Draft
EPA Region 10 Guidance
for
State and Tribal Temperature Water Quality Standards

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I. Introduction

This guidance describes how States and authorized Tribes (Tribes) in the Pacific Northwest may adopt water quality standards (WQS) for temperature that will support sustainable populations of native salmonids and meet the requirements of the Clean Water Act (CWA) and Endangered Species Act (ESA). This guidance was developed through a collaboration with representatives of the Pacific Northwestern States, Tribes, and the U.S. Fish and Wildlife and National Marine Fisheries Services (Services). EPA intends to use this guidance when it reviews State and Tribal temperature WQS or promulgates federal temperature WQS for Idaho, Oregon, or Washington.

This guidance does not preclude States and Tribes from adopting, nor EPA from approving, temperature standards different than those described here provided such standards are demonstrated to be consistent with the CWA and ESA. The burden, however, will be on States or Tribes to demonstrate how a different temperature standard supports salmonids and meets the requirements of the CWA and the ESA.

II. Regulatory Background

The goal of the CWA is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters and where attainable, to achieve water quality which provides for the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water. As a means of meeting this goal, Section 303(c) of the CWA requires States and authorized Tribes to adopt WQS which include designated uses, water quality criteria to protect designated uses, and a policy on antidegradation. Further, States and Tribes may adopt into their standards policies for their application and implementation. EPA is required to approve or disapprove new or revised State and Tribal WQS to ensure they are consistent with the requirements of the CWA. Further, new and revised standards are not in effect for CWA purposes until they are approved by EPA. If EPA disapproves a new or revised State or Tribal WQS or if the EPA Administrator determines that an existing State or Tribal WQS does not meet the requirements of the CWA, EPA must propose and promulgate appropriate WQS itself, unless appropriate changes are made by the State or Tribe.

EPA's approval of State or Tribal WQS that may affect threatened or endangered species or their critical habitat are federal actions subject to Section 7 of the ESA. Section 7(a)(2) of the ESA requires EPA to ensure, in consultation with the Service(s), that any action it takes is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction of critical habitat. For actions that are likely to adversely affect listed species, the ESA requires the Service(s) to issue a Biological Opinion which will, among other things, typically require compliance with specified measures designed to minimize adverse effects. Section 7(a)(1) of the ESA requires EPA to use its authorities to carry out programs for the conservation of endangered and threatened species.

EPA has a federal trust relationship with federally-recognized Pacific Northwest tribes. In the Pacific Northwest, federal courts have affirmed that certain tribes reserved through treaty the right to fish at all usual and accustomed fishing places and to take a fair share of the fish destined to pass through such areas. EPA's approval of a State or Tribal WQS or promulgation of its own WQS may directly impact the habitat that supports the treaty fish. EPA must ensure that its WQS actions do not violate treaty fishing rights.

III. Overview of Water Temperature and Salmonids

Water temperatures significantly affect the distribution, health, and survival of native salmonids in the Pacific Northwest. Since salmonids are ectothermic (cold-blooded), their survival is dependent on external water temperatures and they will experience adverse health effects when exposed to temperatures outside their optimal range. To the extent that cold water is available, salmonids will use behavioral means to avoid harmful temperatures and maintain optimal body temperatures. Salmonids have adapted and thrived under the cold thermal conditions that historically existed (i.e. pre-Euro-American settlement) in Pacific Northwest streams and rivers, even though temperatures were not optimal for salmonids at some places and times.

While there are many factors that have contributed to the decline of native salmonid populations, elevated water temperatures caused by human activities has played an important role, both directly and indirectly through synergistic interactions with other factors such as habitat loss and disease. It follows that human actions to lower water temperatures in streams and rivers that have been altered by human activity will play an important role in restoring and protecting native salmonid populations.

To restore and protect sustainable salmonid populations, optimal thermal conditions must be present in sufficient quantity and well distributed and connected throughout their range. However, because salmonids can use behavioral means to avoid harmful temperature to some extent, optimal temperatures do not have to occur everywhere all the time. The challenge is to ensure that sufficient amounts of optimal thermal conditions exist during the places and times salmonids need it to fulfill their life cycle. Determining this is a difficult task. One reliable reference point, however, is the historical thermal conditions that once existed in the Pacific Northwest, which we know supported large, healthy salmonid populations.

A simple approach to a temperature water quality standard would be to select, for all waters, a single maximum temperature value below which adverse effects are minimized for salmonids. There are three reasons that following this simple approach is problematic for the protection of Pacific Northwest native salmonids. First, salmonids have multiple life stages (e.g. spawning, juvenile rearing, adult migration) with unique water temperature requirements and unique associated adverse effects if temperatures are not optimal (e.g. too warm). Second, as noted above, Pacific Northwest streams and rivers historically experienced temperatures warmer than levels considered protective for salmonids at certain places and times. Salmonids responded to these naturally warm conditions by seeking refuge in areas of colder water. Third, selecting a single protective temperature value may allow the warming of waters that are currently colder than the single temperature value <u>if</u> downstream temperature impacts are not fully addressed. For instance, if cold water in a river's headwaters are allowed to warm up to the single temperature value, that increased heat in the system may cause lower reaches of the river to exceed the protective temperature level. It is important to note that this situation is not legally permissible, but it may happen in practice if appropriate analysis is not conducted.

Each of the these problems represents a challenge to the design of an effective temperature WQS. EPA's recommendations described below collectively address these identified challenges.

IV. Overview of EPA's Recommendations for Water Temperature

EPA recommends the following four-part approach for State and Tribal temperature WQS to support native salmonids in the Pacific Northwest:

- Development and adoption of thermal potential numeric criteria
- Adoption of "interim" species-life-stage numeric criteria
- Adoption of a temperature management plan provision
- Adoption of provisions to protect existing cold water areas

Each of these recommendations are briefly described below along with the rationale for their inclusion. A more detailed description of each of these recommendations is presented in Section V.

EPA believes the most scientifically credible way to ensure that sufficient cold water exists to support salmonids, while allowing some waters to be warmer than optimal thermal conditions, is to develop numeric criteria based on the thermal potential of a water body. Thus, the first recommendation of this guidance is for States and Tribes to embark on a process to estimate the thermal potential of water bodies and adopt numeric criteria based on that potential. EPA believes the most appropriate geographic area to assess thermal potential is generally the sub-basin scale. For reference, a basin is the drainage area of major tributaries to the Snake and Columbia rivers and other major rivers that drain into the Ocean or Puget Sound (e.g. Grand Ronde river in Oregon, Chehalis river in Washington, and the Clearwater river in Idaho). Each of these basins is comprised of several sub-basins. In some situations, however, other scales may be more appropriate. For example, for large main stem rivers it may be more appropriate to estimate thermal potential on just the main stem itself.

Numeric criteria based on a sub-basin or main stem's thermal potential, referred to here as "thermal potential numeric criteria," are adopted as part of a State or Tribe's WQS and are specific to each water body, perhaps varying by river reach. That is, each reach along the river may have a unique numeric criteria based on thermal potential of that reach. The thermal potential numeric criteria would define the maximum allowable temperatures for critical seasons (e.g. summer). These maximums would be reflective of an average meteorological year (e.g. average air temperature and rainfall) with appropriate adjustments for other identified climate conditions (e.g hot/dry and cold/wet years).

EPA recognizes that it will take time to develop thermal potential numeric criteria for all of a State or Tribe's waters or that in some cases a State or Tribe will consider it unnecessary or impractical to do so. To address the interim period prior to the adoption of thermal potential numeric criteria or where a State or Tribe has determined not to develop thermal potential numeric criteria, EPA's second recommendation is that States and Tribes adopt a set of numeric criteria that protects the various salmonid life stages (e.g. spawning and rearing). The recommended "species-life-stage numeric criteria" described below represent thermal conditions that are protective of native salmonids based on their biological thermal requirements and would apply where and when the different life stages occur. These species-life-stage numeric criteria are set at the warmer end of salmonid's optimal thermal range and at levels EPA believes are likely to result in few if any adverse effects.

EPA's third recommendation is for States and Tribes to adopt a temperature management plan provision in their WQS as a means of implementing the species-life-stage numeric criteria for NPDES sources prior to the completion of a TMDL. EPA believes an appropriate way to provide flexibility in meeting species-life-stage numeric criteria is for State or Tribal WQS to allow NPDES sources to meet these criteria by complying with a temperature management plan which ensures offsetting reductions from other sources, if needed, as a means of supporting salmonids. A temperature management plan would require that all feasible steps toward meeting the species-life-stage numeric criteria be implemented and that off-site mitigative actions to reduce temperature be taken if the source's discharge does not meet the species-life-stage numeric criteria after the implementation of all feasible steps.

EPA endorses the use of NPDES temperature management plans because they can provide a mechanism to protect salmonids without placing the burden unduly upon point sources prior to the time a TMDL is established. A TMDL may distribute necessary reductions more broadly between point and non-point sources. The off-site mitigation provisions, in combination with other requirements of a temperature management plan discussed in more detail in Section V, should, when properly implemented, be equivalent or more beneficial to salmonids than meeting the species-life-stage criteria at the source. Moreover, in some situations it may turn out that the thermal potential is higher than the species-life-stage numeric criteria and requiring a NPDES source to meet the species-life-stage numeric criteria at the source prior to determining the thermal potential may result in an unnecessary commitment of resources. After a TMDL is developed and more information about the thermal potential and the overall thermal reduction needs for all sources are known, a NPDES source will need to meet water quality-based effluent limitations derived from its waste load allocation in the TMDL.

EPA recognizes that it will take time to restore the thermal conditions in the Pacific Northwest to fully support salmonids and that in the near term there should be sufficient protections in place to prevent the degradation of existing thermal conditions of water bodies. In particular, protection of existing habitat that is colder than the species-life-stage numeric criteria is likely to be important for the maintenance of downstream temperatures and critical for salmonid survival given their already depleted status. To address this, EPA's fourth recommendation is for States and Tribes to adopt provisions in their WQS requiring no net increase in thermal loadings (i.e. any temperature increase is offset by a decrease) in waters that support salmonids and no increased thermal loads to waters designated as critical cold water salmonid refugia.

Regarding the species-life-stage numeric criteria, temperature management plans, and the provisions to protect existing cold water described above, it is also important to note that EPA's recommendations are based on how these provisions would interact and the combined effect they would likely have on salmonids. While the species-life-stage numeric criteria are set at a level to avoid most or all adverse effects, the allowance for implementation through temperature management plans, though an important source of flexibility for point sources, may lead to localized adverse effects. By implementing temperature management plans with the recommended safeguards described in this guidance, and by implementing the provisions to protect existing cold water, States and Tribes will be appropriately mitigating any adverse effects. EPA believes that implementing this combination of provisions is a sound strategy for ensuring that the mitigation measures already provided for under this approach will adequately counterbalance any adverse effects, thus making it unnecessary to develop new and additional mitigating measures in the ESA consultation process that accompanies EPA's review of the standards.

V. Specific EPA Recommendations for State and Tribal Temperature WQS

V.1. Development and Adoption of Thermal Potential Numeric Criteria

EPA recommends that States and Tribes develop and adopt thermal potential numeric criteria based on an estimate of the thermal potential of rivers and streams within a sub-basin or a main stem river. The recommended process for developing thermal potential numeric criteria is described in detail in Appendix B and is summarized here. Thermal potential is defined here as the estimated thermal regime after all reversible anthropogenic sources of heat are removed. It is important to differentiate this term with *natural or historic* thermal potential, which is defined here as the estimated thermal regime that existed prior to Euro-American settlement. EPA recognizes that in some cases it is unreasonable to expect that the historic thermal regime can be fully re-established given the current level of human development in the Pacific Northwest. Thus, EPA believes it may be acceptable that the thermal potential numeric criteria reflect some level of anthropogenic impact. That said, the closer the thermal potential numeric criteria are to reflecting the historic thermal regime, the higher degree of confidence there will be that the thermal potential numeric criteria support salmonids uses.

If modeling methodologies and data are readily available, EPA recommends that the *natural* thermal potential be estimated first and, if necessary, an irreversible anthropogenic thermal increment can be added to establish the thermal potential numeric criteria. When estimating the natural thermal potential EPA recommends that multiple lines of evidence (i.e. multiple sources of information) be used. Multiple lines of evidence, to the extent that it is available, should include: modeled natural thermal potential, historical and current species presence, historical temperature data, and comparison to similar river systems that are relatively unimpaired. These multiple lines of evidence should be compared and systematically reconciled giving the greatest weight to those lines of evidence that have the highest level of confidence. To assist in this process, uncertainty bounds should be established for each of the lines of evidence.

EPA recognizes that in some cases it may be impracticable to estimate natural thermal potential. This may be true when it is difficult to model certain historical conditions that are considered to be altered by largely irreversible anthropogenic causes. Thus, it may not be worthwhile to spend the time and effort to predict temperatures that States and Tribes believe are not attainable because the temperature impairment is caused by human impacts that cannot realistically be reversed. In this situation thermal potential can be estimated directly. When following this approach, it is important States and Tribes are explicit about what historical conditions are not modeled because they are believed to be caused by irreversible human impacts. One example where this circumstance could arise is for rivers where there is urban development in the flood plain. In this case, it may be difficult to model the historic groundwater conditions in the flood plain that likely helped cool the river in the summer and it is unrealistic that those historical conditions can be fully restored. Even though EPA recognizes that States and Tribes may follow this approach for practical reasons, EPA believes it is preferable to estimate natural thermal potential as described above in order to serve as a reference when evaluating whether a thermal potential criteria other than natural thermal potential supports salmonid uses. Thus, natural thermal potential should be estimated where ever practicable, even if some of the human impacts are viewed to be irreversible.

As mentioned previously, EPA recommends that thermal potential numeric criteria generally be adopted at the sub-basin scale (approximately a 4^{th} field hydrologic unit code). This scale is large enough to map-out the timing and location of the fresh-water life cycles of salmonids, allows for the evaluation of the cumulative impacts of heat in the system (i.e. the impact of upstream water temperature on downstream temperatures can be determined), has been shown to be successfully modeled, and divides a State into a manageable number of units to do this work.

EPA also encourages States and Tribes to use this guidance to adopt the procedures for establishing thermal potential numeric criteria in their WQS regulations. EPA believes doing this will provide a clear indication not only that such criteria will be developed, but how this will be done, thereby improving the transparency and consistency by which thermal potential numeric criteria are derived. EPA believes that it is possible to approve the procedural regulations and avoid the need for approval of thermal potential numeric criteria for each individual sub-basin, provided the procedures can be defined sufficiently so as to be truly replicable. Whether this can be done will depend on the degree to which the procedural regulations can remove subjective judgement from criteria development. In any event, EPA will likely need to closely review the first few thermal potential numeric criteria to ensure that the process is functioning as expected. Of course, States and Tribes can adopt thermal potential numeric criteria without adopting the procedures to develop them.

Note to Reviewer

As an alternative to adopting thermal potential values as numeric criteria in a WQS, EPA is also considering the option of having thermal potential values be expressed as part of a TMDL. Under this option, thermal potential values would be numeric expressions interpreting a state or tribal temperature WQS that allows thermal potential to be met if the thermal potential is higher than the species-life-stage numeric criteria. Under this option, EPA would approve the thermal potential values as part of its TMDL approval, not as a WQS approval. EPA would use this guidance, including Appendix B, in its approval of the thermal potential values in a TMDL. EPA is interested in your comments on this alternative approach.

V.2. Adoption of Species-Life-Stage Numeric Criteria

Based on review of the most recent scientific literature, EPA recommends that States and Tribes adopt the species-life-stage numeric criteria described below for waters designated to support these various salmonid life stages. These species-life-stage numeric criteria would be effective for all waters until such time thermal potential numeric criteria are adopted to replace the species-life-stage numeric criteria for specified waters. These numeric criteria are based on the biological needs of salmonids and are set near the warm end of the optimal temperature range for these identified salmonid life stages and at levels EPA believes will result in few if any adverse effects.

A summary of the scientific basis for selection of the numeric criteria is described in Appendix A. Guidance regarding State and Tribal beneficial use designations determining where and when these criteria are applied is discussed in Section VI.

Char Salmonids (Dolly Varden and Bull Trout)

Spawning, Incubation, and Juvenile Rearing

Summer maximum temperature should not exceed a single daily maximum of 12°C (54°F)

Migratory Populations

Daily maximum temperature should not exceed 12°C (54°F)

Cold Water Salmonids (Pacific Salmon, Steelhead, and Coastal Cutthroat Trout)

Spawning/Incubation

The seven-day average of the daily maximum temperatures should not exceed 13°C (55°F), and the weekly mean temperature should not exceed 10°C (50°F)

Juvenile Rearing (covers smoltification, except steelhead)

The seven-day average of the daily maximum temperatures should not exceed 16°C (61°F), and the weekly mean temperature should not exceed 15°C (59°F)

Steelhead Smoltification

The seven-day average of the daily maximum temperatures should not exceed 14°C (57°F), and the weekly mean temperature should not exceed 12°C (54°F)

Adult Migration

The seven-day average of the daily maximum temperatures should not exceed 18°C (65°F), and the weekly mean temperature should not exceed 16°C (61°F)

Moderately Cold Water Salmonids (Interior nonadadromous redband trout, Lahontan cutthroat trout)

Spawning/Incubation

The seven-day average of the daily maximum temperatures should not exceed 13°C (55°F), and the weekly mean temperature should not exceed 10°C (50°F)

Juvenile Rearing

The seven-day average of the daily maximum temperatures should not exceed 20°C (68°F)

Note to Reviewer

EPA is interested in your suggestions on appropriate ways to apply the species-life-stage numeric criteria described above in a way that takes into account inter-annual meteorological conditions. EPA is also interested in your suggestions on relatively simple ways to apply these numeric criteria in a way that recognizes that some river reaches in the Pacific Northwest naturally experienced temperatures higher than these criteria for some times of the year prior to Euro-American settlement.

V.3. Interim Temperature Management Plans Provision

EPA recommends that States and Tribes adopt a provision in their WQS allowing NPDES sources to comply with water quality-based effluent limits derived from species-life-stage numeric criteria through a temperature management plan. EPA believes that such temperature management plans could protect the designated salmonid uses if they meet the following conditions. Accordingly, EPA recommends that States or Tribes *require* that temperature management plans meet these conditions:

- NPDES permits must require the implementation of the temperature management plan and that requirement must be enforceable.
- The plan must include implementation of all feasible steps by the facility to reduce thermal loading based on an analysis of all possible options. All feasible steps are defined as all management practices and treatment technologies that can be implemented by the source without causing undue economic hardship, as determined by the permitting authority.
- Under no circumstances shall a source's discharge contribute to incipient lethal temperatures (77F, 25C) in a water body (including within a mixing zone).
- A source's discharge shall not contribute to salmonid migration blockage temperatures (70F, 21C) in more than a quarter of the receiving water.
- If, after implementation of all feasible steps a source's discharge (end-of-pipe) is higher than the species-life-stage numeric criteria, then the source must offset the excess heat load (excess btu input) through mitigative actions elsewhere in the sub-basin. Mitigative actions must be in areas of salmonid habitat that are comparable in life stage supported, and of similar or greater productivity, in order to have similar effects on salmonid survival. Examples of mitigative actions may include, but are not limited to: restoration of stream-side vegetation, purchase of water rights for in-stream flow, and restoration of stream channel conditions to enhance groundwater exchange. Additionally, thermal reductions acquired through mitigation cannot include actions that are currently mandated or funded by existing federal or state regulations and programs.

- Thermal reductions fully realized through mitigative actions during the 5 year term of the permit may offset a source's heat loading on a 1-to-1 basis. If a State or Tribe chooses to allow mitigative actions not realized until later to count as offsets, it should appropriately discount those offsets to counterbalance the present adverse effects to the species. EPA is not presently able to recommend a scientifically-based offset scheme, but is open to evaluating such a scheme if a scientifically sound basis is provided. For illustrative purposes only, such a scheme might provide as follows: the offset is 2:1 for thermal reductions 5-10 years in the future, 3:1 in 10-15 years, 4:1 in 15-20 years, and 5:1 in 20-30 years.

After a TMDL is developed based on either species-life-stage or thermal potential numeric criteria and approved by EPA, NPDES sources must comply with the water quality-based effluent limitations in their permit derived from waste load allocations in the TMDL.

State and Tribes at their own discretion may elect to establish a temperature management plan provision for non-point sources. EPA will view these as state implementation mechanisms for non-point sources, which are outside EPA's authority under the CWA. Thus, EPA will take no action on such plans under Section 303(c) of the CWA.

V.4. Protection Of Existing Cold Water Areas

EPA recommends that States and Tribes adopt provisions in their WQS intended to further protect waters supporting salmonids that are currently colder than the species-life-stage numeric criteria. EPA notes that States and authorized Tribes are required to adopt into their WQS an antidegradation policy which provides for the protection of existing uses, high quality waters unless it is determined that lowering of water quality (e.g. increased heat loading) is necessary to accommodate important economic or social development, and water determined by the State or Tribe to be an outstanding national resource water.

To protect those high quality waters where water quality exceeds the numeric criteria, EPA recommends that State and Tribes adopt into their WQS a provision prohibiting any sources from adding heat to waters that support endangered or threatened salmonids unless the added thermal load is offset through mitigative actions elsewhere in the sub-basin. The same stipulations regarding mitigative actions and offsets that apply for temperature management plans described in Section V should also apply here. Additionally, EPA recommends that States and Tribes designate localized areas of cold water salmonid refugia as outstanding national resource waters of special ecological significance for the support of threatened and endangered salmonids. For these designated waters, additional heat loading is prohibited. In particular, EPA strongly encourages these cold water refugia designations for areas that exist in rivers where the main channel exceeds the species-life-stage numeric criteria.

VI. Additional EPA Guidance Related to Temperature WQS

VI.1 Beneficial Use Designations for Salmonids

The various salmonid life stages for which EPA is recommending species-life-stage numeric temperature criteria occur at certain geographic locations and at specific times of the year. To protect salmonid species, species-life-stage numeric criteria need to apply to specific beneficial use designations that describe where and when the various life stages occur (i.e. the specific life stage is the designated use). Furthermore, the beneficial use designations also define where and when thermal potential numeric criteria can be adopted in place of the species-life-stage numeric criteria.

To sufficiently protect the already diminished native salmonid populations, EPA recommends that States and Tribes designate a species life stage use for areas where there is reasonable potential for that use to exist. Designating areas for protection only where salmonid presence is documented, for instance, would likely not be a sufficiently protective approach, for two reasons. First, for threatened or endangered species listed under the ESA, the appropriate presumption should be that the present range of the species may be insufficient to support survival and recovery (i.e., there may be locations and times where salmonids would exist but for human-caused elevated temperatures). Second, even if the present range were sufficient, commonly-used methods for documenting the presence of fish tend to underestimate actual range, and are insufficiently reliable to function as the sole support for use designation (i.e. absence of evidence is not evidence of absence).

EPA recognizes, however, that it is unreasonable to designate uses for all waters where salmonids once existed in the Pacific Northwest. Some areas, such as above large impassable dams (as defined by NMFS in their critical habitat designations), will not support anadromous salmonid use in the near future. EPA does, however, recognize that removal of some fish passage barriers will occur in the Pacific Northwest to support the recovery of salmonids. EPA recommends that States and Tribes include in their use designations waters that are anticipated to be available for salmonid use due to fish passage improvements in the near term (including areas where "trap and haul" programs allow passage above dams) and that species life stage use designations be reviewed during each WQS triennial review to reflect the latest information on potential salmonid use.

VI.2 Relationship to CWA Section 303(d) Listings and TMDLs

The existing State and Tribal water quality temperature criteria are the applicable water quality standards for purposes of CWA section 303(d) listings and TMDLs and will remain so until the EPA approves new or revised State or Tribal temperature WQS. After EPA approves newly adopted State or Tribal species-life-stage or thermal potential numeric criteria those criteria become the basis for section 303(d) listings and TMDLs. EPA expects section 303(d) lists to be updated during the next section 303(d) listing cycle to identify waters that do not meet the newly adopted and approved criteria.

During the next 303(d) listing cycle after new temperature WQS are effective, TMDLs developed to meet the previous temperature WQS should be reviewed to determine if they are sufficient to meet the new WQS. If they are not, waters covered by the TMDL may need to be re-listed and a new TMDL may need to be developed. That said, it is not EPA's expectation that States or Tribes evaluate or revise recently completed and approved temperature TMDLs or re-list waters covered by these TMDLs in the short term because priority should generally be devoted to completing TMDLs for 303(d) listed waters for which there are no TMDLs.

VII. CWA and ESA Review of State and Tribal Temperature WQS that are Consistent with this Guidance

This guidance outlines an approach and design for temperature WQS that support sustainable populations of salmonids and meet the requirements of the CWA and the ESA. Of course, EPA, in consultation with the Services, must review and approve any new or revised WQS that are adopted by a State or Tribe to ensure the requirements of the CWA and the ESA are met. Because of the specific nature of EPA's recommendations regarding the species-life-stage numeric criteria, temperature management plans, and protection of existing cold water areas, CWA and ESA review of State and Tribal WQS that are consistent with these provisions in the guidance should be streamlined because, as noted previously, any associated adverse effects are likely to be sufficiently mitigated through the combined implementation of these provisions.

Because of the complexity around the development of thermal potential numeric criteria there could be various interpretations of EPA's recommended approach to develop these criteria, so the level of review may be more involved for the first few thermal potential numeric criteria a State or Tribe submits to EPA for approval.

Appendix A
Recommended EPA Temperature Thresholds for use in Establishing Species-Life-Stage and Thermal Potential Numeric Criteria

1. Temperature Limits Recommended to Protect Salmonid Guilds

In this appendix, EPA recommends water temperature threshold values that are needed to fully protect native salmonid fishes of the Pacific Northwest. EPA believes that these threshold values represent general upper limits for optimal thermal conditions to support various species and life stages of salmonids fishes. EPA recommends that states and tribes apply these values to defined salmonid guilds. The species making up the membership of each guild share similar life-strategies and have similar habitat and temperature requirements and limitations. EPA recommends the use of three guilds for establishing temperature values: 1) A Char Guild which includes both bull trout and Dolly Varden; 2) A Cold Water Guild which includes the five Pacific salmon, coastal cutthroat and rainbow trout, and anadromous steelhead trout; 3) A Moderately Cold Water Guild which consists of interior redband trout and Lahontan cutthroat trout.

Within each guild, EPA established temperature values to protect key life stages such as spawning and incubation; juvenile rearing; subadult rearing; smoltification; and adult migration. The EPA did this to ensure that the temperature requirements for life-stages that occur outside the summer period would be protected. By setting values for individual life-stages the temperature thresholds can also be tailored to support the actual temporal patterns of fish use that occur in individual water bodies.

The values EPA recommends are estimates of upper optimal physiological temperature preferences known to support various life stages and biological functions of the salmonid fishes of the Pacific Northwest. The numbers do not represent rigid thresholds, but rather represent temperatures above which adverse effects are more likely to occur. In the interest of simplicity, important differences between various species of Pacific salmon are not reflected in the recommendations. The values thus reflect the characteristics of the guild in general, and any one species may appear to be a little more or a little less protected when their needs are compared to the recommendations. The values were reviewed, however, in recognition of how the species in these guilds temporally and spatially express themselves across the landscape. For example, coho salmon tend to require slightly colder temperatures for optimal incubation than other Pacific salmon. Coho usually occur in watersheds along with other salmon that spawn earlier in the fall, however, and thus application of the recommendations will generally provide that waters are on a fall cooling trend that creates healthy conditions for both earlier and later spawning species.

2. Recommendations for the Char Guild

Bull trout and Dolly Varden define the char guild in this guidance. These species are the region's most temperature-sensitive salmonids, and research has repeatedly suggested that summer maximum temperatures are one of the most important environmental constraint affecting their health and distribution in our region's streams. It is recommended that temperature thresholds that fully protect char include the following:

<u>Spawning, Incubation, and Juvenile Rearing</u>. Summer maximum temperatures should not be allowed to rise above a single daily maximum of 12°C (54°F).

<u>Migratory Life Stage</u>. In waters used by migratory fish during the warmest time of the year, temperatures should not be allowed to rise above a single daily maximum of 12°C (54°F). The important distinction between the recommendation for spawning and juvenile rearing waters and the recommendation for migratory life stage is that the migratory life stage recommendation may be applied on a seasonal basis to specific portions of watersheds, whereas the spawning waters threshold value is to be applied year-round.

The EPA recommends establishment of a single summer maximum temperature for waters used for spawning and tributary rearing in part to create some simplicity in its assignment and implementation and to reflect our knowledge of distribution of the different life stages. Maintaining water bodies at the farthest downstream extent of the early rearing use at a maximum summer temperature of 12°C, in recognition of natural fall cooling patterns, also assumes that sufficient water will be available for spawning and incubation in the early fall when such activity commonly begins. To reduce mortality of incubating eggs and developing larvae, temperatures must be on a downward trend and decline to 6°C in the weeks immediately following the initiation of incubation. The EPA assumes that with a seasonal drop in stream temperatures the average temperatures throughout incubation will remain in the range of 2-4°C. In order to ensure protection is occurring using this simplified framework, it will be important for states and tribes to cross check temperature patterns in watersheds against these incubation requirements to ensure that this expectation is being met on the ground. In site specific cases, where the char spawn in July or early August (during the warmest time of the year), the single day maximum will need to be adjusted to protect the spawning and incubation life-stage.

Char typically rear for the first one to three years in the same tributary where they first emerged from the gravels. The density and health of juvenile fish is supported by temperatures at or below 12°C, and the probability of juvenile occurrence is relatively high in portions of streams with daily maximum temperatures at or below 12°C. The occurrence and health of char populations quickly declines as temperatures increases above 12-13C. In recent laboratory studies examining optimal growth of char, an average daily temperature of 12°C has been shown to produce the best growth under variable diet constraints. This optimal laboratory estimate matches closely with the distributional patterns of these juvenile fish in the natural environment. This lends further strength to the 12°C single daily maximum recommendation.

The recommendation of a 12°C single daily maximum temperature to protect the migratory life stage of char is based on both the general patterns of health and occurrence noted above for juvenile fish and on numerous studies of salmonids that show larger, more mature fish do not have higher temperature thresholds than smaller, younger fish of the same species. It is also based on field studies showing that adult and sub-adult char tend to move out of waters once they warm to greater than 12°C. The flexibility to compare this value only to where and when the char actually occur in these waters is based on recognition that these older fish are more capable of migrating to more preferred waters and making use of thermal refuges along the way. This recommendation may need to be revisited in the future as more research is conducted on migratory char and their interaction with ambient temperatures in waters of the Pacific Northwest.

3. Recommendations for the Cold Water Guild

The cold water guild is defined by the presence of one or more of the following species of fish: any of the five Pacific salmon, anadromous steelhead trout, resident and anadromous coastal cutthroat, or coastal rainbow trout.

Waters used by species of the cold water guild are expected to be supported under the following temperature limits:

Spawning and Incubation. The seven-day average of daily maximum temperatures should not exceed 13°C (55°F), and the weekly mean temperature should not exceed 10°C (50°F) during the incubation period.

Juvenile Rearing. The seven-day average of daily maximum temperatures should not exceed 16°C (61°F), and the weekly mean temperature should not exceed 15°C (59°F). This temperature limit will also protect the smoltification (physiological preparation for salt water residence) of all of the species of the guild with the exception of steelhead, which would require cooler temperatures as specified below.

Steelhead Smoltification. To support the smoltification ability of juvenile steelhead trout, temperatures in tributary systems containing steelhead trout should not exceed a seven-day average of the daily maximum temperatures of 14°C (64°F), and a weekly mean of 12°C (54°F). This threshold should be applied at the scale of a 4^{th} level HUC watershed (for example, the mouth of the John Day River in Oregon, and the mouth of the Wenatchee River in Washington). Water temperatures necessary to support actively migrating steelhead smolts in mainstem rivers such as the Columbia and Snake are unknown. EPA determined that there is considerable scientific uncertainty whether thresholds for other sensitive life stages (i.e. juvenile rearing, adult migration) will provide water temperatures that sustain migratory behavior and sea-water readiness in advanced steelhead smoltification. However, steelhead smoltification thresholds applied to 4^{th} level HUC watersheds are expected to improve water temperature conditions in mainstem Columbia and Snake river migration corridors. Furthermore, recent historic spring water temperature conditions in the Columbia and lower Snake rivers will not exceed our recommendation for steelhead smoltification.

Adult Migration. To support adult migration, the seven-day average of the daily maximum temperatures should not exceed 18°C (64°C), and a weekly mean of 16°C (61°C). This recommendation should be used only in portions of water bodies, or at times of the year, where the adult migration is the only use by the species of this guild. If migration and rearing were to occur simultaneously, the cooler rearing threshold would take precedence. Likewise, spawning and incubation would be more thermally sensitive uses that would take precedence over the rearing or adult migration thresholds.

This cold water guild is composed of the greatest variety of key species, and EPA established recommendations in recognition of the general requirements of the species that comprise this guild, rather than basing them strictly on the most sensitive life-stage for the most sensitive species in the guild. Thus some compromise produced recommended thresholds that will cover this entire guild to result in a recommendation package that is far less complicated than what would have been necessary if each species received separate recommendations. The one clear exception is where EPA made a separate recommendation to protect steelhead trout. The research examined and experts consulted on this topic support the contention that smoltification in steelhead trout is uniquely sensitive to temperatures above 12 - 14°C. Initiation of smoltification and the early stages of smolt migration may be most sensitive to inhibition by warmer water temperatures. While the information reviewed suggested that a temperature threshold of 12°C would protect physiological adaptations necessary for successful sea-water entry of steelhead smolts, research also indicated that several weeks of higher peak temperatures could inhibit smolt development in steelhead trout. For this reason, EPA recommends a seven-day average of the daily maximum temperature of 14°C to limit the extent of daily maximum temperatures during steelhead smoltification. The current state of scientific knowledge concerning smoltification in steelhead trout supports the position that once steelhead smolts are actively migrating, it is unlikely that brief periods of slightly warmer than optimal water temperatures will result in precocious development, parr reversion, inhibition of migratory behavior, or significantly reduce sea-water adaptation.

The EPA considered growth rates, maximum swimming speed, maximum metabolic scope, and disease risks in recommending temperature levels that support juvenile rearing of this guild. Considering growth rates, EPA recognized that we cannot assume that fish will be receiving an unlimited supply of food during the warmest period of the summer rearing season. This recognition resulted in bringing the recommendation down a couple of degrees from the maximum growth rates that have been observed in controlled laboratory experiments where the fish were fed to satiation. This decision is consistent with both the demonstrated effects of reduced rations and with the recommendations of many of the key papers reviewed. Even making this adjustment, the recommended values are expected to result in less than maximum growth during the peak summer period. However, in reviewing temperature profiles of rivers of the Pacific Northwest it is clear that periods of sub-optimal growth due to higher temperatures will be kept sufficiently restricted and balanced with periods of sub-optimal growth due to colder water temperatures. Based on examining the growth rates occurring over longer-term experiments, the minor effects allowed with the rearing recommendation will not create a meaningful or detectable change in the maximum growth occurring at the end of the entire summer growing season.

In establishing the incubation recommendation, EPA recognized that excellent incubation success has been repeatedly observed in tests that were begun at temperatures of 13-14°C but were made to cool sharply over the following approximately two weeks to levels that have been found to be optimal (6-10°C) under constant temperature exposures. Further these studies acknowledged that the average temperature regime rather than the daily maximum temperatures, within reasonable limits (e.g., within limits of approximately 2-12°C), is the most influential factor on the health and survival of eggs and embryos. Temperatures above 13°C have also been associated with significant losses in eggs even while still retained unfertilized in the body cavity of female fish, and evidence is strong that maintaining water temperatures in the range of 12-14°C on the spawning grounds reduces disease and pre-spawning mortality in salmon species. These factors combine to suggest that maximum temperatures of 14°C or higher may pose several direct risks of mortality to spawning fish and their offspring and should be avoided, and that average weekly temperatures of 10°C and lower over the course of incubation may be necessary to ensure that there are not direct losses or harm to fertilized eggs and developing embryos. The EPA recognizes that if this recommendation is applied to the early portion of a fall spawning period or towards the end of the incubation period for spring spawning stocks, it will result in conditions during the preponderance of the incubation period that are solidly in the range of what has repeatedly been determined optimal for these cold water species (6-10°C).

In recommending temperatures that support adult migration, EPA particularly considered temperatures that allowed for sustained swimming performance, that minimized the risks of severe disease outbreaks, and that would not produce unreasonable metabolic demands on the energy reserves of migrating fish when experienced for short periods of time (days versus weeks) during migration through main-stem river reaches. The temperatures recommended provide that during the warmest portions of the day water temperatures still remain within what is optimal or near optimal for negotiating obstacles and swift currents, while remaining below levels that have been shown in field studies to reduced survival (i.e., increase pre-spawning mortality) of migrating adult salmon and their gametes.

4. Recommendations for the Moderately Cold Water Guild

The moderately cold water guild defined by the presence of either interior nonanadromous redband trout or Lahontan cutthroat trout. The recommendations for this guild are to be compared to water bodies where members of the two colder water guilds are typically absent.

The EPA expects, waters used by species of the cold water guild to be supportive under the following temperature limits:

Spawning and Incubation: The seven-day average of the daily maximum temperatures should not exceed 13°C (55°F), and the weekly mean temperature should not exceed 10°C (50°F) during the incubation period.

Juvenile Rearing: The seven-day average of the daily maximum temperatures should not exceed 20°C (68°F)

While species of this guild can thrive under summer water temperatures warmer than what is supportive of the cold water guild, their incubation requirements appear identical. Both these traits are at least partially due to these species spawning in the spring, which enables the species to select the period of time in the winter-to-spring period at which waters first become warm enough to support incubation. This still makes the species susceptible to harm from rapid spring warming that may exceed safe incubation thresholds, but does provide some natural resiliency. Further, the species of this guild are specific stocks or subspecies of the cold water guild that have evolved in warmer waters, and being resident fish that must cope with ambient stream conditions throughout their life-span, appear to have developed somewhat warmer optimal temperature thresholds. While these higher optimal thresholds are not dramatically higher than those exhibited by the species of the cold water guild, as compared to the preferences of warm water species, they are meaningful enough to warrant establishing separate temperature recommendations. Since these species are resident species, it appears that there is only a need to specifically protect conditions appropriate for the two discreet life-stages of incubation and rearing, although, it is possible that there may be a need to establish separate considerations if juveniles and adults fish are found to have different sensitivities to temperature. Due to the relative lack of research specifically testing the species of this guild in general, EPA needs to revisit these recommendations in the future when new research becomes available.

Appendix B
Recommended Process to Establish Thermal Potential Numeric Criteria For Temperature Based on Multiple Lines Evidence

Executive Summary

Although individual fish respond to their local thermal conditions, salmonid populations respond to changes in thermal regimes at coarse spatial scales. Throughout the range of salmonids, various river basins and sub-basins had thermal regimes that differed from one another and fluctuated naturally over time. Although human-caused changes to thermal regimes may have affected salmonid populations in many ways, EPA believes that the loss of cold water habitat has been the most detrimental thermal effect. Therefore, the process described below focuses on developing criteria that will help protect and restore cold water when and where salmonids are or could be present.

EPA believes the mechanisms of anthropogenic warming are diverse and variable over space and time. To manage anthropogenic warming successfully in any particular stream system, EPA believes that it is important to characterize and understand the magnitude and mechanisms of anthropogenic warming in the stream system.

EPA believes that the historic thermal regime of rivers that provided habitat for salmonids in the Pacific Northwest is the only thermal regime that we know with certainty will provide necessary thermal dynamics to support recovery of salmonids in the Pacific Northwest. Therefore, if water quality criteria describe a thermal regime that maintains critical characteristics of the historic regime, EPA believes the criteria will be sufficient to create thermal conditions that are compatible with salmonid recovery even if some anthropogenic thermal degradation is still present. Thus, the historic thermal regime serves as a useful 'compass' for assessing whether or not a proposed standard other than historic thermal potential is both reasonable (i.e., attainable) and compatible with salmonid recovery.

Several different ways of estimating historic thermal potential exist; however, EPA recognizes that we are limited in precisely describing the historic thermal regime. The different ways of estimating historic thermal potential include assessing the historic distribution of salmonids, modeling historic conditions using computer simulation or statistical models, assessing 'reference' conditions in pristine streams, and using historic data. If used alone, each of these different data sources will provide a different estimate of historic conditions. Because of unavoidable limitations in data and models, any estimate of historic conditions will have its inaccuracies. Although, some estimates will be more accurate than others. EPA believes that estimates are more likely to be accurate when derived from multiple lines of evidence that yield similar results.

It is important to note that EPA believes that it may not be possible to re-establish historic conditions everywhere all of the time (some impacts may be irreversible such as location of cities). Therefore, water quality criteria need not require complete restoration of historic conditions. Instead, EPA is recommending a process to develop water quality criteria that provides adequate amounts of cold water when and where salmonids need it, allows for waters that are naturally warm to occur, and also recognizes that certain human impacts are not reversible.

Overview

After reviewing available pertinent information and conferring with State and Tribal Governments and the Services, EPA has concluded:

1) Water temperature criteria need not require that all waters in the Pacific Northwest provide optimal thermal habitat for salmonids all of the time. However, water temperature criteria should require the establishment of thermal regimes sufficient to maintain healthy, viable salmonid populations.
2) The Pacific Northwest's historical thermal regime (spatio-temporal patterns of stream temperature that existed prior to Euro-American settlement in the Pacific Northwest) represents the only set of thermal conditions that can be shown with certainty to support healthy, viable salmonid populations. However, it may be unreasonable to expect that these historical thermal regimes can be re-established in their entirety given the current level of human development and human population in the Pacific Northwest.
3) Current thermal conditions in many rivers and streams of the Pacific Northwest are very likely to contribute to the continued decline of salmonid populations. Therefore, restoration of substantial portions of historical thermal regimes will be necessary to restore health and help prevent the ultimate extinction of many native salmonids in the Pacific Northwest.
4) While we have several means of determining spatially and temporally-specific estimates of historic thermal regimes each has various levels of uncertainty associated with resulting estimates. These different estimate may provide conflicting information and would thus need to be reconciled.

These conclusions underscore EPA's position that the concept of "historical conditions" cannot be used as water quality criteria directly. This is so for two reasons: our estimates of historical conditions are uncertain; and it may not be possible or feasible to reverse some human caused impacts on the environment. Historical conditions serve as a useful conceptual model for identifying a thermal regime that support viable salmonid populations with a high degree of certainty.

Although we cannot precisely identify historical thermal regimes, there are multiple lines of evidence that can be used to establish bounds within which historical conditions are likely to have existed. Within these bounds, credible temperature criteria can be developed that both recognize the limits of potential restoration efforts, while still ensuring that adequate amounts of cold water are available to support viable salmonid populations. Even armed with this information, however, development of temperature criteria is a difficult task. If temperature criteria can not require conditions to be optimal everywhere, at all times, the criteria can describe when and where conditions must be optimal, along with when and where conditions can be sub-optimal or even locally and temporarily stressful or hostile to salmonids. There is not a scientific means of determining precisely how little cold water can be available across the landscape at a given time and still support viable salmonid populations. We cannot and should not expect that "science" will provide that answer. On the other hand we can use scientific information to provide boundaries within which scientifically-credible policy decisions can be made regarding how much cold water there should be and when and where it should be. In essence, the scientific information used to support the policy decisions should provide a realistic portrayal of associated uncertainty.

In order to determine how much cold water is needed in a sub-basin and when and where it should occur, EPA recommends a process that follows the framework provided by Figure 1. In essence, the framework calls for: 1) the assembly of multiple lines of evidence for use in characterizing the historical temperature regime; 2) integration and reconciliation of the multiple lines of evidence into a single, quantitative and spatially-explicit estimate of historical temperatures at key seasons within a sub-basin under (median) conditions of temperature and streamflow; 3) consideration of an allowance for human use expressed as an adjustment to the estimates of historical maximum seasonal temperatures, thereby creating "*potential thermal* conditions" (target conditions) for the sub-basin; 4) an analysis of the "performance" of the target conditions designed to determine how much cold water would be available under differing climatic and flow conditions (other than median conditions). The final product of these four steps would be the numeric criteria for the sub-basin and would then be ready for adoption as the water quality standard. The numeric criteria would be expressed as map of spatially explicit distribution of temperatures across the sub-basin.

In setting forth this process, EPA recognizes that it may not be possible for States and Tribes to follow each step to the fullest extent as described herein. EPA's expectation is that States and Tribes would use, to the best possible extent, the tools, data, and capabilities available to them in carrying out this process. EPA believes one of the main benefits of this process is that it is robust to uncertainties and limitations. For example, if a state were not able to develop a model of the historic thermal potential for the whole sub-basin, or did not have resources/data to produce a sophisticated model of historic thermal potential, the uncertainty analysis would capture these limitations and lean towards the biological distribution line of evidence. The approach EPA has designed can work with any type of model. But it relies on our ability to quantify the uncertainty associated with the model. We can rely more on biology when model uncertainty is high and more on models when model uncertainty is low.

Step 1. Assembling Multiple Lines of Evidence

Water quality criteria for temperature should be set in a process informed by an understanding of the natural thermal potential (NTP). NTP is defined here as the thermal regime that existed prior to Euro-American settlement. This is not to say that criteria should be set equal to NTP. It simply means that knowledge of the NTP, of streams and rivers will help to set criteria to make them fully protective of beneficial uses, yet still achievable.

Unfortunately, no techniques exist to accurately and precisely reconstruct the *natural* thermal regime of any given stream and/or river. Instead, two or more techniques are to be used to *estimate* NTP, and each technique has a variety of shortcomings. Below is an overview of the lines of evidence with their shortcomings; each line of evidence is provided in more detail later.

1) *Biological Distributions:* Since every species has specific habitat requirements, knowledge of a species' distribution and habitat requirements can provide information regarding the distributions of habitats on the landscape. If a species exists at a given location as part of a self-sustaining population, the distribution map of that species is an indicator of habitat conditions that has the potential to support the species. If adequate information regarding the physiological habitat needs has been compiled, a map that approximates habitat conditions can be generated by overlaying distributions of various species and assuming that the habitat therein usually was comprised of conditions that were historically well-suited to the species. With respect to stream temperature, the physiological needs of salmonids have been studied considerably. Thus, maps of historic salmonid distributions and their periods of use can be used to provide rough estimates of thermal conditions that existed prior to Euro-american settlement of the Pacific Northwest.

2) *Modeled Thermal Potential*: Models based on the physical characteristics of streams and rivers can provide estimates of NTP. There are various types of models that are used to estimate thermal conditions of streams and rivers. Each has its own attributes and limitations. Statistical models estimate the NTP of streams and rivers by using multi-variate statistics to find correlations between stream temperature and those landscape characteristics that control temperature (e.g., elevation, latitude, aspect, etc.). Statistical models are most appropriately applied to small, headwater streams. Quantitative estimates of uncertainty associated with predicted thermal potential are relatively simple to calculate, providing additional information useful for determining temperature criteria. Mechanistic models estimate the NTP of streams and rivers using mathematical equations that describe heat flux between streams and their surrounding environment. Unlike statistical models, mechanistic models can be developed without relying on reference conditions and therefore represent the best way available for estimating NTP of large rivers. The error associated with thermal potential predictions derived from mechanistic models can increase especially when models do not adequately represent locally important influences on stream temperature (e.g., the model's structure and capabilities are not well-suited to the system being modeled) or when there is high uncertainty associated with a model parameter that strongly influences model predications Nonetheless, there are accepted and well-established techniques for assessing and quantifying much of the uncertainty and error associated with mechanistic model predictions. When coupled with error assessment and an understanding of the model's limitations, predications from mechanistic models can provide a highly detailed *picture* of a stream's NTP and the factors that influence it.

3) *Historical Data*: Occasionally, temperature data have been collected from a stream prior to human influences on the stream's temperature regime. These data serve as useful reference points, but they often do not adequately capture the spatial and/or temporal variability in stream temperature due to limited spatial or temporal resolution. Further, in some instances, there may be uncertainly about whether or not humans affected temperature prior to data collection. Thus, it may be difficult or impossible to adequately describe the NTP of a stream based on historic data alone. Historical data may be very useful, however, for verifying estimates of NTP based on other techniques such as modeling (discussed below).

4) *Reference Conditions*: The NTP of a thermally degraded stream or river may be assumed to be similar to that of a non-degraded stream, so long as the location, landscape context, and physical structure of the stream are sufficiently similar. However, this approach to estimating NTP is hampered by potential disagreements on the similarity of location, landscape context, and physical structure. Further, non-degraded streams may no longer exist for a given location, context, and/or structure. This is especially true for larger rivers, each of which is relatively unique on the landscape. Further, even when appropriate reference streams are relatively plentiful, this technique has a varying level of accuracy that is difficult to quantify since no two streams have the same location, landscape context, or structure. Thus, while reference conditions may be useful for describing the thermal regime of small streams in a non-degraded state, reference conditions (like historical data) may be most powerful as a means of validating thermal models.

Other data sources may also be useful, but are not covered here. EPA recommends assembly of all four lines of evidence to the extent possible. At a minimum, the biological and modeled thermal potential lines of evidence are needed to support the characterization of natural thermal potential. EPA recommends that the lines of evidence be compiled as described below:

Biological Distributions

Maps of historic salmonid distributions can be used to provide estimates of thermal conditions that existed prior to Euro-American settlement of the Pacific Northwest. EPA cautions that it can not be said or implied that wherever a species can be mapped to have occurred that water temperatures were at or below the specified upper end of optimum physiological thresholds at all times. What can be said is that within a mapped distribution for a given population a sufficient percentage of the water for a sufficient percentage of the period of use was likely at temperatures supportive of a healthy self-sustaining population.

In order to estimate the thermal potential of a stream system using species distribution information, the guild and life-stage thermal tolerances from the main text of the guidance (also in Appendix A) must be assigned to the locations at which life stages for different guilds occur. Therefore, EPA recommends that states and tribes develop maps of potential habitat distributions for each guild and life stage on a sub-basin by sub-basin basis. For each guild, maps of potential habitat for each of the following life-stages should be developed: spawning & incubation, rearing, smoltification, upstream migration, and adult holding.

Multiple sources of data are usually available describing the location and timing of salmonid habitat use within a sub-basin. EPA recommends that states and tribes develop coarse-scale maps of fish distribution in each sub-basin. Where landscape indicators of various physical habitat requirements of subject species converge, it is reasonable to assume that salmonids exist. Additionally, coarse-scale maps can be generated by working with fisheries biologists from fish and game management agencies, and other experts. Once coarse-scale maps have been developed, finer-scale information from field surveys and scientific studies can be used, where needed, to augment the distribution maps by identifying core habitat areas, or areas of especially high habitat value. Generally, where coarse-scale landscape indicators of habitat suggest a species would exist in an area, neither best professional judgement, nor field surveys indicating absence of that species should be used to eliminate the area from the species potential distribution. Best professional judgement is often highly accurate for identifying where healthy populations of species occur, but is generally inadequate for identifying areas where rare species exist or low density populations exist. Field data are generally inadequate to reduce a predicted species' range as well. First, an overwhelming survey intensity is necessary to show that a species is highly likely to be absent from an area identified as having suitable habitat. Secondly, present-day surveys reflect present-day conditions. With restoration of habitat (including thermal conditions), a species may return to areas not currently occupied.

Maps should be generated as GIS layers that describe historic and/or potential spatial distributions for each guild and life stage. Spatial distributions of each life stage should be further subdivided according to the annual period of occurrence so that seasonal occurrence maps can be generated using the GIS. EPA recommends that this information be compiled in GIS layers for several reasons. First, the data will be compatible with other spatially explicit data sets and therefore will be amenable to analysis using other important data sets. Secondly, the data are easier to share and discuss with public interests and decision-makers when expressed in map form.

Modeled Estimate of Natural Thermal Potential

Two broad classes of models are discussed: 1) statistical models, also known as empirical models, and 2) mechanistic or process models. Empirical models are based upon statistical correlations in data and are based on the fact that often a few key characteristics of a stream and its environment predict most of the observed variation in water temperature. Process models are based on fundamental knowledge of the physical mechanisms that cause stream heating and cooling. Their basis is a heat budget that accounts for energy exchange between the stream and its environment. Although presented as a dichotomy, many models are a hybrid of statistical and mechanistic understandings of water temperature. All are valid if properly used.

In many instances, when models have been used to estimate NTP, uncertainty associated with modeled estimates has not been assessed and/or incorporated into the process used to establish temperature standards. By failing to assess model uncertainty, model predictions are used to set temperature standards without a clear understanding of the confidence associated with model predictions. Thus, previous attempts at modeling thermal potential have focused on determining a "centrist" estimate of NTP, rather than determining the confidence intervals that surround the centrist estimate

Regardless of the type of model used (statistical, steady state, or dynamics), there are two sources of uncertainty associated with model predictions: 1) Error associated with the model's calculations. Typically, although model validation may provide an estimate of this error, this estimate of error is acknowledged, but not incorporated into the process of setting a temperature standard, 2) Uncertainty associated with estimates of model parameters. Traditionally, this source of uncertainty has been ignored. Instead, a single value has been selected for each model parameter (often from the center of the range of potential parameter values).

Because models provide only an estimate of a stream's natural potential, it is important to avoid taking the centrist estimate at face value. Rigorous assessment of the factors that influence a model's accuracy will determine the confidence that should be placed in the centrist estimate of NTP. This assessment involves examining the two sources of uncertainty listed above. Thus, any modeling exercise should not be viewed as an attempt to "model NTP" given specific climatic conditions. Instead, the objective should be "to use a model to estimate upper and lower confidence limits for NTP" given specific climate conditions.

The following three steps outlined below describe, in general terms, the steps for determining a confidence range for estimates of natural thermal potential:

1) Assess current and historic conditions of the sub-basin to be modeled. This step includes identifying the dominant physical structures (vegetation, channel morphology, etc) and hydrologic/thermodynamic processes that influence stream temperature in the stream. This should be done for both current and historic conditions. The results of this step are critical for identifying which human activities may have affected stream temperature in a basin and, therefore, assessing the applicability of a given model for determining confidence limits for NTP.

2) Select a model. Select a model that is well-suited to represent the range of dominant structures and processes influencing stream temperature, both historically and currently. EPA recognizes that there are different models available to estimate NTP. The accuracy of those models varies depending on what influences the model most. The accuracy of a statistical model will be strongly influence by: whether or not the primary factors influencing water temperature are successfully incorporated into the model; by the quality of the data used to generate the model; whether the reference streams represent the range of conditions across the landscape that influence stream temperature; and whether the reference conditions truly represent "pristine" or "un-modified" thermal regimes. The accuracy of a mechanistic model (steady state or dynamic) is influenced by: whether or not the equations in the model represent the dominant influences on stream temperature within the stream and the mechanisms of heat storage, transport, and transfer within the stream; whether or not the historical conditions imposed on the model accurately portray historical conditions; the accuracy of the parameter estimates; and the accuracy of driving variables used as input to the model. By rigorously assessing the factors that influence a model's accuracy the uncertainty associated with the predications can be better understood and taken into account in interpretation of the predicted thermal potential. It is important to document the model selection process. The modeling should be run under median temperature and rainfall conditions to estimate water temperature throughout the basin "in a median year."

3) Determine confidence range for the estimate of NTP. The approach outlined in the main section of this guidance document requires a credible assessment of both sources of uncertainty associated with model predictions (listed above). The confidence range for modeled estimates of NTP (i.e., the distance between the upper and lower confidence boundaries) is the centrist estimate plus or minus the sum of the estimated uncertainty from both sources. The uncertainty associated with model calculations can be assessed using verification data. The verification data must be

independent of any data used to calibrate the model. Ideally, current conditions would be used to calibrate the model and reference conditions (undisturbed streams, historical data, etc) would be used to validate the model; this approach will accurately quantify the error associated with "back-calculation" of historical conditions. Uncertainty associated with parameter estimates can be addressed by Monte Carlo assessment of the model or other methods that perform a similar type of assessment. Whatever assessment tool is used for either type of model, it should credibly assess the uncertainties associated with both types of model error. The result of these steps should be a graphic display of the upper and lower confidence boundaries of NTP.

Historical Data
Historical data is most useful for verifying models. Historical data generally should not be used to directly establish sub-basin temperature standards since historical records only reflect stream temperatures under the specific climate conditions experienced when the historic data were gathered. These data are unlikely to be useful for directly establishing the thermal potential under median climate conditions.

Reference Conditions
Reference conditions are most valuable for verifying mechanistic models and creating statistical models. Reference conditions measured in one stream generally should not be used to directly establish temperature criteria for another stream since reference conditions reflect stream temperatures specific to the stream from which they were gathered under the climate conditions experienced when the data were gathered. These data will seldom be useful for directly establishing the thermal potential under median climate and flow conditions.

Step 2. Integrating and Reconciling Multiple Lines of Evidence

Integrating and reconciling multiple lines of evidence is the process of finding a single, new estimate of NTP that is compatible with estimates derived from each line of evidence. Two lines of evidence are compatible if their uncertainty ranges overlap. They are incompatible if their uncertainty ranges don't overlap. For instance, if a computer model estimates the NTP of a stream is 22°C ± 2°C, then another estimate of NTP of 21°C±2°C is compatible. In another instance, an estimate of 17°C± 2°C is incompatible.

The multiple lines of evidence discussed above could be used in a variety of ways to compile a NTP baseline, which when used with the other steps below (allowance for human use, inter-annual conditions analysis), could be used to derive water quality criteria. In order to implement EPA's recommended approach, described below, at least these two lines of evidence are needed from the previous step: 1) the spatial distribution, timing, and thermal requirement of various species and life stages of salmonids, 2) estimate of the natural thermal potential of the stream.

While there may be other lines of evidence that can be used, this guidance focuses on integrating two lines of evidence; models and biological data. EPA review of estimate of NTP will be based on an evaluation of the reasonableness of the states interpretation of the lines of evidence and the types of evidence used by the states. States may choose other means of integrating and reconciling multiple lines of evidence than the example below.

One example of how the integration and reconciliation is shown in Figure 2. The rationale for this approach is that the model provides statistical confidence boundaries surrounding the estimate of NTP. The biological data provides a clue as to where within those boundaries the true NTP exists. Additionally, although the final NTP may be established anywhere within the modeled confidence range depending on the biological use in the stream, in no case would the final NTP get set outside of the modeled confidence estimates. If the lower end of the certainty bounds is higher than the biological threshold, and you have greater confidence in the model data then the biological data, then you can set NTP at the lower confidence bound of the modeled estimate.

In some cases, there may be no single estimate of NTP that is compatible with all lines of evidence. For instance, if salmonids with a thermal requirement for water less than 15°C are known to have existed in high densities in the same stream where a model suggested a historic potential of 22°C $\pm$ 2°C, we have two lines of evidence that can not be integrated; any temperature that is compatible with the first line of evidence is, by definition, incompatible with the second. In this case, EPA recommends attempting to reconcile the lines of evidence by questioning the confidence we have in each line of evidence. To reconcile lines of evidence, questions about the evidence must be asked and answered: 'How reliable is the fish identification data?', 'Is the model considering all of the processes that influence stream temperature?', etc. In the process of reconciling lines of evidence, estimates derived from each line of evidence should begin to converge due to improved estimates of historic conditions or increased uncertainty associated with the lines of evidence.

In summary, where more than one estimate of historic thermal potential produces similar results, we should rely on those estimates, so long as we understand the uncertainty associated with them. Where estimates of NTP are derived from different sources but yield dissimilar results, we should seek to understand why the estimates differ so that we can determine what course of action to pursue.

Step 3. Allowance for Human Use

The third step in EPA's recommended approach is the step that accounts for the fact that some human activities are not reversible. The work done in the first two steps results in an estimate on NTP. This is not the criteria, as stated earlier, because of the uncertainty with our ability to estimate NTP and because it may not be possible or feasible to reverse some of humans' impact on the environment. As stated earlier, EPA recognizes that states and tribes may find that some human impacts may not be reversible (i.e. move a town). To address such situations, EPA recommends an 'allowance for human use' be incorporated into the estimate of NTP. The result of this step would be called the 'thermal potential' of the sub-basin. To accomplish this step EPA recommends adding a set incremental amount of warming to the estimate of NTP. The increment for human use must not be so great that thermal potential can no longer support salmonids. Thus an assessment must be completed on a proposed allowance for human use to check to make sure that there is still adequate amounts of cold water. After determining the NTP from multiple lines of evidence and adding an appropriate allowance for human use (if any), the resulting distribution of temperatures can be viewed as "proposed" temperature criteria for the sub-basin. The chart below provides a hypothetical example of what the resulting criteria for a sub-basin might look like. The chart provides the criteria for the summer time maximums. In order to have complete criteria, this chart would need to be developed to cover spring and fall maximums.

River/Stream Name	River Mile	Median Conditions Temperature Values
Red Salmon River	0 - 20 *	65°F
	21 - 50	62°F
	51 - 75	58°F
Blue Trout Creek	0 - 5	60°F
	6 - 15	56°F
	15 - 20	54°F

* Designated Cold Water Refugia are to be protected in this section of the river. They are critical areas for salmonids to navigate through this generally warm water stretch of the river.

Step 4. Assessing the Performance of the Proposed Thermal Target During Different Climatic and Flow Conditions (accounting for inter-annual variation)

After determining the NTP from multiple lines of evidence and establishing an appropriate allowance for human use (if any), the resulting distribution of temperatures can be viewed as "proposed" temperature criteria for the sub-basin. Before the criteria is adopted, however, EPA recommends a process to characterize the extent of optimal thermal habitat that would be provided under a variety of climate and flow scenarios.

EPA recommends compiling tables that provide estimates of the amount of habitat that would be provided for each salmonid guild and lifestage, in different sized streams, under three different annual climate scenarios: median conditions, the 90th percentile of warm temperatures combined with the 10th percentile of stream baseflow, and the 10th percentile of warm temperatures combined with the 90th percentile of stream baseflow. The tables are designed to give managers and other citizens a better understanding of how well the criteria would protect salmonid habitat under different conditions. A sample table follows for an imaginary guild and sub-basin:

Rocky River Temperature Standard Assessment: Warmest Day, Guild A

Designated habitat for:	Stream Order	Stream Miles	Cold / wet year			Median Year			Warm / Dry Year		
			Optimal	Sub-Optimal	Non-support	Optimal	Sub-Optimal	Non-support	Optimal	Sub-Optimal	Non-support
Spawning/ Incubation	1-3	50	100%	-	-	95%	5%	-	60%	25%	15%
	4-5	20	90%	10%	-	80%	10%	10%	40%	40%	20%
	6+	8	80%	20%	-	65%	20%	15%	30%	40%	30%
Rearing	1-3	200	100%	-	-	80%	15%	5%	55%	30%	15%
	4-5	40	80%	20%	-	70%	30%	-	40%	50%	10%
	6+	4	90%	10%	-	60%	35%	5%	45%	35%	20%
Smoltification	1-3	-	-	-	-	-	-	-	-	-	-
	4-5	20	75%	25%	-	70%	25%	5%	40%	40%	20%
	6+	22	70%	30%	-	65%	25%	10%	30%	40%	30%
Upstream Migration	1-3	-	-	-	-	-	-	-	-	-	-
	4-5	48	100%	-	-	80%	20%	-	60%	20%	20%
	6+	22	90%	10%	-	40%	60%	-	35%	60%	5%
Holding	1-3	12	100%	-	-	95%	5%	-	70%	20%	10%
	4-5	18	100%	-	-	90%	5%	5%	60%	30%	10%
	6+	6	90%	10%	-	80%	15%	5%	50%	30%	20%

The final product from the four step process described above is sub-basin criteria that can be expressed as a spatially explicit map of temperature distribution or thermal regime. Augmenting the map, would be a table, such as the one below, that would provide the temperatures expected under varying climatic conditions.

River/Stream Name	River Mile	Median Conditions Temperature Values	Cold/Wet Conditions	Hot/Dry Conditions
Red Salmon River	0 - 20 *	65°F	63°F	67°F
	21 - 50	62°F	60°F	64°F
	51 - 75	58°F	55°F	60°F
Blue Trout Creek	0 - 5	60°F	58°F	63°F
	6 - 15	56°F	54°F	59°F
	15 - 20	54°F	52°F	57°F

* Designated Cold Water Refugia are to be protected in this section of the river. They are critical areas for salmonids to navigate through this generally warm water stretch of the river.

Figure 1. Flow chart illustrating the steps involved in EPA's recommended approach for establishing Thermal Potential Numeric Criteria

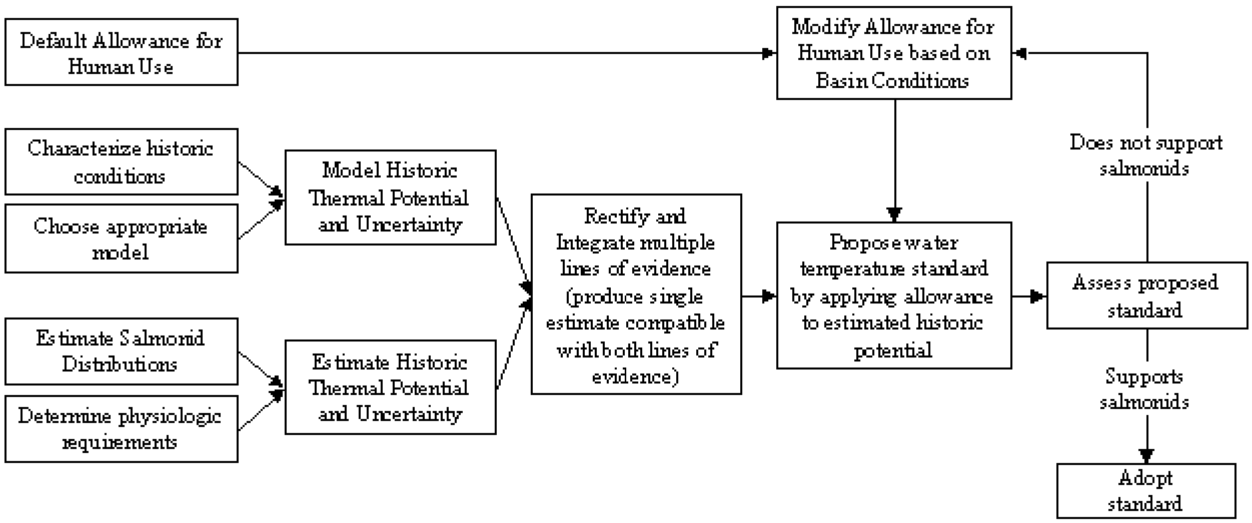
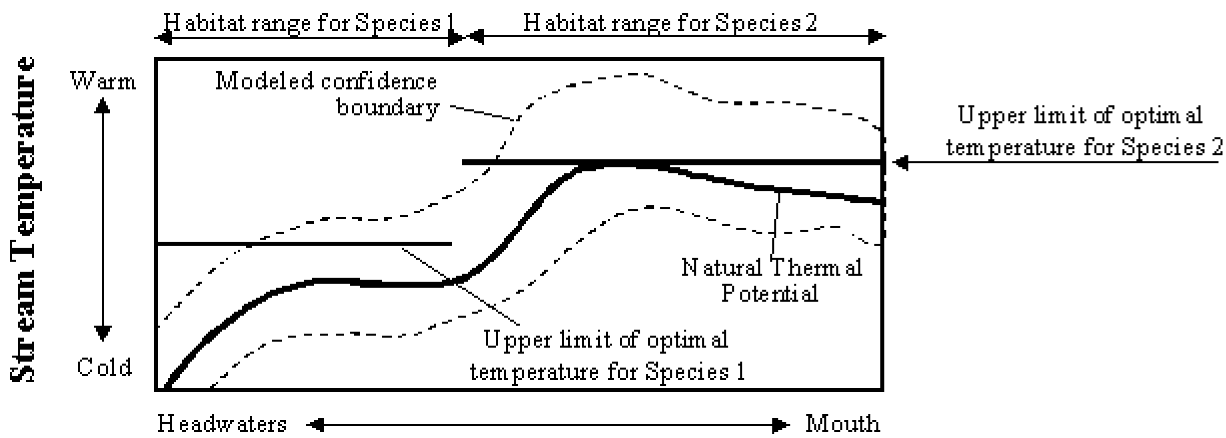


Figure 2. Integrating and Reconciling Multiple Lines of Evidence
Thermal potential is established by integrating model results with biological data. The chart below shows habitat use along a river from headwaters to mouth along with biological temperature thresholds representing the *warmer limit* of *optimal* temperature for each species. Superimposed on the biological thresholds are modeling results that show confidence boundaries for the modeled thermal potential of the stream. (The model results represent the stream's thermal potential on the warmest day of a year with *median* inter-annual air temperature and stream discharge). The biological data and model results are integrated by choosing an estimate of thermal potential that is within the confidence boundaries of the model, but does not exceed the biological thresholds. Solid wavy lines are examples and would be considered the thermal potential of the stream based on multiple lines of evidence.



Appendix B References:

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Kaufmann, P.R. and Robison, E.G., 1998, Physical Habitat Characterization. pp. 77-118. In: J.M. Lazorchak, D. J. Klemm and D.V. Peck (eds.). Environmental Monitoring and Assessment Program--Surface Waters: Field Operations and Methods for Measuring the Ecological Condition of Wadeable Streams. EPA/620/R-94/004F. U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C.

Theurer, F.D., Voss, K.A., and Miller, W.J., 1984, Instream water temperature model-- Instream flow information paper 16: U.S. Fish and Wildlife Service, FWS/OBS 84/15 [variously paged].

U.S. Environmental Protection Agency, 1996, Level III ecoregions of the continental United States (revision of Omernik, 1987): Corvallis, Oregon, U.S. Environmental Protection Agency - National Health and Environmental Effects Research Laboratory Map M- 1, various scales.

Other Supporting Materials

As part of developing the scientific foundation for this draft guidance, five technical issue papers covering key aspects of water temperature and salmonids were developed along with an overall technical synthesis paper. These paper are available on EPA's website: www.epa.gov/r10earth/water.htm.