

salmonid designated uses because river temperatures prior to human impacts clearly supported healthy salmonid populations. EPA intends that the estimate of the temperature reflecting natural conditions be determined by the State or EPA using a scientifically-defensible method that utilizes the best available data, as indicated in the proposed rule at 40 CFR 131.39(d)(1). Typically, this determination is made in the context of a TMDL. EPA recognizes, however, that there will always be uncertainties in estimating natural conditions. Potential sources of uncertainty are numerous, including, but not limited to, data gaps, measurement errors, model errors, omissions in identification of impacts, and aggregation errors. It is important that regulatory agencies document the sources of uncertainty in any assessment for the benefit of decision-makers, stakeholders, and the public.

Where the natural temperature conditions so estimated exceeds 20°C/68°F, EPA proposes that the river must have well-distributed cold water refugia. EPA views cold water refugia to be an important aspect of the natural condition that must be specifically identified in waters where the estimated natural condition exceeds 20°C/68°F because of the significant adverse effects to salmon and steelhead exposed to temperatures exceeding 20°C/68°F. See Table 1. Well-distributed cold water refugia allows salmon and steelhead to minimize their exposure to temperatures that exceed 20°C/68°F. As discussed in section III.C.3.iv., EPA believes the amount of cold water refugia would be sufficient if salmon or steelhead could access waters that are at least 2°C/4°F colder than the estimated natural maximum temperature for the main channel for at least 12 hours a day. Refer to section III.C.3.iv. for a discussion on how cold water refugia should be addressed in the context of TMDLs, NPDES permits, and waterbody assessments.

*Overview of Methods to Estimate Natural Background Temperatures:* There are a number of different ways of estimating natural temperature conditions for the purposes of applying this proposed narrative criterion. These include: (1) Demonstrating that current temperatures reflect natural conditions, (2) using a non-degraded reference stream for comparison, (3) using historical temperature data, (4) using statistical or computer simulation models, and (5) assessing the historical distribution of salmonids. There may be other ways as well. Each approach has its strengths and weaknesses and therefore may or may not be most

appropriate for a given situation. Moreover, all of these approaches have uncertainty, which should be quantitatively described where possible. EPA encourages the use of a combination of approaches to estimate natural background temperatures, where feasible. Below is an overview of the five approaches listed above.

*Demonstrating That Current Temperatures Reflect Natural Conditions:* Under this approach, the past and present human activities that could impact the river temperatures are documented and a technical demonstration is made that the human activities do not currently impact temperatures. This approach is most applicable to non-degraded watersheds (e.g., State and National parks, wilderness areas, and protected State and National lands). These watersheds can be used as "reference" streams for estimating the natural background temperatures of degraded streams (see below). If there is a small human impact on temperatures, it may also be possible to estimate the human impact and subtract it from current temperatures to calculate the natural temperatures.

*Comparisons to a Reference Stream:* It is often reasonable to assume that the natural temperatures of a thermally degraded stream are similar to those of a non-degraded stream, so long as the location, landscape context, and physical structure of the stream are sufficiently similar. The challenge to this approach is finding a reference stream that is of similar location, landscape context, and physical structure. Because large rivers are unique and most in the Pacific Northwest have been significantly impacted by human activities, this approach is most applicable to smaller streams where a reference stream with current temperatures at natural conditions exists.

*Historical Temperature Data:* For some rivers, historical temperature data are available that reflect temperatures prior to human influences on the river's temperature regime, and can be used as an estimate of natural temperatures. Factors that lend uncertainty to historic temperature data are the uncertain nature of the quality of the data and whether or not humans affected temperature prior to data collection. Further, historical temperature data often do not adequately capture the spatial and/or temporal variability in stream temperature due to limited spatial or temporal sampling. Historical data may be useful, however, for verifying estimates of modeled natural temperatures.

*Temperature Models:* Two major methods have been commonly used for water quality modeling in the United States over the last 20 years: (1) Statistical models, which are based on observed relationships between variables and are often used in conjunction with measurements from a reference location, and (2) process-based models, which attempt to quantify the natural processes acting on the water body. Process-based models are often employed when no suitable reference locations can be identified.

Statistical models, also referred to as empirical models, estimate the thermal conditions of streams by using statistics to find correlations between stream temperature and those landscape characteristics that control temperature (e.g., elevation, latitude, aspect, riparian cover, etc.). The equations in statistical models describe the observed relationships in the variables as they were measured in a specific location. If the specific location is a non-degraded reference stream, then the model can be used to estimate natural conditions in degraded streams. Statistical models have the advantage of being relatively simple, as they rely on general data and statistics to develop correlations.

The comparability between the reference water body where the statistical correlations are generated and the assessment water body strongly affects the applicability of statistical models. Uncertainties in statistical model results increase with increasing dissimilarity between the landscape characteristics of the reference and assessment water bodies. Uncertainties also increase when models do not include landscape characteristics that control important processes affecting the water temperature. For these reasons, statistical models are best suited for small headwater streams or for generalized predictions across a large landscape. Process models, also referred to as simulation models, are based on mathematical characterizations of the critical processes that affect water temperature in rivers. The equations are constructed to represent the observed or expected relationships and are generally based on physical or chemical principles that govern the fate and transport of heat in a river (e.g., net heat flux from long-wave radiation, direct short wave radiation, convection, conduction, evaporation, streamside shading, streambed friction, and water's back radiation) (Bartholow, 2000).

Estimating water temperature with a process model is generally a two-step process. As a first step, the current river temperatures are estimated with system characteristics (e.g., amount of shade