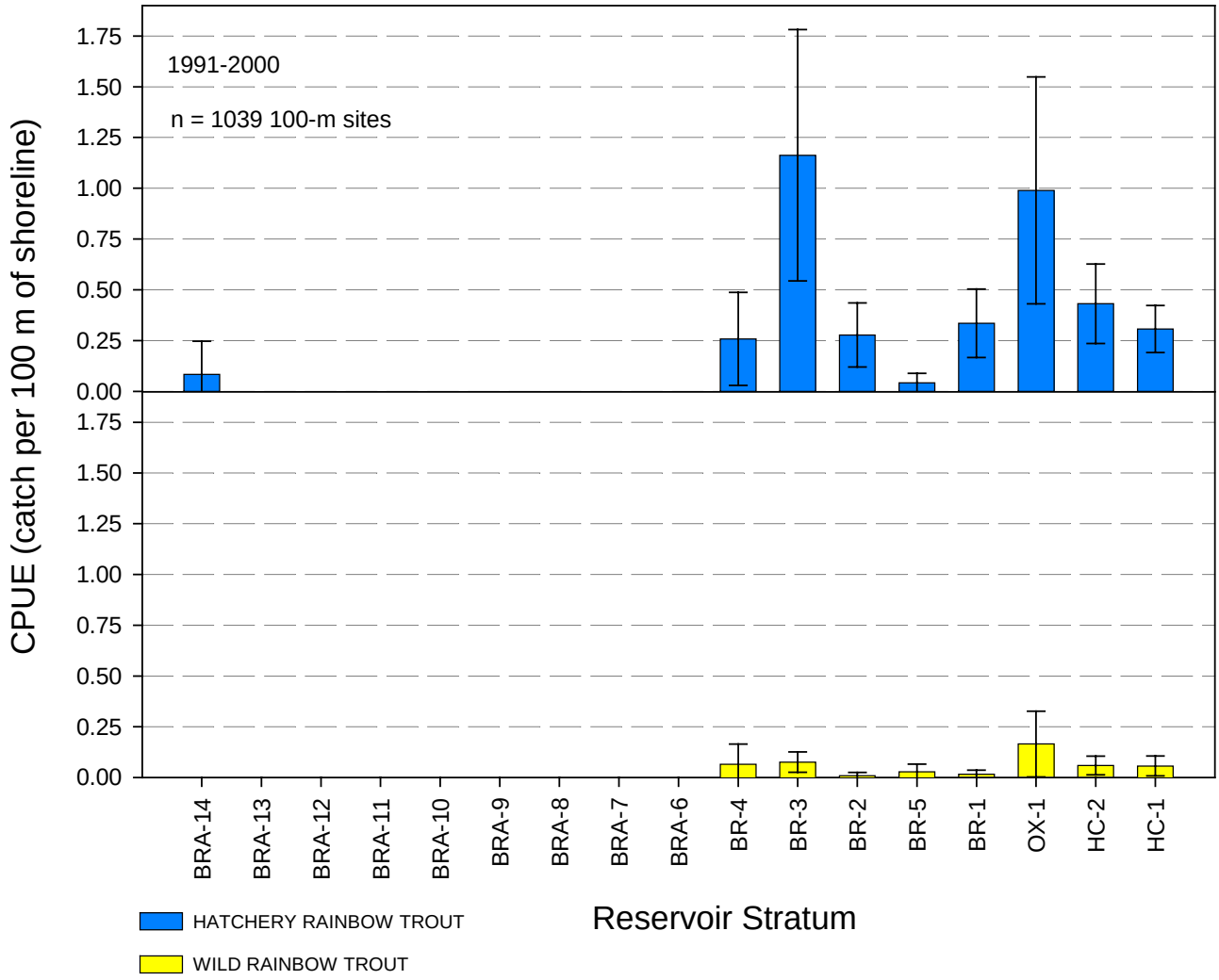


Figure 3.6.8. Relative abundance based on catch per unit of effort (CPUE per 100 m of shoreline electrofishing) of hatchery and wild rainbow trout in the Snake River from Swan Falls Dam to Hells Canyon Dam by sampling stratum. Sampling occurred annually during spring and fall, 1991 to 2000. Sampling strata BRA-14 to BRA-6 include the free-flowing reach from Swan Falls Dam to Brownlee Reservoir, sampling strata BR4-BR1 include Brownlee Reservoir, and sampling stratum BR-5 includes the Powder River Arm of the Brownlee Reservoir, OX1 includes Oxbow Reservoir, and HC1-HC2 include Hells Canyon Reservoir. (Data collected and plots generated by Idaho Power Company). (The reach codes are defined in Figure 3.6.6)

downstream of Swan Falls Dam and the inflow of Brownlee Reservoir. Within the reservoir segments however, both hatchery and wild rainbows are observed. The largest relative abundance based on catch per unit of effort values for both hatchery and wild rainbow trout were observed in Brownlee Reservoir (at BR3) and in Oxbow Reservoir.

The rainbow trout observed in Brownlee, Oxbow and Hells Canyon reservoirs and the Downstream Snake River segment (RM 247 to 188) showed a fairly wide range of size classes. As total body length in most fish species is substantially dependent on habitat, genetic and climatological factors, a straight length to age correlation cannot be accurately applied. Site-specific data is recommended for any such correlation. A study conducted by ODFW in McGraw Creek (a tributary to Hells Canyon Reservoir) provides a general estimation of these site-specific correlations.

This study developed length to age relationships for rainbow trout by using scale characteristics to age fish for which length measurements had been recorded. As fish age, thicker bands or growth "rings" known as annulus are formed, usually during cooler winter months when growth is slower. By counting the number of these rings present on scales a general idea of the number of winters a fish had lived could be determined. This study found that rainbow trout with scales containing 2+ annulus averaged 160 mm (6.3 inches) in length; these fish were estimated to be approximately 2 years old. Rainbow trout with 6+ annulus averaged 288 mm (11.3 inches) in length, these fish were estimated to be approximately 6 years old. Fish with 1+ annulus (considered fingerling fish) averaged 51 mm (2.0 inches) in length; these fish were estimated to be approximately 1 year old or less. If these same relationships are applied to the fish length data collected by IPCo shown in Figure 3.6.9, it can be seen that the reservoirs and the Downstream Snake River segment (RM 247 to 188) are home to a broad age range of fish.

Within Brownlee Reservoir, wild rainbows range from fingerling fish one year of age or less to over six years of age. In Brownlee Reservoir wild rainbows aged from fingerlings to approximately two years of age were most abundant. Wild rainbow trout in Oxbow range from approximately one year to over six years of age. In Oxbow Reservoir wild rainbows aged from two years to over six years were the most abundant. In Hells Canyon Reservoir wild rainbow trout range from fingerlings to over six years in age. In Hells Canyon Reservoir wild rainbows approximately two years of age and those over six years of age were the most abundant. Below Hells Canyon Dam, in the Downstream Snake River segment (RM 247 to 188), wild rainbow trout ranged from approximately six years in age.

Current beneficial use reconnaissance protocol defines full support criteria for fishes as supporting three age classes. If the assumptions above are correct, all three reservoirs support the designated salmonid rearing/cold water aquatic life use.

Spatial and Temporal Use Patterns.

As stated previously, a primary premise of the approach applied by this TMDL is the acknowledgement of distinct spatial and temporal (including seasonal) use patterns of the specific segments by the designated beneficial uses within the Snake River-Hells Canyon aquatic ecosystem. Within the complex system of mainstem and tributary waters within the SR-HC TMDL reach, these spatial and temporal use patterns are not always completely captured in designation of beneficial uses by reach or watershed. In the reservoir and Downstream Snake River segments of the SR-HC TMDL, joint use of reservoir and tributary systems provides support of salmonid rearing/cold water aquatic life designated uses.

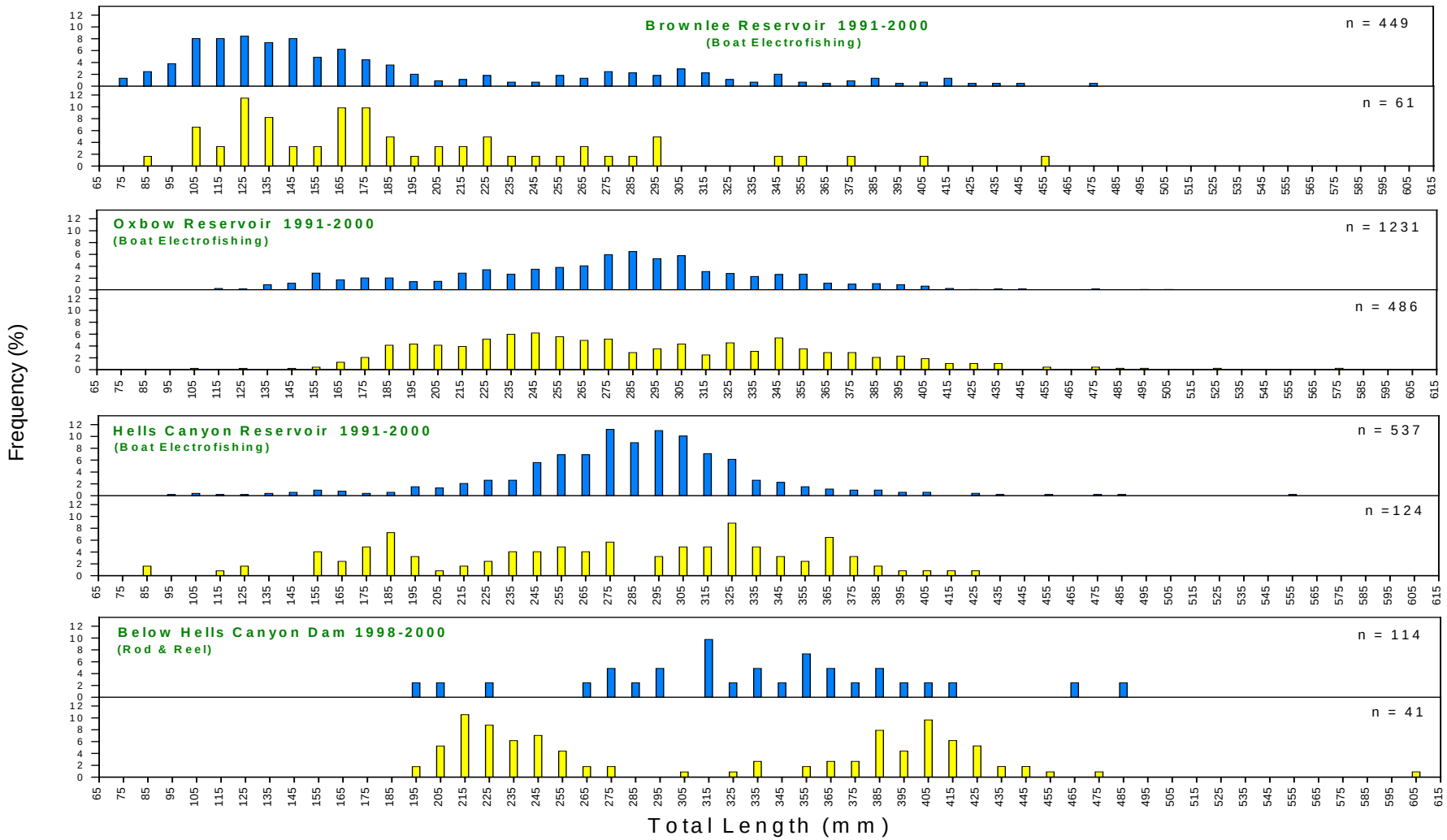


Figure 3.6.9. Percent length frequencies of wild and hatchery rainbow trout in Brownlee, Oxbow and Hells Canyon reservoirs from annual shoreline electrofishing sampling during spring and fall months from 1991 to 2000 (top three graphs). Percent length frequencies of wild and hatchery trout below Hells Canyon Dam from rod and reel sampling from 1998 to 2000 (bottom graph). (Data were collected and plots generated by Idaho Power Company.)

This temporal and spatial use mosaic is documented through a tracking study authored by IPCo for the reservoir and Downstream Snake River segments. Data was collected to identify relative population distributions on a monthly basis in the mainstem Snake River in the Hells Canyon Complex. The collected data for the 1998 through 2000 time period are shown in Figure 3.6.10.

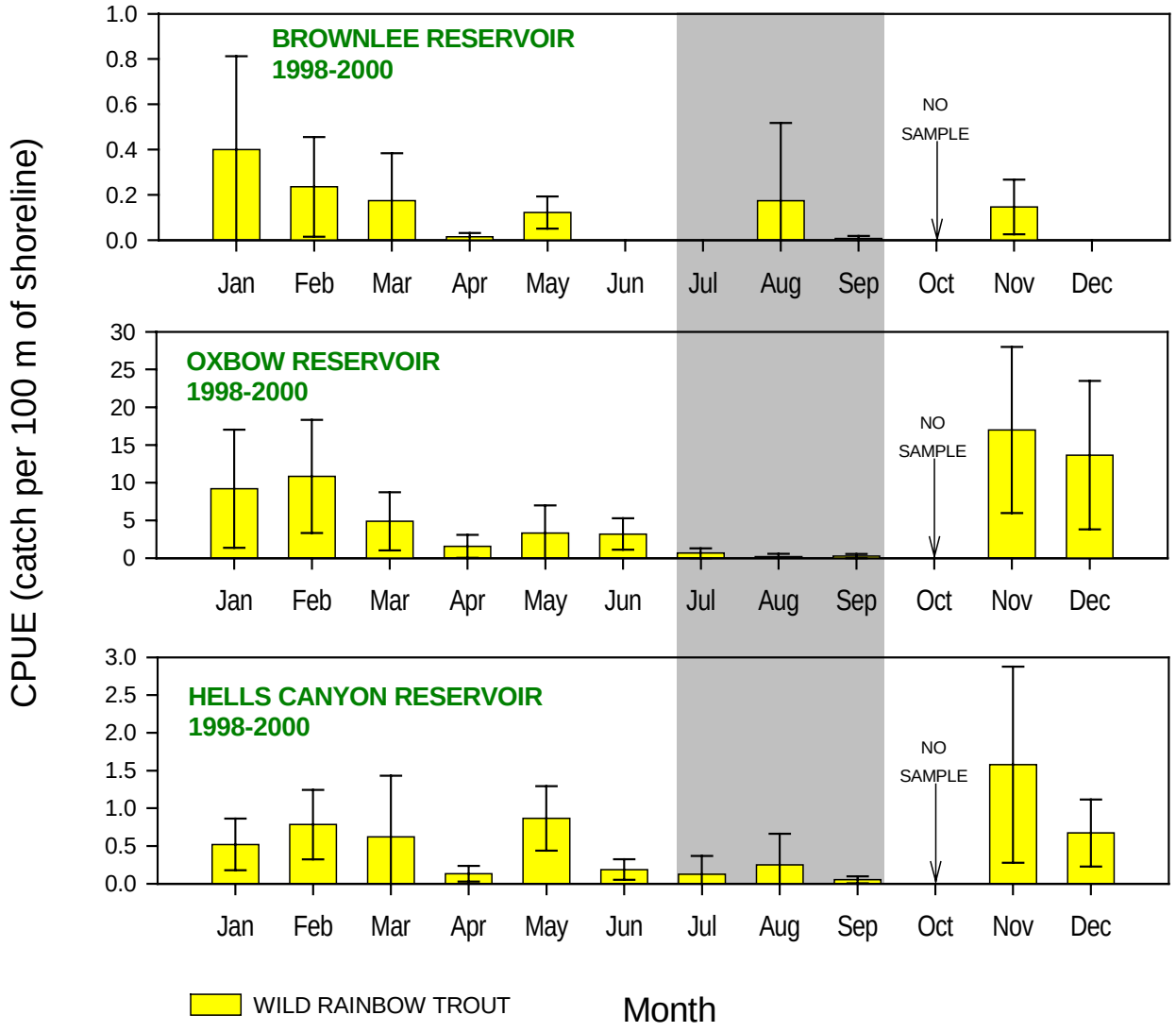


Figure 3.6.10. Monthly relative abundance of wild rainbow trout in Brownlee, Oxbow and Hells Canyon Reservoirs based on catch per unit of effort (CPUE per 100 m of shoreline electrofishing) during 1998 to 2000. Gray shaded area represents the period of warm summer water temperatures. (Data were collected and plots generated by Idaho Power Company.)

For all three reservoir systems, relative abundance of wild rainbow trout increases during the fall and winter months, then decreases during late spring and summer months. Data collected for hatchery raised rainbow trout show a similar relative abundance pattern.

When compared to the available water temperature data for the Hells Canyon Complex discussed in the preceding sections, a temperature triggered pattern is evident. Wild populations are present in Brownlee, Oxbow and Hells Canyon reservoirs throughout the winter and spring months (November through May). During the month of June, when water temperatures become elevated, relative abundance of rainbow trout in the reservoirs start to decrease. The lower relative abundance levels in-reservoir continue through the summer months (July through September) and then increases again in November.

Tributary monitoring through migrant weir placement shows an opposite pattern. In-migration to the reservoir occurs in October and November. Out-migration from the tributaries was observed during this same time period. Figures 3.6.11 a – c illustrate this pattern for tributaries to Brownlee Reservoir (Brownlee Creek), Oxbow Reservoir (Wildhorse Creek), Hells Canyon Reservoir (Indian Creek) and the Downstream Snake River segment (Sheep Creek). Relatively few fish were detained behind the migrant weirs in early to mid-September; frequency of daily captures increases throughout late September into October, and then decreases through November.

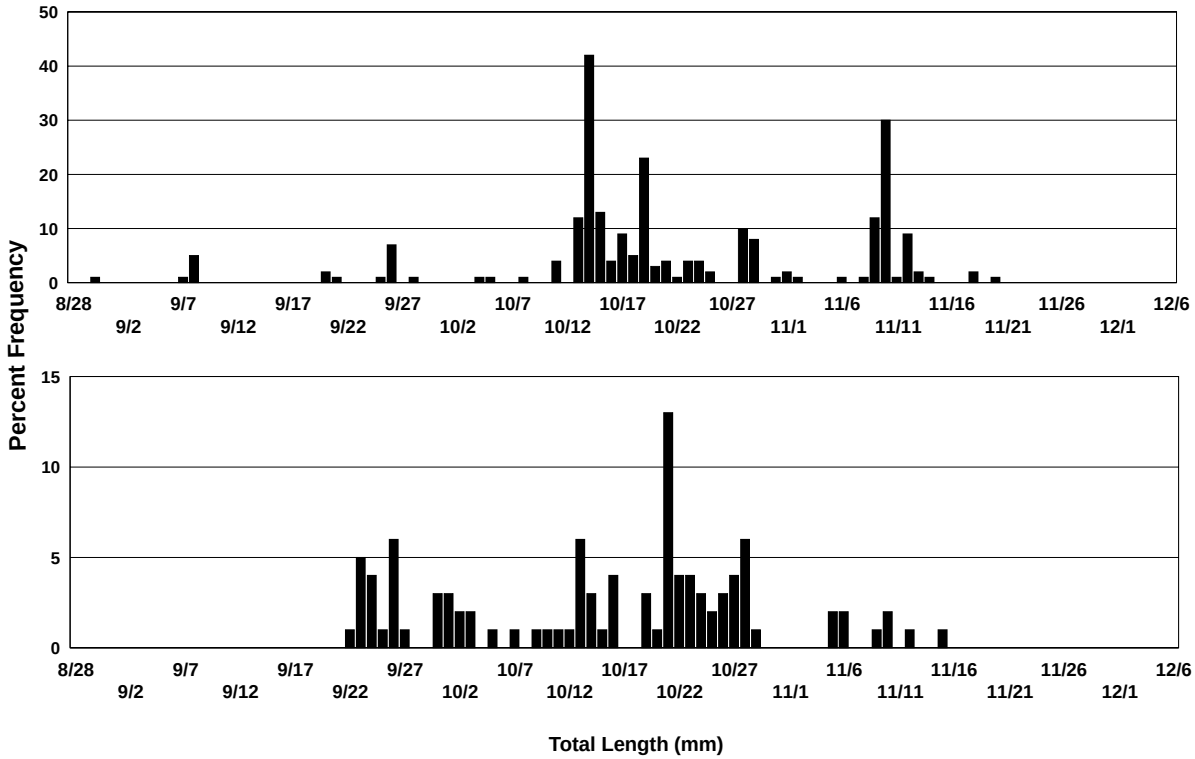


Figure 3.6.11 a. Frequency of daily captures of wild rainbow trout in a downstream migrant weir in Wildhorse River during 1998, and Brownlee Creek during 2000. (Data collected and plots generated by Idaho Power Company.)

This observed migratory pattern correlates well with water temperature increases in the mainstem Snake River in early summer (i.e. water temperatures above 18 ^{o}C become common near the surface in Brownlee Reservoir) and with water temperature decreases in the reservoir systems and tributaries in the late fall. The water temperature data shown in Figure 3.6.12 suggests that tributary temperatures below 10 ^{o}C may act as a trigger for migration into the reservoir systems. Observed relative abundance of both wild and hatchery rainbow trout in Brownlee, Oxbow and Hells Canyon reservoir rebound in close correlation with the occurrence of these temperature levels in the inflowing tributaries. It is theorized that the somewhat higher water temperatures in the reservoir segments may represent a less stressful overwinter environment for some fish species than the inflowing tributaries that experience substantial ice cover during the winter months.

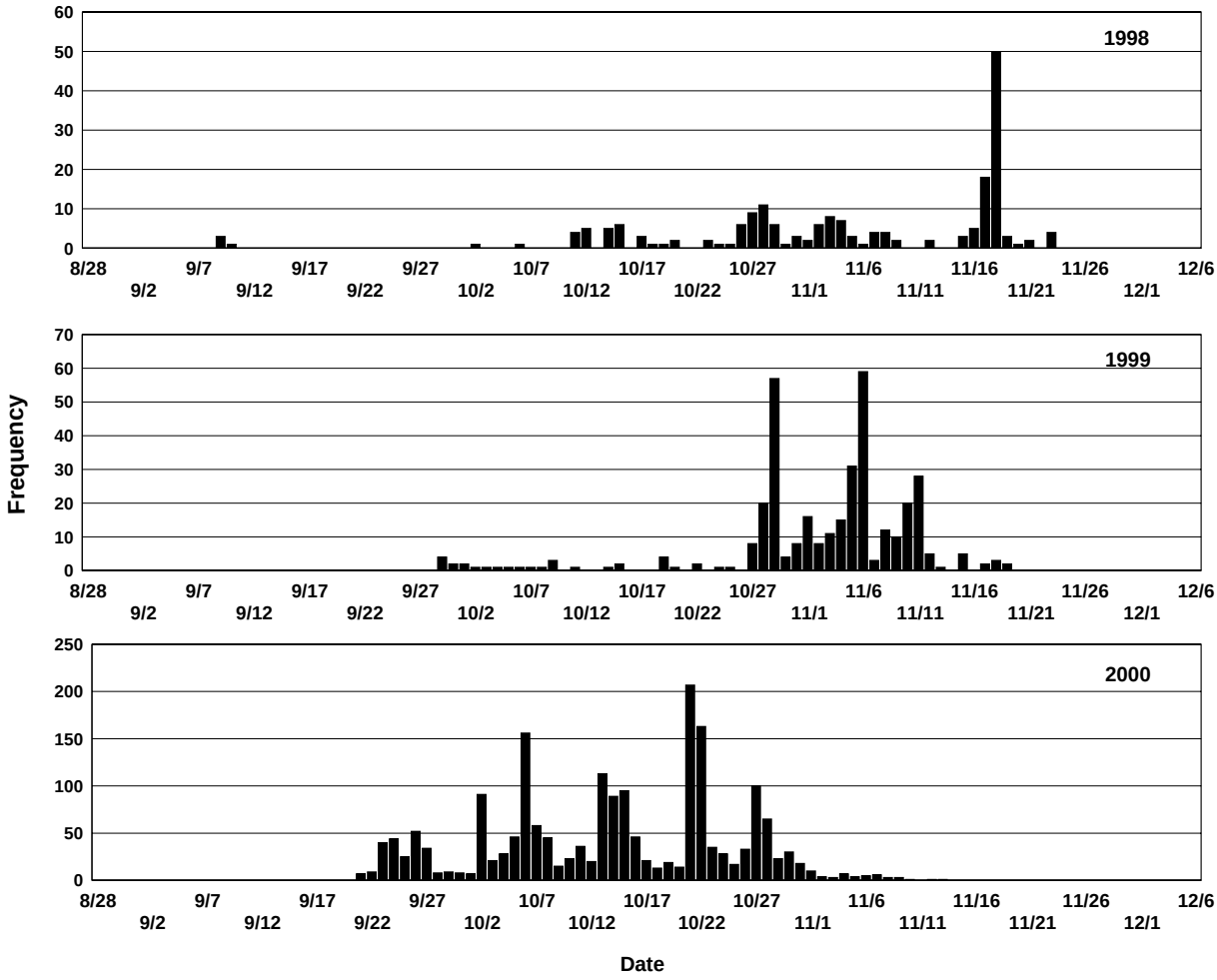


Figure 3.6.11 b. Frequency of daily captures of wild rainbow trout in a downstream migrant weir in Indian Creek during 1998, 1999 and 2000. (Data collected and plots generated by Idaho Power Company.)

As shown in Figure 3.6.13 a – c, the age distribution of migrating tributary populations observed in the above study correlate well with those identified for Brownlee, Oxbow and Hells Canyon

reservoirs and the Downstream Snake River segment (RM 247 to 188). In Brownlee Creek (discharging to Brownlee Reservoir at RM 285.5), wild rainbows range from fingerling fish one year of age or less to over six years of age. In Brownlee Creek wild rainbows approximately two years of age were most abundant. Wild rainbow trout in Wildhorse Creek (discharging to Oxbow at RM 284.4) range from approximately one year to over six years of age.

In Oxbow Reservoir wild rainbow fingerlings and those from two years to three years of age were the most abundant. In Indian Creek (discharging to Hells Canyon Reservoir at RM 270) wild rainbow trout range from fingerlings to over six years in age. Indian Creek wild rainbows approximately two years of age and under were the most abundant. In Sheep Creek (discharging to the Downstream Snake River segment at RM 229), wild rainbow trout ranged from

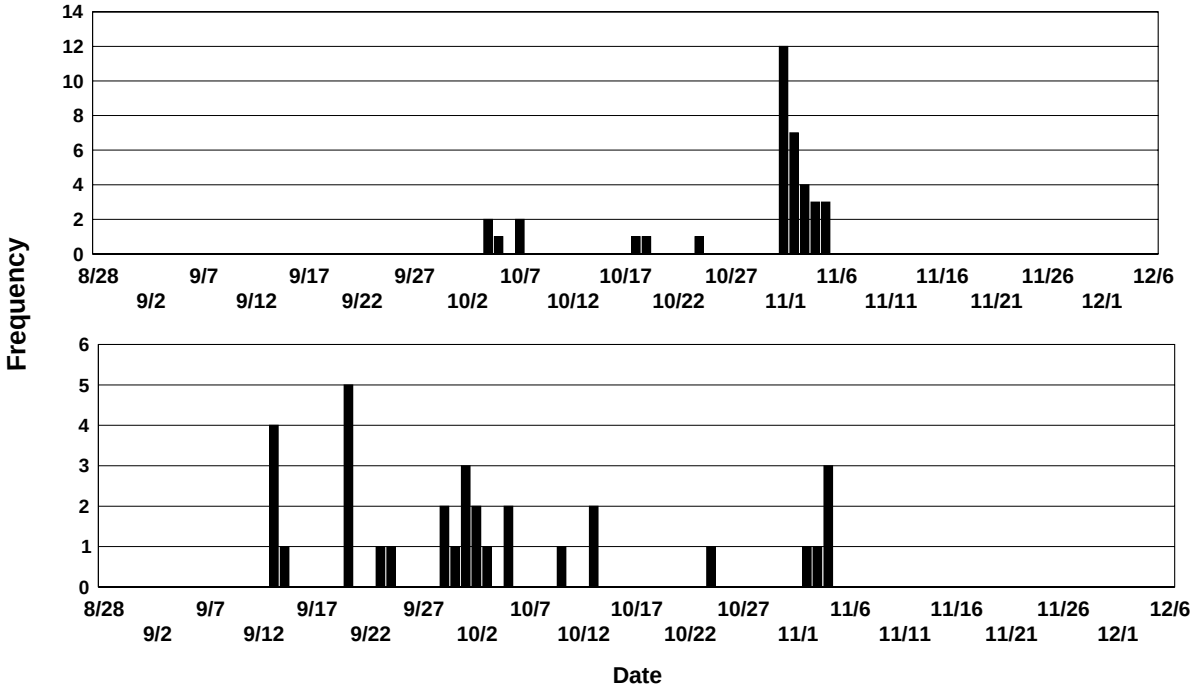


Figure 3.6.11 c. Frequency of daily captures of wild rainbow trout in a downstream migrant weir in Sheep Creek during 1999 and 2000. (Data collected and plots generated by Idaho Power Company.)

approximately six years in age, with wild rainbows approximately two years of age and under being the most abundant.

The tributaries to Brownlee, Oxbow and Hells Canyon reservoirs and the Downstream Snake River Segment are cooler during the critical summer months than the reservoir waters. Thus these tributaries provide cold water refugia that allows cold water species to avoid the higher water temperatures in the reservoirs during the summer months. The collected data show that designated beneficial use support is occurring given joint use of both reservoir and tributary systems. Within the Hells Canyon Complex of reservoirs and the Downstream Snake River segment, these distinct spatial and temporal (seasonal) use patterns occur to support salmonid rearing/cold water aquatic life designated beneficial uses.

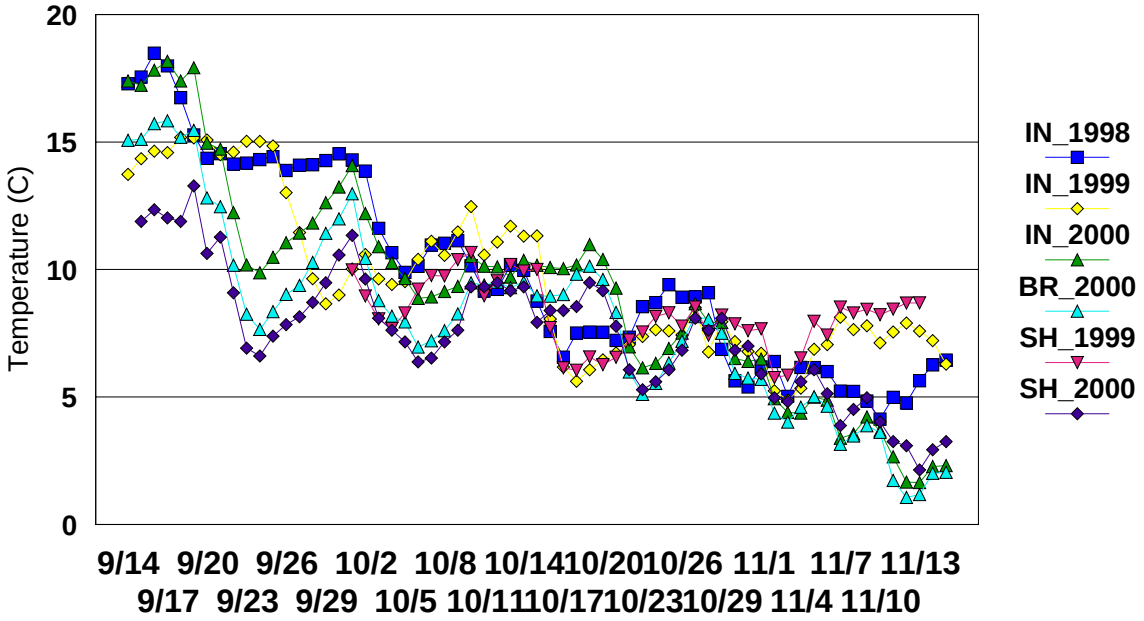


Figure 3.6.12. Water temperature (^{o}C) from Indian Creek (IN), Brownlee Creek (BR), and Sheep Creek (SH) during fall months of 1998 to 2000. (Data collected and plots generated by Idaho Power Company.)

In contrast, rainbow trout populations in the Upstream Snake River segment (RM 409 to 335) are nearly nonexistent. For the most part, the tributaries discharging to the Snake River in this segment are not cold, fast moving streams like those inflowing to the Hells Canyon Complex reservoirs and do not provide the necessary level of cold water refugia for rainbows and other cold water fish in the system. Therefore, a viable population of rainbows is not observed in the Upstream Snake River segment (RM 409 to 335).

Creation of this type of refugia in the Upstream Snake River segment may represent a possible mechanism to deal with natural temperature loading concerns and lower rainbow trout populations in this section. Where slopes are more gradual in this section, it is unclear how possible or successful the creation of such refugia would be. A separate option is a full evaluation of the appropriateness of the designated beneficial uses of salmonid rearing and cold water aquatic life in this segment of the SR-HC TMDL reach. An effort toward this end is currently underway by stakeholders of the SR-HC TMDL process. Data generated by this effort will be evaluated within the iterative nature of the SR-HC TMDL process. If designated use refinement is judged to be necessary, the appropriate legislative processes will be followed and the TMDL will be adjusted accordingly.

Within the Hells Canyon Complex and the Downstream Snake River segment (RM 247 to 188), designated beneficial uses are being supported through availability of cold water refugia. Without question, existing refugia in the SR-HC TMDL reach must be protected and improved as necessary to continue support of the designated beneficial uses.

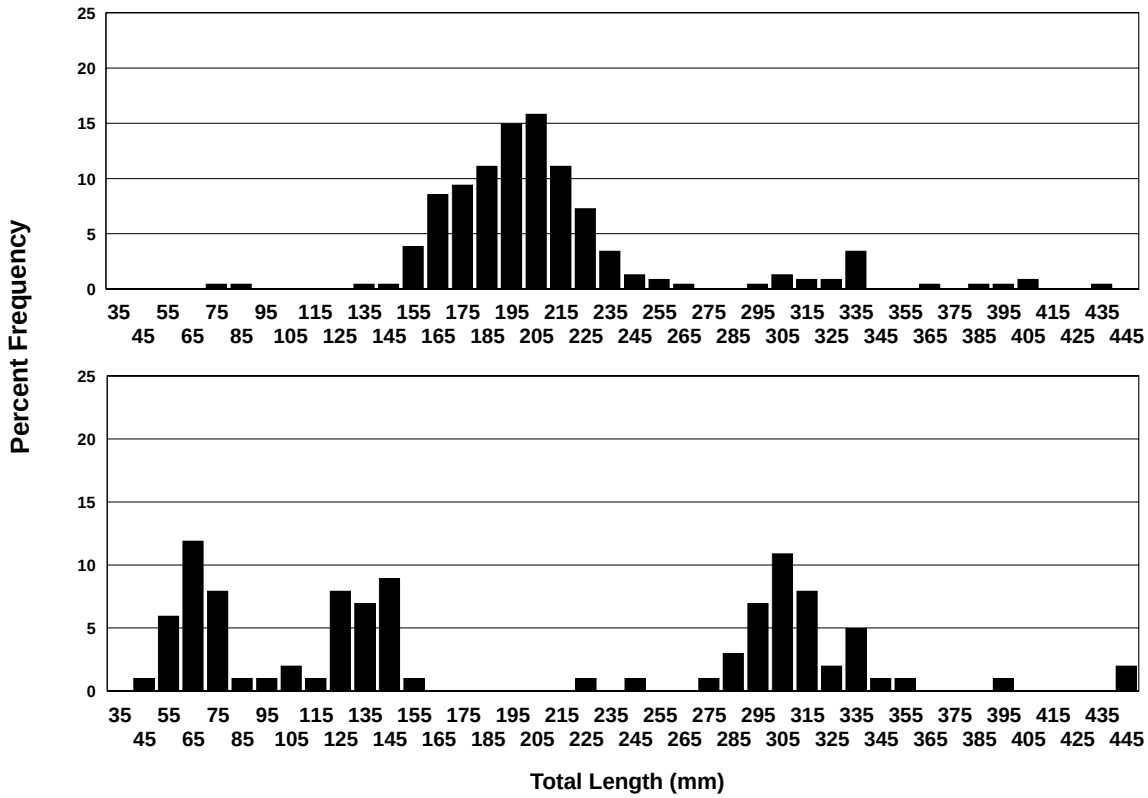


Figure 3.6.13 a. Length frequencies (percent) of wild rainbow trout captured in the downstream migrant weir near the mouth of Wildhorse River during fall of 1998 (top graph) and near the mouth of Brownlee Creek during fall of 2000 (bottom graph). (Data collected and plots generated by Idaho Power Company.)

In correlation with the proposed approach therefore, tributaries currently providing cold water refugia must be managed so that they continue to represent alternative habitat for salmonid rearing/cold water aquatic life during the critical months of June, July, August and September. Additionally, those tributaries that could provide such refugia but are not currently doing so due to anthropogenic influences should be managed so that such refugia is provided as appropriate.

In this way those portions of the SR-HC TMDL system that are being utilized as habitat for support of the designated beneficial uses of salmonid rearing/cold water aquatic life, namely those tributaries that currently are or could be providing cold water refugia during the critical time period, will meet criteria, and will support designated beneficial uses without imposing inappropriate and unreachable water quality targets and implementation expectations on the system as a whole.

3.6.9.2 ADAPTATION OF FISH SPECIES PRESENT.

The alternative explanation proposed above, that water temperatures have always been elevated in much of the SR-HC TMDL reach due to climatological influences and that native fish species may have adapted to these conditions with either physiological or migration adaptations also has some application. The discussion of cold water refugia above cited work by IPCo showing

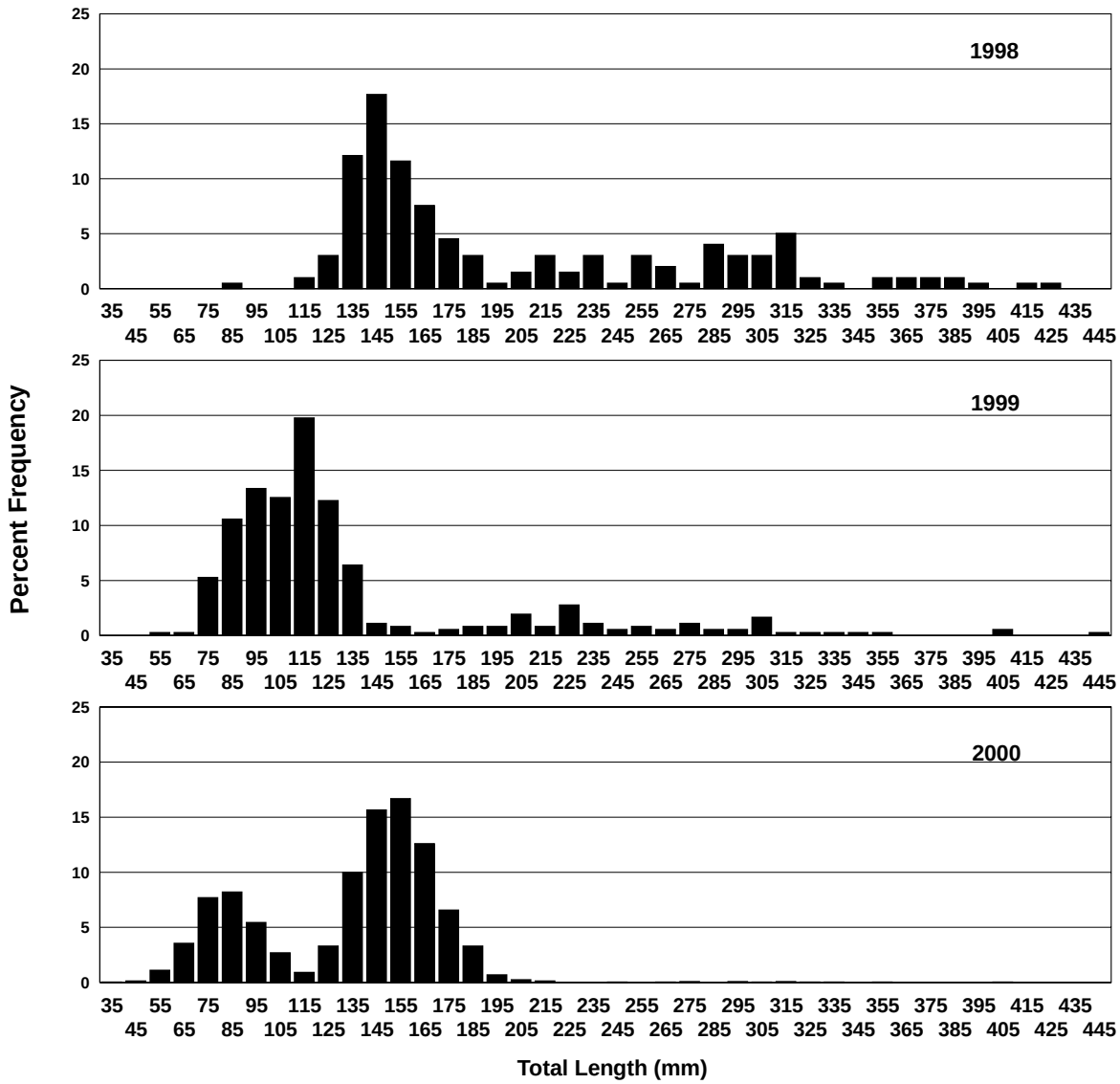


Figure 3.6.13 b. Length frequencies (percent) of wild rainbow trout captured in the downstream migrant weir near the mouth of Indian Creek during fall months of 1998, 1999 and 2000. (Data collected and plots generated by Idaho Power Company.)

migration patterns of rainbow trout within the Hells Canyon Complex (IPCo, 2001g). This migration is an adaptive behavior apparently triggered by temperature changes within the water column. Warm water temperatures trigger the out-migration to cooler tributary waters during the critical time period of June through September. Return-migration also appears to be temperature driven in that the majority of movement from the tributaries to the reservoir occurs when the tributary water temperatures first drop below 10 ^{o}C.

This adaptive behavior serves two purposes for the migrating fish. It removes them from tributaries that may not have enough flow to support a larger population over the winter period

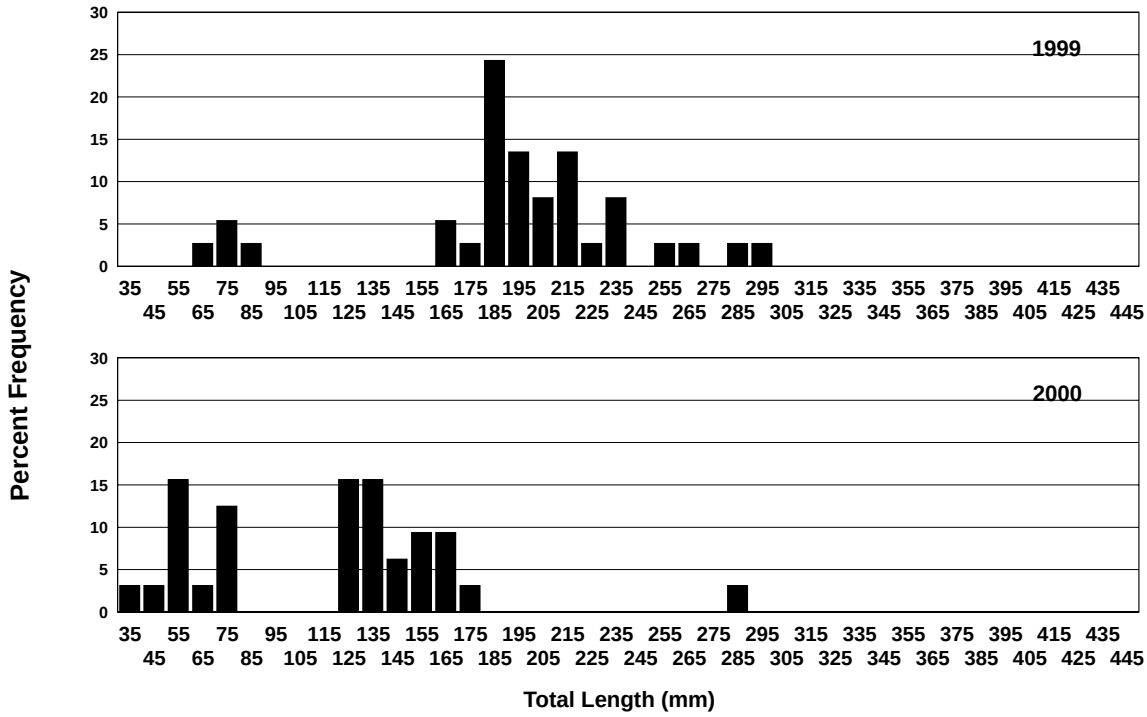


Figure 3.6.13 c. Length frequencies (percent) of wild rainbow trout captured in the downstream migrant weir near the mouth of Sheep Creek during fall months of 1999 and 2000. (Data collected and plots generated by Idaho Power Company.)

(ice-in and over winter concerns increase with smaller pool size and depth) and provides, through migration back into the reservoir, and more plentiful food source than would be available in the tributaries over the winter months. Studies have shown that moderate water temperatures result in better growth characteristics than waters that are substantially colder over extended periods of time (Appendix C and associated references). Therefore, this temperature triggered migration potentially provides a source of cool water during the critical summer months and an improved food supply during the colder winter months.

Additionally, an assessment of total population distribution for the SR-HC TMDL reach shows that warm water fishes dominate the system. Data on species distribution is available from before the CWA was finalized in 1975 (IDFG, 1973a and b) that indicates that warm water species were the dominant population. More recent studies (IPCo, 2000a; IDFG, 2000; ODFW, 2001) show that a similar distribution remains today within the SR-HC TMDL reach.

Rainbow trout, redband trout and mountain whitefish are listed as present in the Upstream Snake River segment (RM 409 to 335); although population counts like the one described earlier (Figure 3.6.6) show that the dominant cold water species in this segment is mountain whitefish. In the Brownlee and Oxbow reservoir segments rainbow trout, redband trout and mountain whitefish are listed as the cold water species present. While the population of mountain

whitefish does not dominate in the reservoirs, the warmwater and coolwater species still substantially outnumber the cold water species (Table 3.6.7).

Table 3.6.7. Fish species present in the Snake River - Hells Canyon TMDL reach as identified by IDFG, ODFW, IDEQ, USFWS/IPCo and ACOE.

Segment	Warm Water Species	Cool Water Species	Cold Water Species
Upstream Snake River	largemouth bass channel catfish flathead catfish bluegill white crappie black crappie bullhead	smallmouth bass yellow perch pumpkinseed bridgelip sucker largescale sucker white sturgeon	rainbow trout* redband trout* mountain whitefish white sturgeon
Brownlee Reservoir	largemouth bass channel catfish bluegill white crappie black crappie bullhead common carp tadpole madtom flathead catfish warmouth	smallmouth bass pumpkinseed chiselmouth northern pike minnow bridgelip sucker largescale sucker peamouth sculpin[1] yellow perch white sturgeon	rainbow trout* redband trout* mountain whitefish* sculpin[1] white sturgeon
Oxbow Reservoir	largemouth bass bluegill white crappie black crappie bullhead common carp bridgelip sucker largescale sucker bridgelip sucker warmouth	smallmouth bass yellow perch pumpkinseed chiselmouth northern pike minnow white sturgeon	rainbow trout* redband trout* mountain whitefish* sculpin white sturgeon
Hells Canyon Reservoir	largemouth bass channel catfish bluegill white crappie black crappie bullhead common carp warmouth	smallmouth bass yellow perch pumpkinseed chiselmouth northern pike minnow bridgelip sucker largescale sucker sculpin[1] white sturgeon	rainbow trout* redband trout* mountain whitefish* bull trout** sculpin[1] white sturgeon
Downstream Snake River	largemouth bass channel catfish flathead catfish bluegill white crappie black crappie bullhead goldfish common carp tadpole madtom	stoneroller[2] smallmouth bass pumpkinseed chiselmouth northern pike minnow longnose dace bridgelip sucker largescale sucker yellow perch white sturgeon	chinook salmon (spring)* chinook salmon (summer)* chinook salmon (fall) sockeye salmon** rainbow trout/steelhead* redband trout* mountain whitefish kokanee salmon bull trout** white sturgeon

* Indicates species that spawn in the tributaries only – not in the mainstem.

[1] Depending on Species
[2] Not previously described in Idaho

** Indicates species that spawn in the upper tributaries only – not in the mainstem

The Hells Canyon Reservoir shows the addition of adult Bull Trout to the cold water species list but the warm water species still substantially outnumber the cold water species. Tributaries to the SR-HC TMDL reach are often nearly exclusively cold water species, especially in the upper reaches; however, the mainstem segments are consistently dominated by warm water species.

In the Downstream Snake River segment (RM 247 to 188), cold water species represent a greater portion of the overall fish population but warm water species are still present in a nearly equal role. The shift from cold to warm water species with distance downstream from the headwaters is certainly driven to some extent by water temperatures. Cold water fish are observed to be more plentiful in those areas where water temperatures are lower and warmer water species are more plentiful in areas with elevated water temperatures.

In addition to the overall population distribution however, some selectivity has been noted within the cold water species. Redband trout are plentiful in the Hells Canyon Complex. These fish are somewhat more elastic than the rainbow trout in adapting to elevated water temperatures, and show viable populations in the reservoir complex (IPCo, 2001g).

Fish requiring colder water temperatures or more stringent substrate conditions are not known to spawn within the SR-HC TMDL reach. Rather, these fish have been observed to spawn higher up in the tributaries to the system, using the available resources in a spatial and temporal fashion to meet habitat requirements for all life stages within the SR-HC watershed.

3.6.10 Conclusions

Temperature increases naturally within the SR-HC TMDL reach, the relative levels calculated for natural atmospheric and non-quantifiable (background) temperature influence in the Upstream Snake River segment (RM 409 to 335) during June equal 98.9 percent of the total, during July equal 99.5 percent of the total, during August equal 98.5 percent of the total and during September are assumed to be comparable to the values calculated for June (> 98%).

Temperature increases calculated for the permitted point sources within the Hells Canyon Complex of reservoirs and the Downstream Snake River segment (RM 247 to 188) are less than 10 percent of the level defined as no-measurable-increase by the State of Oregon, and less than 5 percent of the level defined as no-measurable-increase by the US EPA (Colville tribe) and the State of Idaho. All calculations were made in a conservative fashion and are based on available data.

The calculations indicate that natural atmospheric and non-quantifiable sources are clearly the dominant influence on the water temperature of the river, and that air temperature plays an important role in the elevated water temperatures observed in the SR-HC TMDL reach.

An evaluation of cold water aquatic life focusing on rainbow trout and redband trout show that they are present in viable populations in Brownlee, Oxbow and Hells Canyon Reservoirs. Evidence indicates that these populations have adapted to the naturally elevated water

temperatures in the SR-HC TMDL reach by migrating into cold water tributaries during the summer season when reservoir temperatures exceed the conditions appropriate for salmonids. Alternatively, the reservoirs provide an appropriate habitat for over-winter growth when the tributary temperatures drop below approximately 10 ^{o}C. Support of these species is being provided by the availability of cold water refugia during the critical time period of June through September.

The same level of support is not available in the Upstream Snake River segment (RM 409 to 335), as is evidenced by the lack of diversity in local populations and the dominance of mountain whitefish as opposed to rainbow trout and other salmonid species. This section of the SR-HC TMDL reach experiences elevated water temperatures due predominantly to natural atmospheric and non-quantifiable influences. As the climate and landforms are very similar throughout the lower end of the Snake River Basin, it is expected that exceedence of water quality targets in inflowing tributary systems is also driven predominantly by natural atmospheric and non-quantifiable influences.

The Hells Canyon Complex causes a shift in temperatures from those that would occur were the Hells Canyon Complex not in place. Peak summer temperatures are several degrees cooler due to withdrawals from below the reservoir surface, and the decline in temperatures in the fall is delayed from that observed immediately upstream of the Hells Canyon Complex. While the temporal distribution of this temperature shift is due to the delay in flow caused by water moving through the Hells Canyon Complex, the actual heat load (warmer water) is not. The impoundments are not a heat source.

Data available to this TMDL effort and modeling work completed by IPCo shows that the Hells Canyon Complex is not the source of the heat load in the reservoirs and that if upstream conditions were cooler, the water exiting the Hells Canyon Complex would also be cooler. Therefore, it is concluded that IPC is not contributing to temperature exceedences specific to the cold water aquatic life/salmonid rearing designated use

However, data assessment and calculational modeling by the DEQs, and IPCo water temperature modeling also shows that water exiting the Hells Canyon Complex would not meet the salmonid spawning criteria (although by only a small margin) because of the temporal shift created by the Hells Canyon Complex. It is, therefore, concluded that the responsibility for exceeding the salmonid spawning criteria is specific to the presence and operation of the Hells Canyon Complex.

3.7 Total Dissolved Gas Loading Analysis

3.7.1 Water Quality Targets and Guidelines

The purpose of TMDL development is to meet applicable water quality standards. The SR-HC TMDL is a bi-state effort; both Oregon and Idaho share the same numeric water quality standard for total dissolved gas (TDG). The target concentration for the SR-HC TMDL reach is therefore, the common water quality standard; that the concentration of total dissolved gas relative to atmospheric pressure at the point of sample collection shall not exceed 110 percent of saturation, except when stream flow exceeds the ten-year, seven-day average flood flow (See Section 2.2.4.7). Attainment of this target will ensure that the water quality requirements of both states will be met. Currently, exceedences of this target are known to have occurred downstream of Brownlee Dam.

The State of Oregon has an additional requirement that in hatchery receiving waters and waters of less than two feet in depth, the concentration of total dissolved gas relative to atmospheric pressure at the point of sample collection shall not exceed 105 percent of saturation. The total dissolved gas target for the SR-HC TMDL will include this additional requirement where applicable.

While total dissolved gas exceedences have been documented to occur within the SR-HC TMDL reach, no segment of the reach is listed for total dissolved gas by either the State of Oregon or the State of Idaho. However, as part of the public process outlined in Idaho by House Bill 1284, if a local watershed advisory group (WAG) requests that an unlisted pollutant be addressed in a TMDL, IDEQ should make every reasonable effort to accommodate the request. Two members of the SR-HC Public Advisory Team (which acts as the WAG for the SR-HC TMDL process) requested that the SR-HC TMDL address total dissolved gas. In an effort to accommodate this request, total dissolved gas has been incorporated into this loading assessment.

The Hells Canyon Complex is licensed by FERC, and requires 401 Certification from both the State of Oregon and the State of Idaho. Re-licensing of the Hells Canyon Complex is running somewhat concurrently with the TMDL process, and 401 Certification will run concurrently with the FERC re-licensing process. A very broad and capable effort involving many at the private, state and federal level is currently working to identify the full extent of total dissolved gas concerns, designated use support needs, and viable treatment options associated with total dissolved gas violations in the Hells Canyon Complex. As the re-licensing process proceeds, these efforts will be used to augment the general discussion included here, through 401 Certification of the Hells Canyon Complex. In addition, these processes will act in an enforcement capacity to provide reasonable insurance that total dissolved gas improvements in the Hells Canyon Complex will be realized and designated beneficial uses fully supported.

3.7.2 Designated Beneficial Use Impairment

Elevated total dissolved gas concentrations (above 110% of saturation) are known to have a detrimental effect on aquatic biota. High concentrations of gas dissolved in the water can result in *gas bubble trauma*. This condition occurs when air bubbles form in the circulatory

systems of salmon and resident fish (USA COE, 1999) "Gas bubble trauma results when the sum of the dissolved gas pressures exceeds the compensating pressures of hydrostatic head, blood, tissue, and water surface tension" (IPCo, 1998c, 1999b, 1999f).

The severity of the effects of this condition varies among the different aquatic species and among life stages within a species. Signs of gas bubble trauma have been observed in trapped adult fish below Hells Canyon Dam. Spring chinook salmon and steelhead trout are exposed to elevated total dissolved gas concentrations during spills, in both the adult and smolt stages of life. Fall chinook juveniles are exposed to elevated total dissolved gas. Little is known about the life stages and populations of resident and fluvial bull trout within the Snake River (IPCo, 1998c).

Elevated total dissolved gas levels from spills through the Hells Canyon Complex reservoirs may be a significant factor in resident and anadromous fish survival both in the reservoirs and downstream in the Snake River. A study by IPCo determined that in general, spills in excess of 2,000 to 3,000 cfs result in total dissolved gas levels that exceed the state standard of less than 110 percent of saturation both within the reservoirs and downstream in the Snake River (IPCo, 1998c, 1999b, 1999f).

3.7.2.1 SALMONID SPAWNING.

This designated beneficial use applies to the Downstream Snake River segment (RM 247 to 188) only, and is specific to those salmonids identified to spawn in this area, namely fall chinook and mountain whitefish. When runoff volume forecasts consistently indicate that an upcoming season will be an above average runoff year, reservoir volumes are evacuated to make a sort of buffer for the snowmelt/runoff. As a result, spill occurs and total dissolved gas concentrations downstream have the potential to exceed the state standards for saturation. This can often occur for much of the juvenile and adult spring migration period (April through June).

3.7.2.2 THREATENED AND ENDANGERED SPECIES.

A number of species listed as threatened or endangered under the Federal ESA, are known to inhabit the SR-HC TMDL reach. Adult bull trout, known to utilize the reservoir segments, are listed as threatened under the ESA. The SR-HC TMDL reach and some inflowing tributaries below Hells Canyon Dam also provide habitat for the Snake River fall and spring/summer chinook as well as steelhead, all of which are listed as threatened under the ESA.

A more complete description of these species, their status and their habitat needs is outlines in the Subbasin Assessment (Section 2.2.2.3). A general listing is included below.

Bliss Rapids snail (*Taylorconcha serpenticola*)
Distribution: mainstem Snake River below Hells Canyon Dam from RM 229 to 225 (IPCo, 2001a).

Bull Trout (*Salvelinus confluentus*)
Distribution: mainstem Snake River from RM 272.5 to RM 188

Fall Chinook (*Oncorhynchus tshawytscha*)
Distribution: Mainstem Snake River from RM 247 to RM 188.

Spring and Summer Chinook (*Oncorhynchus tshawytscha*)
Distribution: Mainstem Snake River from RM 247 to RM 188.

Steelhead (*Oncorhynchus mykiss*)
Distribution: Mainstem Snake River from RM 247 to RM 188.
All of the species listed above as threatened or endangered rely on good water quality for survival. Waters are designated for salmonid spawning and rearing in the downstream Snake River segment (RM 247 to 188) of the SR-HC TMDL reach. Waters so designated are required to exhibit appropriate concentrations of water column dissolved oxygen, intergravel dissolved oxygen, temperature, pH, ammonia, toxics, and turbidity for full support of fish during the spawning, incubation and rearing periods for those salmonid species inhabiting the designated waters. General time periods for spawning and incubation of the salmonid species identified to use the Downstream Snake River segment are shown below. A complete table of fish species in the SR-HC TMDL reach is available in section 3.6.9.2 of this document.

- Chinook salmon (fall) Oct 23 to April 30*
- Mountain Whitefish Nov 01 to March 15*

*represents spawning times identified by IDFG and ODFW as specific to the SR-HC reach.

Elevated total dissolved gas concentrations from spills through the Hells Canyon Complex reservoirs may be a significant factor in resident and anadromous fish survival both in the reservoirs and downstream in the Snake River. A study by IPCo determined that in general, spills in excess of 2,000 to 3,000 cfs result in total dissolved gas concentrations that exceed the state standard of less than 110 percent of saturation both within the reservoirs and downstream in the Snake River (IPCo, 1998c, 1999b, 1999f).

3.7.3 Sources

Elevated total dissolved gas from hydropower operations is a wide spread problem throughout the Pacific Northwest. Gas supersaturation is caused when air becomes dissolved in water while spilling over a dam into the depth of a plunge pool. High hydrostatic pressure causes the air to be driven into solution, resulting in supersaturation. The detrimental effects of supersaturation on aquatic biota are well documented. Elevated total dissolved gas concentrations pose a potential threat to threatened and endangered species of fish along with other aquatic biota within the Snake River (IPCo, 1998c, 1999b, 1999f). Elevated total dissolved gas concentrations are the result of spilling water over spillways of dams. Spill at Brownlee and Hells Canyon Dams is the only source of elevated total dissolved gas in the SR-HC reach.

3.7.3.1 NATURAL SOURCES.

There are no known natural sources of total dissolved gas that result in substantial loading or standards violations in the SR-HC TMDL reach.

3.7.3.2 ANTHROPOGENIC SOURCES.

Elevated total dissolved gas concentrations are the result of spilling water over spillways of dams. Spill at Brownlee and Hells Canyon Dams is the only source of elevated total dissolved gas in the SR-HC reach.

Voluntary Spill. At this time, voluntary spill does not occur within the Hells Canyon Complex. Spill at dams occurs only involuntarily, usually as a result of flood control constraints.

Involuntary Spill. The US Army Corps of Engineers (USA COE) is responsible for defining flood control requirements for the Hells Canyon Complex. At times of rapid runoff within the Snake River system, upstream facilities may not be able to retain the quantity of water passing through. In these cases, Brownlee Reservoir may be required to evacuate some reservoir volume to retain this excess flow and prevent flood events downstream. In this event, water may be spilled with attendant high total dissolved gas concentrations. Brownlee Reservoir is the only reservoir in the Hells Canyon Complex to be operated for flood control. The decision to release water from Brownlee Dam for flood control purposes is made on a system wide basis, and may be in response to conditions upstream rather than in response to hydraulic capacity concerns specific to Brownlee Reservoir or the Hells Canyon Complex.

3.7.4 Transport and Delivery

A study conducted by IPCo in 1999 showed a declining trend in total dissolved gas concentrations with distance downstream from the Hells Canyon Dam. Spill episodes at Hells Canyon Dam over 19,000 cfs caused exceedences of the less than 110 percent of saturation standard throughout the Downstream Snake River segment (RM 247 to 188) of the SR-HC TMDL. Total dissolved gas concentrations did not drop below 110 percent of saturation upstream of RM 188 at this level of discharge. Standard exceedences from spill volumes between 9,000 cfs and 13,400 cfs were not observed below RM 200, and spill volumes of 2,400 cfs showed standard exceedences that extended downstream to RM 230 only. The total distance downstream of the dam where water was observed to exceed the less than 110 percent of saturation standard was directly related to the volume of the spill. When spill occurred at 16,500 cfs at Brownlee Dam, but with no spill at Hells Canyon Dam, the less than 110 percent of saturation standard was not observed to be exceeded downstream of Hells Canyon Dam. In this case, elevated total dissolved gas concentrations were not “transported” through the reservoir complex to downstream segments.

3.7.5 Data Available for the Snake River - Hells Canyon TMDL Reach

Only summary data was available for this assessment. Plant capacities for the Hells Canyon Complex Reservoirs are 35,00 cfs (Brownlee Dam), 28,000 cfs (Oxbow Dam), and 30,500 cfs (Hells Canyon Dam) (IPCo, 1998c, 1999b, 1999f). Because of the limited capacity for flood storage within the Hells Canyon Complex reservoirs, high flows are spilled through the three dams on a regular basis. Whenever the reservoirs are full, river flows that exceed the hydropower plant capacity of the dams are passed over the spillway (IPCo, 1998c, 1999b, 1999f).

Spill within the SR-HC TMDL reach generally occurs during the time period from December through June/July for the Hells Canyon Complex reservoirs. The highest frequency of spill is during the time period from April through June.

It should be noted that while upstream impoundments are known to have no effect on total dissolved gas concentrations in Brownlee Reservoir, water entering the reservoir is often at or near saturation (100%).

3.7.5.1 Observed Effects of Spills from Brownlee Dam.

Spill tests were conducted at Brownlee Dam on June 4, 1998 at a spill level of 39,000 cfs. The tests were conducted to determine if spilling through the upper or lower gates resulted in a measurable difference in total dissolved gas in the downstream waters. The total dissolved gas concentrations observed from spilling through the upper gates averaged 114 percent of saturation while spill through the lower gates averaged 127.7 percent of saturation. This difference, probably due to degassing from wave effects and surface turbulence after the plunge from the spillway, was considered to represent a potential benefit to aquatic species in the Oxbow and Hells Canyon reservoirs as spill from Brownlee Dam is the largest influence on total dissolved gas concentrations within these reservoirs (IPCo, 1998c, 1999b, 1999f).

When spill occurred at 16,500 cfs at Brownlee Dam, with no spill at Hells Canyon Dam, the less than 110 percent of saturation standard was not observed to be exceeded downstream of Hells Canyon Dam. Therefore, while elevated total dissolved gas concentrations from spill at Brownlee Dam have been observed to have an effect on the total dissolved gas in Oxbow and Hells Canyon reservoirs, the effect is not observed to extend to the Downstream Snake River segment (RM 247 to 188) of the SR-HC TMDL reach.

3.7.5.2 Observed Effects of Spills from Hells Canyon Dam.

Spill tests were conducted at Hells Canyon Dam on June 3, 1998 at a spill level of 28,000 cfs. The tests were conducted to determine if spilling through the upper or lower gates resulted in a measurable difference in total dissolved gas in the downstream waters. The total dissolved gas concentrations observed from spilling through the upper gates averaged 139 percent of saturation while spill through the lower gates averaged 135 percent of saturation. This difference was much smaller than that observed with Brownlee Dam, but was considered to represent sufficient benefit to aquatic species in the Downstream Snake River segment (RM 247 to 188) that the lower gates were recommended to be used for spill when ever possible.

Spill episodes at Hells Canyon Dam over 19,000 cfs caused exceedences of the less than 110 percent standard throughout the Downstream Snake River segment (RM 247 to 188) of the SR-HC TMDL. Total dissolved gas concentrations did not drop below 110 percent of saturation upstream of RM 188 at this level of discharge. Standard exceedences from spill volumes between 9,000 cfs and 13,400 cfs were not observed below RM 200, and spill volumes of 2,400 cfs showed standard exceedences to RM 230 only. The total distance downstream of the dam where water was observed to exceed the less than 110 percent standard was directly related to the volume of the spill.

During the period of no spill, the state standard of less than 110 percent of saturation within the Snake River below Hells Canyon Dam was never exceeded.

Hourly monitoring of total dissolved gas concentrations below Hells Canyon Dam in 1999 (IPCo, 1999f) showed a defined relationship between spill and total dissolved gas below the dam. Total dissolved gas in the tailwater area of Hells Canyon Dam ranged from 108 percent of

saturation to 136 percent of saturation while spill was occurring from Hells Canyon Dam. Nearly all levels of spill monitored resulted in total dissolved gas concentrations above the less than 110 percent of saturation target. The data collected indicate that total dissolved gas concentrations in the Downstream Snake River segment (RM 247 to 188) of the SR-HC TMDL are largely dependent on the occurrence of spill at Hells Canyon Dam and that upstream spill has little effect (IPCo, 1999f). Turbine operations seem to have little affect on total dissolved gas concentrations relative to the effects of spill (IPCo, 1999f, 2000e).

3.7.6 Determination of Total Dissolved Gas Loading

An accurate determination of total dissolved gas loading is not possible with the limited amount of data available to the SR-HC TMDL process. This assessment is being accomplished as part of the FERC re-licensing process, and will be evaluated as part of the State 401 Certification processes. It is not critical to this effort therefore, to generate an estimate of total loading at this time. Rather, it is sufficient to observe that the Hells Canyon Complex reservoirs along with dam operations have resulted in periodic exceedences of the less than 110 percent of saturation total dissolved gas target within the SR-HC TMDL reach.

Exceedences of the total dissolved gas target of less than 110 percent of saturation occur in both Oxbow and Hells Canyon reservoirs (as related to spill from Brownlee Dam in excess of 2,000 to 3,000 cfs).

Similarly, spills from Hells Canyon Dam in excess of 2,000 to 3,000 cfs result in total dissolved gas concentrations exceeding the total dissolved gas target of less than 110 percent of saturation in the Downstream Snake River segment (RM 247 to 188) of the SR-HC TMDL reach (IPCo, 1998c, 1999b, 1999f).

As they represent both a direct violation of state standards and an exceedence of the SR-HC TMDL target, and therefore pose a potential threat to threatened and endangered species of fish along with other aquatic biota within the Snake River, a TMDL for total dissolved gas in the SR-HC TMDL reach has been established that will ensure support of designated beneficial uses and attainment of the SR-HC total dissolved gas target. This will result in attainment of State total dissolved gas standards.

3.7.7 TMDL Determination

The TMDL for total dissolved gas in the SR-HC TMDL reach is set at the target value of less than 110 percent of saturation.

The total allowable mass of total dissolved gas (as nitrogen) equates to: Allowable Saturation (</=110%) multiplied by the solubility constant of N_2 (as determined for the appropriate temperature and pressure), multiplied by the appropriate flow value for the designated mixing zone. This applies to all discharge flows not exceeding the ten-year, seven-day average flood flow volume for Brownlee and Hells Canyon Dams, identified by Idaho Power Company as 72,500 cfs.

It is recognized that the FERC re-licensing and State 401 Certification processes may utilize site specific data and designated beneficial use needs to identify a more site specific target for total dissolved gas in the SR-HC TMDL reach. If this occurs, and if the alternative target proposed by these processes is shown to fully support the designated beneficial uses within the system, the load allocation from this TMDL will be revised to reflect the new target.

3.7.8 Load Allocations

Section 4.0 contains detail on load allocations for total dissolved gas.

3.7.9 Appropriate Actions

Controlling elevated total dissolved gas can be achieved through controlling spill. If possible, spilling from projects with the least propensity for developing high total dissolved gas level, changing the spill patterns, and using spillway bays with deflectors are all potential options for reducing total dissolved gas exceedences. Additional options in a managed system may include storing more water in the upstream reservoirs within the system, putting more water through the turbines, or transferring spills outside the system.

Unfortunately, given the nature of the SR-HC TMDL system and the conditions during which spill occurs (high runoff volumes), there is not always enough time or system capacity to utilize the full suite of options.

A number of options for the management of total dissolved gas within the Hells Canyon Complex have been discussed as part of the FERC re-licensing process. The options selected will be the decision of the Complex operators (IPCo) and the overall requirements of the re-licensing process. Obviously, key decisions needed to manage high total dissolved gas will be driven by aquatic life support considerations, based on projected spill and total dissolved gas conditions.

The implementation of the final TMDL load allocation requirements for total dissolved gas will be incorporated into the state specific 401 Certification process, thus lending a substantial amount of assurance that a mechanism for implementation will be available to the process.

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