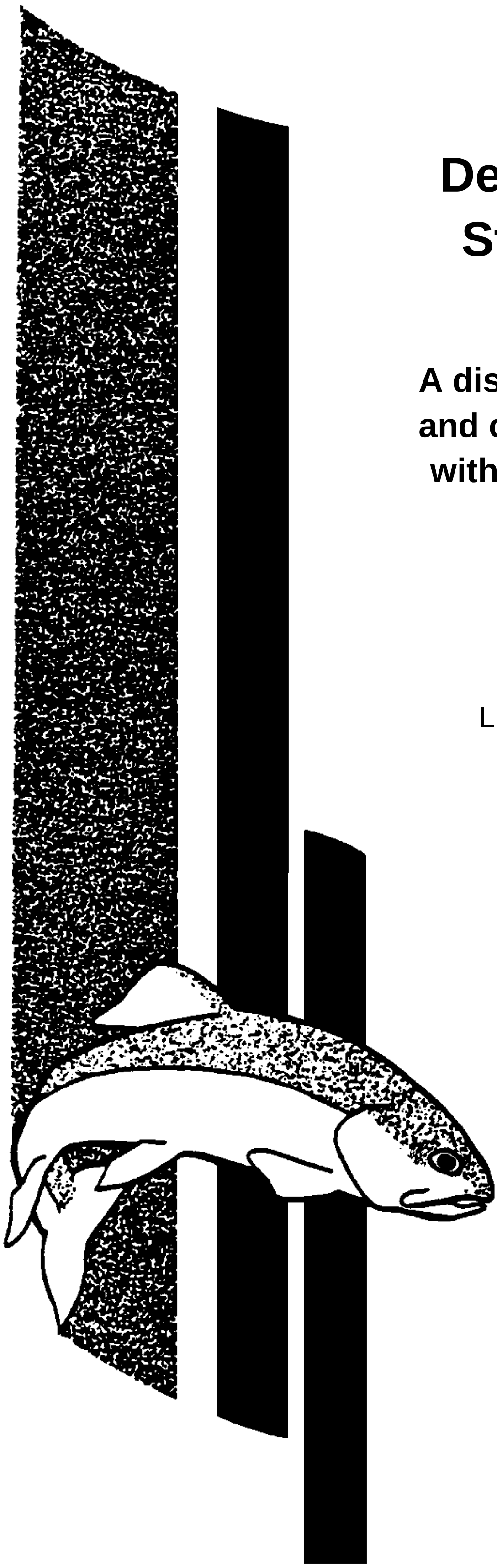

Designating Temperature Sensitive Streams (TSS) in British Columbia

A discussion paper exploring the science, policy, and climate change considerations associated with a TSS designation procedure.

by

Lars Reese-Hansen[a], Marc Nelitz[b], and Eric Parkinson[c]

[a] Habitat Management Section, Ministry of Forests, Lands and Natural Resources Operations, P.O. Box 9338, Stn Prov Govt., Victoria, B.C., V8W 9M1; [b] ESSA Technologies Ltd., Suite 600, 2695 Granville Street Vancouver, B.C. V6H 3H3; [c] 3281 West 38th Avenue, Vancouver, B.C., V6N 2X5

Fisheries Management Report No. RD123

2012

v1.0

Province of British Columbia

Ministry of Environment

Ecosystem Protection & Sustainability Branch

Acknowledgements

We would like to thank Andy Witt, Richard Thompson, Judy Godfrey and John Rex, for their contributions and comments toward development of this document. We would also like to thank Jennifer Psyllakis, John Rex and Peter Tschaplinski for their insightful comments while conducting a peer review of the document prior to publication. Funding for this work has been provided from National Resources Canada (NRCAN), Fraser Basin Council, Ministry of Forests, Lands, and Natural Resource Operations, and the Ministry of Environment (B.C.).

Disclaimer

This document is a discussion paper which puts forward a proposal for designating “Temperature Sensitive Streams” based on the authors’ interpretation of the best available knowledge of current regulatory direction, policy, and management objectives of government, as well as the current state of science. The proposal has been developed with the intention of being a feasible procedure that could function within the existing regulatory framework and achieve the intended outcomes around the designation of these streams.

This designation procedure, and its related requirements and steps, has not been endorsed by the Government of B.C. and is subject to modifications resulting from new findings and any revised government direction. Implementation will be subject to appropriations, priorities, and budgetary constraints of the participating jurisdictions and organizations.

Citation

Reese-Hansen, Lars, Marc Nelitz, and Eric Parkinson. 2012. Designating Temperature Sensitive Streams (TSS) in British Columbia: a discussion paper exploring the science, policy, and climate change considerations associated with a TSS designation procedure. B.C. Ministry of Environment, Fisheries Management Report RD# 123. Victoria, B.C.. 71 pp.

Table of Contents

List of Figures

List of Tables

1 Introduction and context

In British Columbia, riparian areas are protected from adverse effects of forest harvesting by applying mandatory no-harvest reserves to all fish-bearing streams > 1.5 m wide (B.C. Ministry of Forests and B.C. Ministry of Environment 1998). However, there is no regulatory requirement for riparian reserves on small fish-bearing streams (< 1.5 m channel width) and on all non-fish-bearing streams regardless of channel width. Section 15 of the B.C. Government Action Regulations (GAR) [1] provides for the use a regulatory tool that allows forest managers to designate “Temperature Sensitive Streams” (TSS) to protect critical fish-bearing streams that could be altered by stream heating. A TSS designation could be applied to riparian class S4, S5, or S6 streams[2] which, by definition, do not have mandatory riparian reserves under the of the *Forest and Range Practices Act* (FRPA), for example under the Forest Planning and Practices Regulation.

Stream temperature conditions are critical for fish, and temperature shifts associated with climate change are predicted to be an important factor in various physical and biological watershed processes (Pike et al. 2010a). It is envisioned that, by implementing existing and proposed regulations that help mitigate stream temperature sensitivity and by ensuring that appropriate management strategies are used at the operational level, maintaining riparian thermal buffering functions will help mitigate the predicted impacts of climate change.

This paper discusses the underlying science, regulatory authority, evaluation procedures, and management requirements supporting designation of Temperature Sensitive Streams. The objectives of this paper are to: (1) summarize the science and consider alternative sources of information / data for designation; (2) propose a candidate designation procedure, and (3) present a proposal that can be used to solicit feedback from scientists on the defensibility of information requirements and managers on the feasibility of the procedure. In pursuing these objectives, the overall goal of this paper is to raise awareness and encourage support for designation of Temperature Sensitive Streams in British Columbia, especially in light of the potential for increased thermal vulnerability due to climate change.

---

[1] Forest and Range Practices Act – Government Actions Regulation – Temperature Sensitive Streams. Available at: http://www.qp.gov.bc.ca/statreg/reg/F/ForRangPrac/582_2004.htm#section15

[2] S4 = fish-bearing streams (< 1.5 m wide); S5 = non-fish-bearing streams (> 3 m wide); S6 = non-fish bearing streams (< 3 m wide)

1.1 Scientific context

Water temperature plays a fundamental role in structuring stream ecosystems. It influences the physiology and behavior of fish through all life history stages, affecting growth, survival and distribution of individuals and populations, as well as species interactions within fish communities. In particular, water temperature affects dissolved oxygen content (Eheart and Park 1989), primary productivity (Morin et al. 1999), macroinvertebrate production and species composition (Vannote and Sweeney 1980; Pritchard et al. 1996; Hawkins et al. 1997), egg survival rates and emergence timing (Velsen 1987; Murray and McPhail 1988), juvenile growth rates (Hokanson et al. 1977; Brett et al. 1982; Selong et al. 2001), and disease transmission rates (Holt et al. 1975; Fryer et al. 1976; Roberts 1978). In extreme situations, water temperatures can be lethal for juveniles and adults (Brett 1952; Hokanson et al. 1977; Selong et al. 2001; Richter and Kolmes 2005). Given these life stage and species-specific influences, it is not surprising that temperature has been related to species distributions (Shuter and Post 1990; Welsh et al. 2001; Heino 2002; Dunham et al. 2003a, 2003b) and interactions among species which can alter the structure of fish communities (Wehrly et al. 2003; Brazner et al. 2005). Moreover, water temperature has been used to help explain some of the inherent ecological variation across a watershed, from headwater streams to mainstem rivers (see Vannote et al. 1980).

The relationships among physical drivers and stream temperature have been studied for many decades and are generally well established, (e.g., Magnuson et al. 1979; Poole and Berman 2001; Caissie 2006; Webb et al. 2008; Rex et al. 2012). Key physical drivers of stream temperature include climate conditions (air temperature, solar radiation, and wind), stream morphology, surface and groundwater influences, and riparian cover. These drivers influence the exchange of energy and water within channels and watersheds, which ultimately determine a stream's thermal regime (

Figure 1). Variation in channel, riparian, and upslope characteristics alter the relative influence of these physical drivers leading to somewhat predictable, though naturally varying, patterns in thermal regimes among streams (Table 1). Diurnal and seasonal cycles, overlaid on year-to-year variation in climate add to this natural spatial variation (Caissie 2006; Quilty and Moore 2010). Human activities can substantially affect stream temperatures by directly and indirectly altering these physical drivers, primarily riparian cover, surface water, groundwater influences, and stream morphology (Magnuson et al. 1979; Beschta et al. 1987; Poole and Berman 2001; Moore et al. 2005; Caissie 2006; Webb et al. 2008; Rex et al. 2012).

For instance, harvesting of riparian vegetation or channel widening due to bank erosion can increase summer water temperature by increasing direct solar radiation and convective heating of streams, whereas extraction of groundwater or surface water for irrigation or industrial purposes can further alter thermal regimes. Though stream temperatures can recover following riparian harvesting, studies show that recovery to pre-harvest conditions can take 10 years and in some situations can take upwards of 20 years or more depending on a watershed's location, amount of post-harvest channel widening, and other factors (Johnson and Jones 2000; Moore et al. 2005; Nordin et al. 2009; Tschaplinski et al.2004; Tschaplinski and Pike 2010). There is also evidence that a lack of riparian buffers on headwater streams can lead to cumulative effects on downstream reaches (Moore et al. 2005). This issue is significant given an improved understanding of the role of headwater streams in the biological production of watersheds (Gomi et al. 2002; Wipfli et al. 2007). Based on this foundation of science, most jurisdictions across the Pacific Northwest restrict forest harvesting in the riparian zone to avert impacts on stream temperature and freshwater ecosystems (Young 2000; Peterman and Semlitsch 2009; Smith et al. 2009).

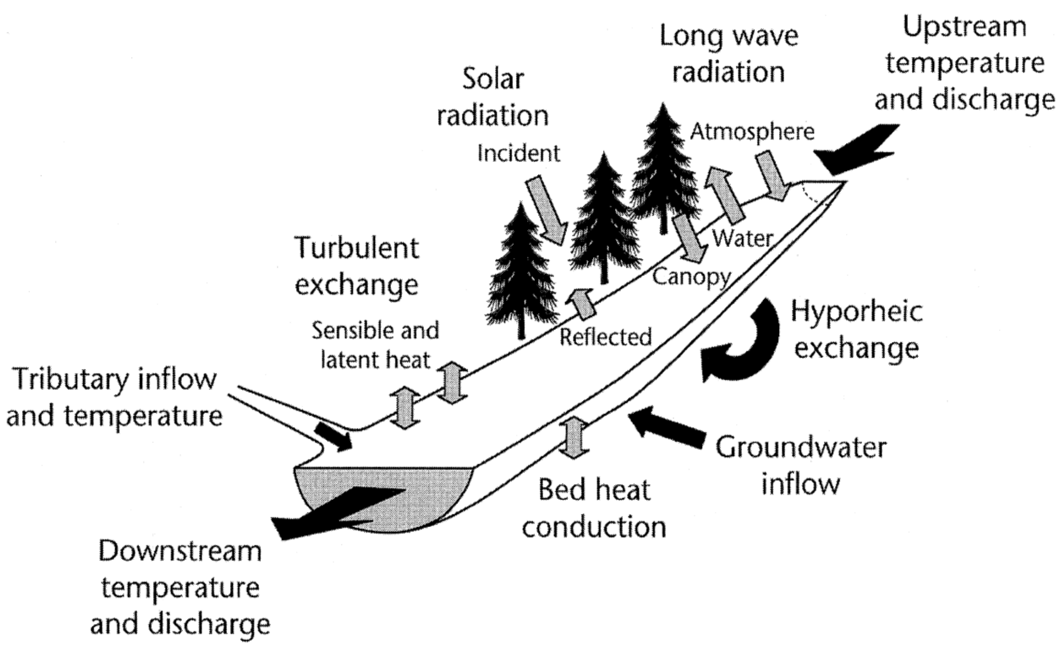

Figure 1. Illustration of factors that influence stream thermal regime (from Moore et al. 2005)

Beyond the direct influence of human activities, recent studies show direct and indirect changes in the thermal regimes of freshwater habitats due to changes in air temperatures, precipitation, and hydrology, as well as forest cover due to altered pest and fire disturbance regimes (O'Neal 2002; Battin et al. 2007; Dunham et al. 2007; Leach and Moore 2008; Isaak et al. 2010; Nelitz et al. 2010; Rex et al. 2012). In British Columbia, relatively little is known about anticipated changes due to climate change, though stream and lake temperatures are predicted to rise, with higher increments expected in northern areas compared with other regions (Tyedmers and Ward 2001; Pike et al. 2008). Analyses of data from the Fraser River show that maximum water temperatures have increased by approximately 1.8°C over the last 50 years, with a further 2°C of warming expected by 2080 (Foreman et al. 2001; Morrison et al. 2002; Farrell et al. 2008). Warmer thermal regimes in smaller streams can also be expected given the strong relationship between air and water temperatures (Stefan and Preud'homme 1993; Scholz 2001; Moore 2006; Nelitz et al. 2007a). Furthermore, climate induced changes in surface water and groundwater flows have the potential to either increase or decrease stream temperatures depending on the direction, magnitude, and timing of changes in precipitation, snow pack, and glaciers (Whitfield et al. 2003; Leung and Qian 2003; Merritt and Alila 2004; Naiman et al. 2005; Merritt et al. 2006; Stahl et al. 2008).

Table 1. Relative influence of stream characteristics on water temperature (adapted from Poole and Berman 2001).

Stream order	Stream characteristics					General description of relative influences
	Riparian canopy	Upstream discharge	Tributary inflow	Phreatic groundwater	Hyporheic groundwater	
1-2	High	Low	Mod *	High	Low-mod	Riparian shade and lateral phreatic groundwater inputs provide thermal stability. Lateral tributaries can frequently affect overall stream temperature. Large wood stores sediments and creates streambed complexity, influencing hyporheic flow (though hyporheic influence is high and shade moderate in alpine meadows).
3-4	Mod	Mod	High	Mod.	Mod-high	Temperature of lateral tributaries has strong influence on stream temperature; effects of riparian shade modest. Thermal inertia due to larger flows becomes more important. Where floodplains form, channel patterns become more complex, and alluvial aquifers are well developed. Hyporheic influence can be high. Large wood creates habitat complexity and forms channel-spanning jams that may provide significant shade to the stream.
5+	Low	High	Low-mod	Low-mod	Mod-high	Complex floodplain morphology creates a diversity of surface and subsurface flow pathways with differential downstream flow rates allowing for stratification, storage, insulation, and remixing of waters with differential temperatures. The resulting mosaic of water temperatures continually remix to buffer channel temperature and create thermal diversity. The thermal inertia of large water volumes allows streams to resist temperature change. Where side channels exist, shade from vegetation can be important.

* Mod = moderate

Given the fundamental role of water temperature in stream ecosystems, the biological implications of climate-induced changes in thermal regimes are significant (e.g., Hauer et al. 1997; Schindler 1997; Schindler 2001; Nelitz et al. 2007a; US EPA 2008; Wenger et al. 2011). The timing of Pacific salmon migrations has been linked to in-river water temperatures causing adults to avoid conditions that are physiologically demanding or associated with increased risk of diseases, which can increase holding time, delay spawning, or block access to suitable habitats (Macdonald et al. 2000; Hodgson and Quinn 2002; Hyatt et al. 2003; Lapointe et al. 2003; Cooke et al. 2004; Naughton et al. 2005; Goniea et al. 2006; Rand et al. 2006). In smaller streams, the coincidence of peak summer temperatures and low flow conditions will likely increase mortality of adult and juvenile fish, and alter the thermal suitability of all habitats (Irvine 2004; Nelitz et al. 2007a; Bisson 2008). Predictions of changes to thermal regimes in the Cariboo-Chilcotin indicate that there will likely be “winners” and “losers” in terms of the resulting changes in freshwater habitats due to climate change (Nelitz et al. 2010). Fish-bearing streams in headwater areas may be the most adversely affected. These areas could provide cold-water refugia for bull trout whose habitats may become fragmented and nearly eliminated in some watersheds if sufficient warming occurs (Figure 2). For Chinook salmon, predictions suggest that overall there would be more gains than losses regarding the thermal suitability of rearing habitats, though important corridors are also expected to warm, which might begin to pose thermal barriers for adult migration (Figure 3).

The available science provides regulators, policy makers, and resource managers with a practical understanding of the interactions among climate, human activities, water temperature, and freshwater ecosystems.

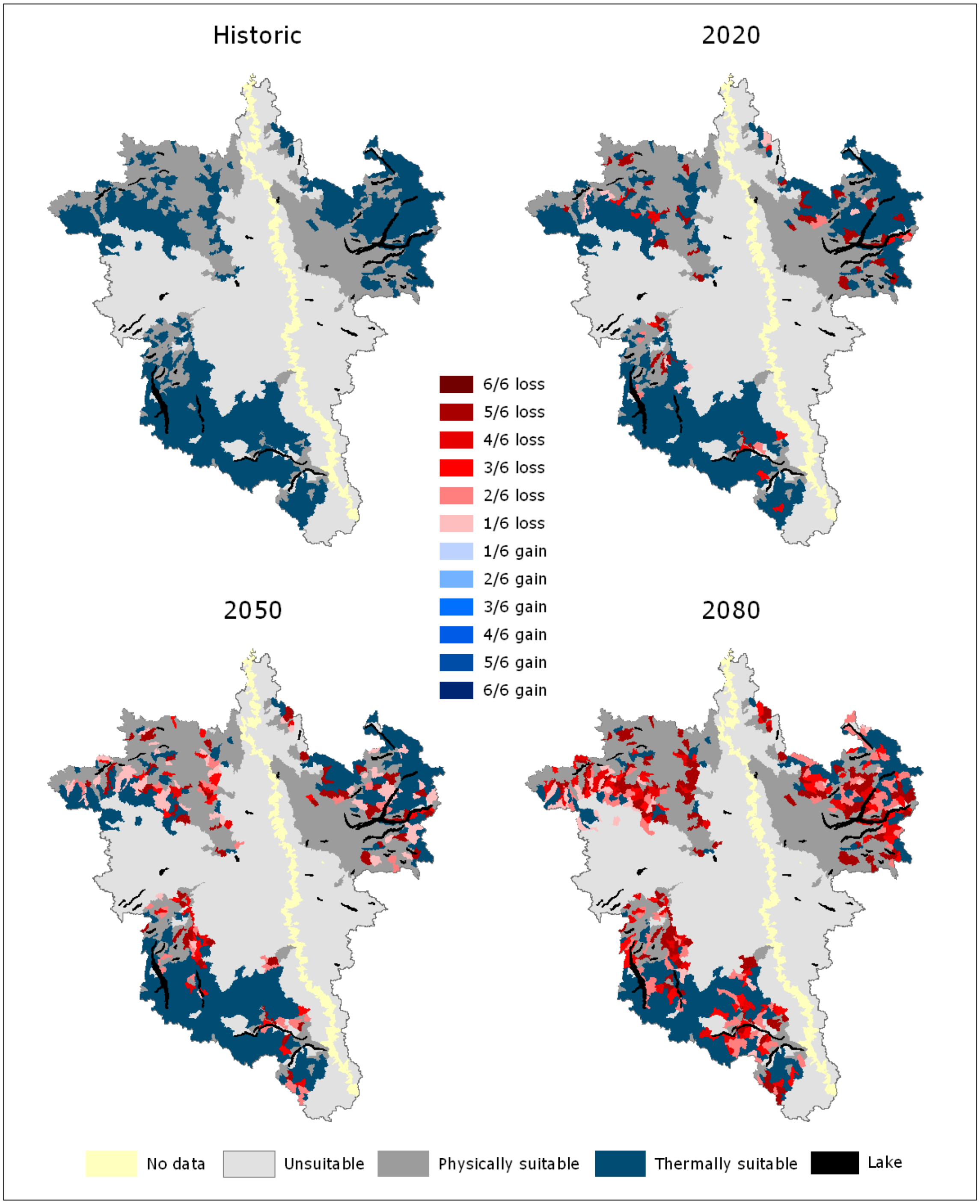

Figure 2. Representation of physically accessible and thermally suitable polygons for bull trout across the Cariboo-Chilcotin region

Note: Polygons with increasingly deeper shades of red (or blue) denote the number of climate change models / scenarios that predict the loss (or gain) in thermal suitability of a polygon. Map from Nelitz et al. (2010).

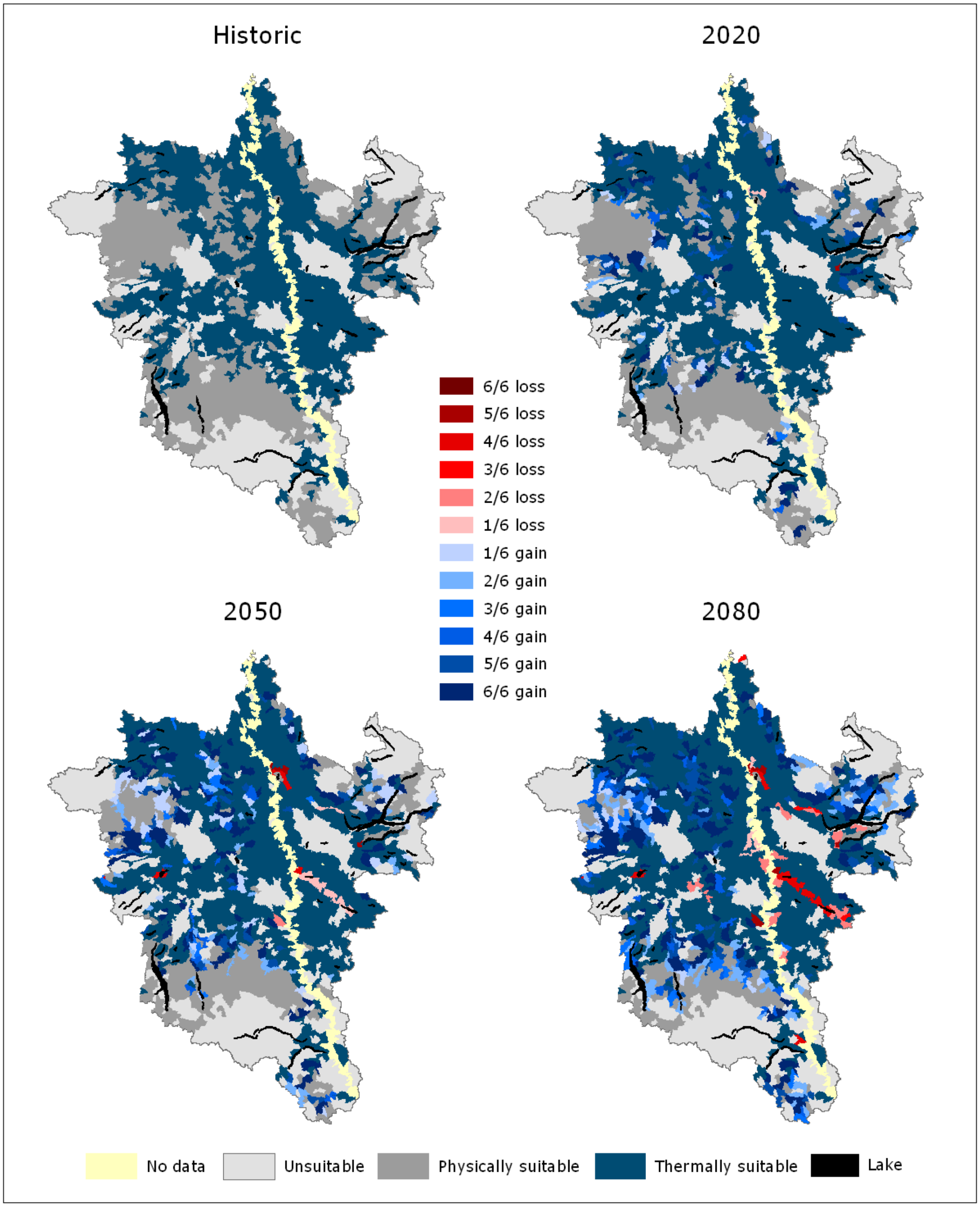

Figure 3. Representation of physically accessible and thermally suitable polygons for Chinook salmon across the Cariboo-Chilcotin region

Polygons with increasingly deeper shades of red (or blue) denote the number of climate change models / scenarios that predict the loss (or gain) in thermal suitability of a polygon. Map from Nelitz et al. (2010).

1.2 Regulatory context

Governance of the natural resource sector is directed by statute, regulation, and policy. Management (operational) activities result from interpretation of this direction. Although each of these governance elements is distinct, together they can be seen as on a continuum that provides legal requirements (statutes) at the legislative level, through to natural resource management procedures and guidance at the local (operational) level. There can, however, be significant overlap among the various levels of policy—from legislative through to operational—making it difficult to make clear distinctions between them. To simplify the discussion is this paper, regulation and policy are separated into regulatory sections by forest and oil and gas sectors, an overarching policy context section, and an overview section describing regulatory tools that may complement TSS management.

1.2.1 Regulatory requirements in the forestry sector

In British Columbia, the provincial government first exercised its statute-making authority to protect TSS with the establishment of the *Forest Practices Code of B.C. Act* (FPC). Under this legislation, and section 15(1) of the accompanying Timber Harvesting and Silviculture Practices Regulation (British Columbia 2002), retention of riparian vegetation was required to provide shade and thermal buffering to a stream. Using the FPC, both the Nicola River (Grozier 2000) and the Nadina River (Andy Witt, per. comm.) were recognized as TSS. However, when the FPC was superseded by the *Forest and Range Practices Act* (FRPA) neither of these rivers received legal status as TSS, nor are they currently recognized as such.

When the FRPA was enacted in 2004, it dealt with stream temperature sensitivity by using two regulations together to achieve a regulatory framework similar to the former FPC. First, section 15 of the Government Actions Regulation (GAR) provides authority to the Minister, or Minister's designate [3] responsible for the *Wildlife Act* to legally designate a "fish stream" as a TSS when satisfied that the stream meets two particular technical criteria. This designation, in turn, triggers practice requirements set out in section 53 of the Forest Planning and Practices Regulation (FPPR). Pertinent sections of both regulations are highlighted below. (Also see Appendix 1 for further discussion on the operational implementation of these regulations and related legal definitions).

[3] Delegations of statutory authorities are addressed through the *Interpretation Act* and Part 7 Division 3 of the *Forest and Range Practices Act*.

GAR (s.15) authority to designate a TSS:

"Temperature sensitive streams

15. The minister responsible for the *Wildlife Act* by order may designate a portion of a fish stream as a temperature sensitive stream if satisfied that:

(a) trees are required adjacent to the stream to manage the temperature of the designated portion for the protection of fish, and

(b) management of the temperature of the designated portion is not otherwise provided for under this regulation or another enactment."

FPPR (s.53) sets out the practice requirement:

"Temperature sensitive streams

53. An authorized person who fells, modifies or removes trees in a riparian management area adjacent to a temperature sensitive stream, or a stream that is a direct tributary to a temperature sensitive stream, must retain either or both of the following in an amount sufficient to prevent the temperature of the temperature sensitive stream from increasing to an extent that would have a material adverse impact on fish:

(a) streamside trees whose crowns provide shade to the stream;

(b) understory vegetation that provides shade to the stream."

1.2.2 Regulatory requirements in the oil and gas sector

Environmental regulation that applies to the oil and gas sector came into effect in 2010 through the establishment of the Environment Protection and Management Regulation (EPMR) (British Columbia 2010) under the *Oil and Gas Activities Act* (OGAA) (British Columbia 2008a). Although the content of the regulation is modeled after FRPA, it differs in distinct ways.

Under OGAA and the EPMR, when a stream is designated as a TSS, practice requirements or operating standards are not triggered as they would be under the FPPR. Rather, under the EPMR the onus is on the permitting authority—the Oil and Gas Commission (OGC)—to ensure that the appropriate conditions have been added to any permitted oil and gas activities. This is achieved when the minister responsible for the *Wildlife Act* designates by order a portion of a fish stream as a TSS [if satisfied that trees are required adjacent to the stream to manage the temperature of the designated portion for the protection of fish (section

28)], which triggers section 5(b), the government's environmental objective for temperature sensitive streams:

> "sufficient streamside trees and understory vegetation be retained to prevent the temperature of a temperature sensitive stream from increasing or decreasing to an extent that would have a material adverse impact on the fish in the stream".

The Oil and Gas Commission (OGC) must then consider this objective when adjudicating permit applications in accordance with section 25 (1) (b) of the OGAA:

> 25 (1) …on application by a person under section 24 [Application for a permit and authorization] and after considering…
>
> > (b) the government's environmental objectives, if any have been prescribed for the purposes of this section,
>
> the commission may issue a permit to the person if the person meets the requirements prescribed for the purposes of this section.

The *Oil and Gas Activities Act* further stipulates that a permit holder must follow conditions surrounding government's environmental objectives as specified in a permit allowing an oil and gas activity to be performed.

Another difference is in the application of the EPMR. Identification and designation of a TSS under the EPMR (s.28) is identical to GAR; however, where FPPR (s.53) stipulates the extent of riparian management associated with TSS protection, the EPMR leaves the extent open to the requirements necessary to provide thermal buffering.

The approach used under section 5 (b) to protect a stream's thermal vulnerability may prove more effective in that the actual riparian area specified for buffering purposes can be tailored to specific conditions within the stream network. Furthermore, this regulation includes consideration of winter-time low temperatures, which can be particularly important where cold conditions (Naiman et al. 2005), such as those found in B.C.'s northern and interior regions, are often experienced.

Since the regulation is relatively new, details surrounding the implementation of the TSS aspects of EPMR are vague. Based on the differences described above, it is clear, however, that stream temperature protection requires the various government agencies with an interest in thermal stream protection to develop appropriate guidance and to work closely with OGC to ensure that the additional detail required to thermally buffer streams is reflected in the permitting process.

1.3 Policy context

“Government policy” is a somewhat broad term because it exists at various scales and levels of influence as government exercises and implements its law making authorities. Two examples illustrate the breadth of government policy: at one level of influence, creation and implementation of statutes and regulations are driven by overarching government policy; at another level of influence, government proclamations, interpretation of regulations, including the development of detailed standards, guidelines, and procedures, also represent government policy. Furthermore, government policy may change as priorities adjust to changing public priorities and demands. The following discussion highlights some of the context surrounding current government policy in relation to implementation of TSS protection measures.

1.3.1 Government direction and goals

From the perspective of maintaining fisheries values, the protection of streams having temperature sensitivity is among the Government of British Columbia’s sustainability priorities. The Ministry of Forests, Lands, and Natural resource Operations has recognized the considerable environmental, social, and economic benefits that are derived from maintaining the productive capacity of British Columbia’s natural environment in their Service Plan by setting stating direction for the Ministry’s areas of focus including:

> “...*ensuring that environmental standards are upheld and environmental sustainability is achieved with resource use activities in British Columbia...”* B.C. Ministry of Forests, Lands, and Natural Resource Operations 2012).

Objective 2.1 of the Service Plan (Ibid 2012) speaks to the necessity of natural resource development activities adhering to government’s legislative and regulatory framework. Furthermore, this objective is recognized strategically under Goal 2 of the Service Plan through government’s commitment to climate change adaptation measures and enhancing public trust in natural resource management practices and operations, all of which will be addressed by establishing temperature sensitive streams under GAR or the EMPR.

The Ministry of Environment, the Ministry of Forests, Lands, and Natural Resource Operations and other public agencies are obliged to pursue government goals throughout their respective business obligations including showing a commitment to sustaining environmental values, including those associated fish and fish habitat. Such direction is intended to be reflected as a priority in agency planning and practices when undertaking statutory and service delivery commitments. Examples of this are reflected through cabinet endorsed documents such as the Freshwater Fisheries Program Plan (B.C. Ministry of

Environment 2007), Ecosystems Program Plan (Ibid 2009),Conservation Framework (Ibid 2010), and Priority Setting for Implementation of Fish and Wildlife Habitat Conservation under the Government Actions Regulation (Ibid 2011). In addition, land use plans and other such regional and local level planning processes may also emphasize localized government priorities for fish and stream temperature-related management direction.

All of these help establish a rationale and priority for designating streams with temperature sensitivity by demonstrating a social—and often the supporting technical—imperative for the conservation value under consideration. For the purposes of the proposed TSS procedure herein, "conservation value" is any population of a fish species or groups of fish species (communities) that reside within a candidate stream and that are known to be vulnerable to temperature changes outside their tolerance or preference limits during any life stage

1.3.2 Policy harmonization among resource management sectors

Regulation and policy surrounding the management and exploitation of natural resources on Crown land is often differentiated by sector. In some instances this separation has been due to the nature of the activities unique to a sector, which requires rules tailored specifically to that sector. In other cases, one sector will be required to adhere to regulatory requirements with which another sector is not legally compelled to comply, despite conducting identical activities with similar levels of impact on important resource values. For example, road building and stream crossing standards often differ by sector. This situation complicates the administration and implementation of natural resource management across the landscape, often with unfavourable economic and environmental costs.

The recent reorganization of B.C.'s resource sector ministries that resulted in the creation of the Ministry of Forests, Lands, and Natural Resource Operations (MFLNRO) may indicate a move to regulatory and policy harmonization. Under the proposed harmonization model, if fully implemented, a commitment to co-ordinated service delivery across all natural resource sectors may result in increased efficiencies. The new MFLNRO vision, "*Economic Prosperity and Environmental Sustainability*", coupled with a commitment to science-based decision making and cumulative effects management may also signal a move toward streamlining regulation and policy and uniform application of environmental standards across all sectors.

In B.C., only the forestry sector has had a regulation for the legal designation of a stream as temperature sensitive and that legally compels this sector to thermally buffer sensitive streams by retaining riparian vegetation. As stated above, government has recently put in place provisions to manage oil and gas sector activities to further protect TSS. However, implementation of this new regulation is in its infancy, and procedural details surrounding how temperature sensitivity will be protected under OGAA have not been finalized. It is assumed, however, that evaluation and designation of these streams will largely mirror and follow GAR procedures because the environmental provisions in the Environmental Protection and Management Regulation (EPMR) was modeled after the FRPA's GAR and FPPR and then tailored to the oil and gas industry. Accordingly, establishment of the EPMR for the oil and gas sector is a first step in government's move to harmonize policy around the natural resource sector activities, including implementation and procedural direction.

1.3.3 Other regulatory tools that can complement TSS protection

In addition to the policy considerations discussed so far, there are tools that can influence and direct management of stream temperature that singular regulatory requirements for TSS alone do not provide. For example, there are regulatory tools both within and outside the forestry and oil and gas sectors that can contribute to the management of stream temperature sensitivity. Currently, these tools (e.g. overlapping GAR designations, Fish Act provisions, and the Water Act Modernization process) are not explicitly used together and are discussed further here. For instance, where subsurface water is intercepted and subjected to warming influences (e.g., localized atmospheric temperatures and solar radiation) as a result of road construction and other forestry activities, and these activities impose additional impacts on a stream's temperature vulnerability, a GAR s.14 fisheries sensitive watershed (FSW) designation could be used to manage these situations in addition to the TSS riparian protection provisions specified in the FPPR. In this situation, a water quality objective might be established using GAR s.14 to emphasize the need for special management of streams upstream and upslope of a TSS in order to prevent additional adverse thermal changes.

Another example would be to use a wildlife habitat area (WHA) designation under GAR in conjunction with a TSS designation to highlight the need for special management over an area (non-watershed based landscape unit) that would protect specific thermal habitat for a species at risk such as bull trout (e.g., areas of coldwater hyporheic or groundwater inflows to streams). In either example, a combination of TSS-FSW or TSS-WHA designation would overlap and work together to address a different set of thermal processes affecting the same stream. It is expected that multiple designations would be used in specific cases and based on the site-specific requirements of the area in question.

Section 9 of the *Fish Protection Act* (British Columbia 1997a) offers another avenue for protection. During summer, when stream water levels are typically at their lowest, streams become vulnerable to excessive heating. Where licensed water withdrawals in a watershed put fish at risk due to exacerbated summer low flows and thermal conditions, the Minister responsible for the Act can order a temporary reduction in withdrawals to protect fish (e.g., B.C. Ministry of Environment 2009).

Although not currently enacted in the regulation, the *Fish Protection Act* has provisions built into the statute that could be utilized at some future date to achieve protection similar to section 9 of the *Act* (e.g., section 8, which sets aside stream flows and volumes in a permanent reserve for environmental and conservation purposes; see British Columbia 1997b). Under various climate change scenarios, the utility of these sections may become more apparent, resulting in their increased implementation. One of the strengths of this legislation is that, consistent with government's policy harmonization goals, actions taken under the *Fish Protection Act* apply to all sectors, including agriculture.

Broad authorities for water allocation and management are provided under the *Water Act*. This statute is currently undergoing a significant review called Water Act Modernization (British Columbia 2008b). The four goals of Water Act Modernization are to: (1) protect stream health and aquatic environments; (2) improve water governance arrangements; (3) introduce more flexibility and efficiency in the water allocation system; and (4) regulate ground water use in priority areas and for large withdrawals. In addition to provisions under the *Fish Protection Act*, and recognizing the emphasis on stream and environmental health goals, it is expected that there may be additional provisions under a modernized *Water Act* which may apply to managing the withdrawal of water from streams at times of critically low flows.

It would be prudent to consider synergies among all of these regulatory tools. Although it is recognized that a TSS designation under GAR or EPMR is not appropriate for all thermally sensitive streams, or the full stream network of a designed TSS, such a designation would alert those responsible for water allocation and management to the vulnerability of a designated stream. A consideration of ways in which these tools can be used together would be an important near-future policy initiative.

2 A proposed TSS designation procedure

A procedure used to establish a legal order under the GAR is subject to a series of tests.[4] These tests are applied sequentially and can be separated into two broad categories: (1) unique “technical criteria” and (2) generic “regulatory tests”. The first uses technical criteria to assess the conservation values under consideration (discussed in Section 2.1), and the second uses generic regulatory tests as laid out in GAR (summarized in Section 2.2). Each test must be considered appropriately for a legal designation under the regulation (see Appendix 2 for summary of these tests).

The technical criteria are unique to the specific action being considered under GAR, (fisheries sensitive watershed criteria are very different from, for example, the criteria used to evaluate a wildlife habitat areas), and are used to assess whether the conservation values under consideration are sufficient to warrant conservation. The general regulatory tests are generic in that they apply universally to all actions undertaken under GAR (regulatory tests are the same for a fisheries sensitive watershed, wildlife habitat area, etc.), and determine whether the effect of the proposed GAR action is disproportionate to impacts on a forest licensee or the forest sector generally. These two categories of tests directly influence the procedural steps (described in Section 2.3) used to evaluate a proposal for TSS designation.

The following subsections describe the proposed method for evaluating the technical criteria (section 2.1), briefly outline the application of the technical criteria (section 2.2), summarize the regulatory tests as required under GAR (section 2.3), and lays out the procedural steps to guide government staff and interested parties in the TSS evaluation and designation process (section 2.4).

[4] The procedure summarized in this section focuses on TSS designation under FRPA. A procedure for designation of a TSS under OGAA has yet to be developed. However, with the exception of completing the details concerning formalization of a procedural relationship between government agencies responsible for stream temperature sensitivity and OGC (including the OGA’s permitting process), it is expected an EPMR oriented TSS procedure will be similar in approach, in many respects to that of GAR’s.

2.1 Technical criteria

The technical criteria described here reflect a method for evaluating the suitability of a candidate stream as a TSS that is informed by the relevant biological and physical parameters supporting the proposed designation. The prevailing approach for managing stream temperature in other jurisdictions is often linked to identifying "water temperature criteria" (e.g., Oliver and Fidler 2001; US EPA 2003). Management practices, such as riparian forest harvesting, are then modified to maintain a stream's natural thermal buffering capacity (Naiman et al. 2005; Tschaplinski and Pike 2010). While the merits of an approach focused on water temperature are recognized, limited financial and human resources can preclude using this approach because it often involves developing complex monitoring and analysis systems that can be costly and time consuming. Therefore, more practical methods must be considered which reasonably achieve similar ecological outcomes. The technical criteria proposed here recognize the significance of a temperature centered approach, but allow for the consideration of a range of available science and additional factors associated with temperature sensitivity enabling a timely and cost effective evaluation of a stream's suitability for TSS designation.

The proposed technical process for evaluating whether a stream should be designated as temperature sensitive focuses on three interrelated criteria: 1) the presence of a conservation value, or values, of interest (i.e., fish species or community); 2) the quality of evidence that indicates stream temperature is likely to impact conservation value(s); and 3) the feasibility of realizing net benefits to the conservation value(s). Application of the technical criteria requires assessment of each criterion such that it results in a simple yes or no answer and where a stream advances as a TSS candidate only if the answer to each criterion is yes.

While some approaches are highly technical, and determining suitability becomes a complex question to resolve, the approach proposed here results in a clear "yes" or "no" indication of whether or not a candidate stream qualifies as a TSS. Furthermore, this approach allows government to select and prioritize candidate streams for TSS designation where the highest priority candidates for designation would be those having (i) high conservation values, (ii) sufficient evidence to support a designation, and (iii) the greatest immediate conservation benefit (see Appendix 3). Finally, this approach is consistent with the technical requirements for stream sensitivity evaluation provided in GAR. Each criterion and its related question are discussed in greater detail, below.

2.1.1 Technical criterion 1: conservation values

The first criterion identifies the fundamental conservation value that GAR (s.15) is intended to protect, specifically, any population of a fish species, or groups of fish species (communities) that reside within a candidate stream and that are known to be vulnerable to temperature changes outside their tolerance limits during any life stage. The nature of vulnerability is not limited to acute effects (e.g., extreme effects such as fish mortality) but includes chronic effects as well (e.g., behavioral changes, etc.). In this case, the conservation value includes species that may be at risk (e.g., rare, endangered, threatened, etc.) and those that have human-use significance (e.g., First Nations food and ceremonial uses, economic benefits, recreational values, etc.). Ideally, where the conservation value is being fully protected, the species of interest would benefit from the maintenance of optimal temperatures for viability. Therefore, the first step in determining whether a candidate stream is a TSS is to confirm (a) whether fish are present and, if yes, (b) whether they are sensitive to certain variations in temperature. Thus, the question criterion 1 aims to answer is:

Are there fish species of conservation value that reside in the stream that are vulnerable to changes in stream temperature during any stage(s) in their life cycle?

Answering this question requires knowledge of the stream's fish population(s) and the specific temperature-related vulnerabilities by life stage for each species of interest. (Of course, seasonal variations in stream temperature correlate with life stage vulnerability and are relevant to the overall determination—this is addressed separately in the next criterion). As shown in Table 2, by assessing a fish species' or fish community's vulnerability to temperature, technical criterion 1 can be answered with a "yes" or "no". For example, any population in a stream that meets vulnerability conditions rated as *moderate* or higher would receive a "yes" answer.

Table 2. Fish species/community temperature vulnerability rating

Vulnerability	Description of vulnerability	Criterion 1 answer
Very High	At least one known salmonid or fish species at risk is known to utilize the stream during any critical stage in its life cycle when stream temperatures are elevated.	Yes
High	An assemblage of species (community) will undergo a shift (or has undergone a shift) as a result of water temperatures reaching a known threshold.	
Moderate	A fish species is known to utilize the stream network during one (or more) life cycle stages when the fish is vulnerable to elevated temperatures.	
Low	At least one fish species is known to utilize the stream network but is not temperature sensitive relative to occupancy, life cycle susceptibility, and the (seasonal) stream conditions.	No
n/a	No fish currently or historically utilized the stream network.	

2.1.2 Technical criterion 2: quality of evidence

Assessment of this criterion is the most complex of the three technical criteria, and involves evaluating the quality of evidence that indicates impact(s) upon the conservation value. For this criterion, a yes or no determination is sought based on the question:

Is the quality of evidence or information that indicates a temperature-related impact or potential for impact upon the conservation value sufficient to support a TSS designation?

By their nature, assessments of quality of evidence such as that proposed in this subsection are vulnerable to subjectivity. To avoid subjectivity in resolving criterion 2, the assessments must be approached logically and expert advice sought if needed to help confirm the decision. Evidence that shows a correlation between some form of an effect on the conservation value and temperature will in almost all cases be necessary to satisfy a “yes” answer to criteria 2.

Several examples are offered below to help illustrate this approach and the range of considerations involved in evaluating quality of evidence. In Table 3, evidence assessment criteria are depicted on a scale ranging from weak to strong, and where the quality of information is demonstrably strong, a “yes” answer is concluded.

Evaluating the quality of evidence for a stream’s temperature sensitivity can be seen as determining where the supporting information lies along a continuum. The strongest evidence would be of considerable quality and might include data from well-designed, published, multi-year, temperature monitoring studies of the stream of interest. At its weakest, evidence that is anecdotal (i.e., no quantitative data) would be considered as being of poor quality.

For instance, well-designed *multi-year* temperature monitoring studies linked to conservation value vulnerabilities would be assessed as having sufficient quality, mainly due to the temporal duration of the study (e.g., annually repeated). In most situations, such evidence would be assessed as sufficient on its own to provide a “yes” answer to criteria 2. In contrast, impromptu temperature readings alone, taken incidentally while a biologist happened to be in the field, would be assessed as weak or poor quality of evidence. Where incidental temperature data corroborates other evidence, e.g., temperature measurements that coincide with a hypothesised thermally induced fish kill, these two corroborating forms of information, when taken together, support a “yes” answer to criterion 2 because each increases the quality of the other. But even that will depend upon the validity of methods used to collect the temperature data.

Table 3. Evaluating the quality (strength) of different forms of information

Evidence	Description	Criterion 2 answer
↑ Strong	Any combination of information described in the two Yes boxes below indicates a very high strength and quality of evidence.	Yes
	• Calibrated/validated localized models • Publically available peer reviewed reports or publications	Yes
Increasing quality of information	• Fish kill & temperature data • Generalized (encompassing large areas) models & temperature data • Temp stress & temperature data • Behavior & temperature data • Opinion of professionals	Yes
Weak	• Suspected temperature-related fish kills • Temperature stress suspected due to behavior observations • Anecdotal information	No

Another aspect of evaluating the quality of evidence relates to the type of information and how it pertains to the environmental context in which the information applies. In the case of temperature sensitivity and fish vulnerability, biological data may be regarded as having less certainty if there is difficulty in establishing specific causal linkages. For example, how certain is the inference that a fish-kill was caused by thermal stress versus some other cause? Confirmation usually requires a necropsy, a costly and specialized procedure that must be performed soon after mortality. On the other hand, assessments of physical parameters e.g., water temperature, adequacy of existing riparian buffers from amount of available riparian shade, etc., are much easier to capture. As described above, correlating biological evidence with physical indicators can increase the strength of evidence that indicates a candidate stream is temperature sensitive. Examples of biological and physical information include the following:

Biological evidence

- Historical trends (temporal considerations), such as a temperature sensitive species that may once have resided in a stream, or measures of declining abundance in a resident population;
- Impacts on a specific life stage, e.g., fry emergence, juvenile rearing, or overwintering survival;

- Changes in individual behavior, e.g., rates of holding in cold water refugia;
- Change and rates of change in temperature-induced mortality, e.g., directly due to increased physiological stresses or indirectly due to increased incidence of thermally responsive diseases;
- Presence of a thermally vulnerable species, e.g., bull trout or sockeye salmon;
- Impacts on fish communities associated with known temperature thresholds, e.g., shift from a cold water to cool water fish community, or a shift from a cool water fish community to a warm water fish community;
- Biological models.

Physical evidence

- History (temporal considerations), e.g., long-term temperature monitoring; past or potential for future riparian harvesting;
- Physically based models, e.g., Nelitz et al. 2008 and Ptolemy 2010;
- Temperature monitoring data linked to known thresholds for community shifts and stress/mortality as per criterion 1 – conservation values, etc.
- The suitability and capacity of the riparian buffer to provide shade for thermal regulation.

Underlying the evaluation of criterion 2 is the application of basic scientific principles of data collection, analysis, and interpretation. A published study with data (e.g., water temperature) that supports temperature sensitivity specific to a candidate stream is evidence of very high quality, or strength; however, incidental data collected on an ad hoc or otherwise limited basis with no study design would be considered as evidence of little strength and quality. Replication is also important in determining quality of evidence because it can demonstrate statistical significance to a hypothesis test (Johnson 1999). For instance, independent studies that yield similar results using different approaches or methods, applied at different times, can add considerably to the quality of evidence (Johnson 1999).

From a professional reliance perspective, Reader (2006) offers additional guidance on appraising the quality and validity of scientific and technical information (Table 4). Here, Reader lists various attributes (characteristics) associated with different forms of scientific and technical information that can be used in the professional realm. As with other scientific and technical evaluation schemes, well designed and peer reviewed studies are weighted the strongest, but other types of information are also held as valid if certain attributes supporting the information are present.

An example of how various forms of information could lead to a “yes” answer to the question of whether the evidence is sufficient to support designation of a candidate stream as a TSS might follow this logic: 1) a fish kill attributed to temperature based on observations made by a professional fisheries biologists combined (correlated) with 2) temperature data collected at the location at or around the time of the incident in a manner suitable to reasonably support the observation.

There may be situations, where evidence from different sources is conflicting. In these instances, if the quality of evidence is determined to be weak, it may be necessary to collect additional evidence that improves the confidence or refutes the estimates supporting a TSS proposal.

Table 4 helps illustrate how the evaluation process for this criterion can be used to make a yes or no determination.

Table 4. Validating scientific and technical information using attributes (from Reader 2006)

SOURCE OF SCIENTIFIC INFORMATION	CHARACTERISTICS *					
	Peer Review	Methods	Logical conclusions & reasonable inferences	Quantitative analysis	Context	References
A. Research. Research data collected and analyzed as part of a controlled experiment (or other appropriate methodology) to test a specific hypothesis.	x	x	x	x	x	x
B. Monitoring. Monitoring data collected periodically over time to determine a resource trend or evaluate a management program.		x	x	y	x	x
C. Inventory. Inventory data collected from an entire population or population segment (e.g. individuals in a plant or animal species) or an entire ecosystem or ecosystem segment (e.g. the species in a particular wetland).		x	x	y	x	x
D. Survey. Survey data collected from a statistical sample from a population or ecosystem.		x	x	y	x	x
E. Modeling. Mathematical or symbolic simulation or representation of a natural system. Models generally are used to understand and explain occurrences that cannot be directly observed.	x	x	x	x	x	x
F. Assessment. Inspection and evaluation of site-specific information by a qualified scientific expert. An assessment may or may not involve collection of new data.		x	x		x	x
G. Synthesis. A comprehensive review and explanation of pertinent literature and other relevant existing knowledge by a qualified scientific expert.	x	x	x		x	x
H. Expert Opinion. Statement of a qualified scientific expert based on his or her best professional judgment and experience in the pertinent scientific discipline. The opinion may or may not be based on site-specific information.			x		x	x

x = Characteristic must be present for information derived to be considered scientifically valid and reliable

y = Presence of characteristic strengthens scientific validity and reliability of information derived, but is not essential to ensure scientific validity and reliability

Description of Characteristics of Scientific Information	
Peer review	The information has been critically reviewed by other persons who are qualified scientific experts in that scientific discipline. The criticism of the peer reviewers has been addressed by the proponents of the information. Publication in a refereed scientific journal usually indicates that the information has been appropriately peer-reviewed.
Methods	The methods that were used to obtain the information are clearly stated and able to be replicated. The methods are standardized in the pertinent scientific discipline or, if not, the methods have been appropriately peer-reviewed to assure their reliability and validity.
Logical conclusions & reasonable inferences	The conclusions presented are based on reasonable assumptions supported by other studies and consistent with the general theory underlying the assumptions. The conclusions are logically and reasonably derived from the assumptions and supported by the data presented. Any gaps in information and inconsistencies with other pertinent scientific information are adequately explained.
Quantitative analysis	The data have been analyzed using appropriate statistical or quantitative methods.
Context	The information is placed in proper context. The assumptions, analytical techniques, data, and conclusions are appropriately framed with respect to the prevailing body of pertinent scientific knowledge.
References	The assumptions, analytical techniques, and conclusions are well referenced with citations to relevant, credible literature and other pertinent existing information.

2.1.3 Technical criterion 3: feasibility of realizing a net benefit

Conceptually, evaluating the feasibility of realizing a net benefit to the conservation value(s) is the most straight-forward criterion. This evaluation requires discerning whether or not there is a reasonable likelihood of a net thermal buffering benefit provided by maintaining or restoring an intact (healthy) riparian area. A “yes” answer can be assigned to this criterion if a net increase in thermal buffering can be achieved through riparian protection above what is ordinarily afforded by the FPPR. For criterion 3, a “yes” or “no” determination is based on answering the following question:

Is there a reasonable likelihood that riparian vegetation retention or riparian restoration/recovery will provide a net benefit to the stream’s thermal-buffering capacity? [5]

The goal in designating a candidate stream as a TSS is to provide a net temperature benefit that has a reasonable likelihood of sustaining fish within the identified stream network. This can be achieved by ensuring that water temperatures do not exceed a practical physiological threshold linked to outcomes that would, for example, lower stream temperatures from sub-lethal levels to within a species’ tolerance or, more important, to the optimal or preferred range for a vulnerable life stage, species, or community. However, precisely associating riparian management practices and specific water temperature outcomes under the FPPR would be excessively difficult and impractical. In contrast, understanding the physical processes that achieve temperature buffering and/or regulation within a stream network is a more effective and practical way to achieve this goal. Determining this can be tied to an analysis of the known physical processes and features that provide thermal buffering and regulation. In some cases, although the TSS network may be relatively large compared to specific locations where a net benefit will occur (e.g., habitat types such as a thermal refuge associated with shade, or where the introduction of groundwater or hyporheic upwelling occurs), designating the larger area may be necessary to preserve the natural processes required to maintain the habitat type(s) that provide net benefit(s). It is also important to consider that areas often change spatially over time as riparian vegetation changes, and stream dynamics cause channels to shift spatially. Protecting spatially small features, and taking into account inevitable changes that take place over time, may therefore require conservation of an extended stream network to

---

[5] A similar question can be posed for the oil and gas sector around water withdrawals, i.e.: Is there a reasonable likelihood that limiting upstream water withdrawals will provide a *net* benefit to the stream’s thermal-buffering capacity?

maintain natural processes and meet future requirements. If a sound case can be made that providing even small areas of refuge during critical periods will meet the net benefit requirement under this criterion, then the answer to the criterion 2 question would be ”yes”.

Assessing the net benefit does not necessarily mean limiting considerations to within the TSS designation process alone. As discussed in section 1.3.3, combining regulatory tools under a statute (e.g., FRPA) may in some situations be required to achieve the intended conservation goal behind a proposal to designate a stream as a TSS. In these situations a combination of both GAR actions, i.e., TSS and associated FSW might be required to be effective.

A simple GIS modeling of the candidate stream network can be a good starting point [6] to help assess what proportion of additional riparian protection that might be needed (see Figure 8 and associated discussion in Appendix 1). The method used should be based on existing fish inventories and attributing default FPPR stream classifications and retention requirements on various segments of the candidate stream network. Using this method may provide a useful generalized comparison of the area that would receive a potential net benefit from incremental riparian retention upon designation. In some cases the method may provide a reasonable means on its own or with other information for determining an answer to the question posed in criterion 2. Some level of analysis will be required to determine if a “yes” answer can be attributed to this question.

Finally, a critical aspect underlying the FRPA results-based framework is verification of effectiveness. Scientifically sound monitoring protocols are necessary to test the effectiveness of TSS designations, to demonstrate to all parties that the intended goals are being met, and that the net benefit is and continues to be realized (see section 2.6 for further discussion of TSS monitoring).

---

[6] In many situations GIS modeling might present challenges because most commonly available stream network coverages do not accurately depict the true full extent of a stream network. Also, the attribute data associated with these coverages do not provide the classification system used on the ground by the FPPA that is necessary to understand which specific streams and stream reaches require management under a TSS designation (see Table 9 in Appendix 1 for description of the FPPA stream classification system). In addition, topographic or geophysical features may require some additional analysis to determine the level of protection provided by site-specific features such as shading due to aspect or topographic relief.

2.2 Applying the criteria

The technical criteria should be applied sequentially, starting with criterion 1. Iteration may be required, with a previous criterion being reconsidered to ensure each has been logically and defensibly met. This especially applies if there is reasonable evidence that a stream meets the technical criteria but the information is insufficient to fully support or refute designation as a TSS.

A typical evaluation process for a TSS designation would follow that laid out in Figure 4, in which the solid line emphasizes that the level of certainty of the answer is high, whereas the dotted line indicates uncertainty and that more information must be captured to definitively answer the criterion's question.

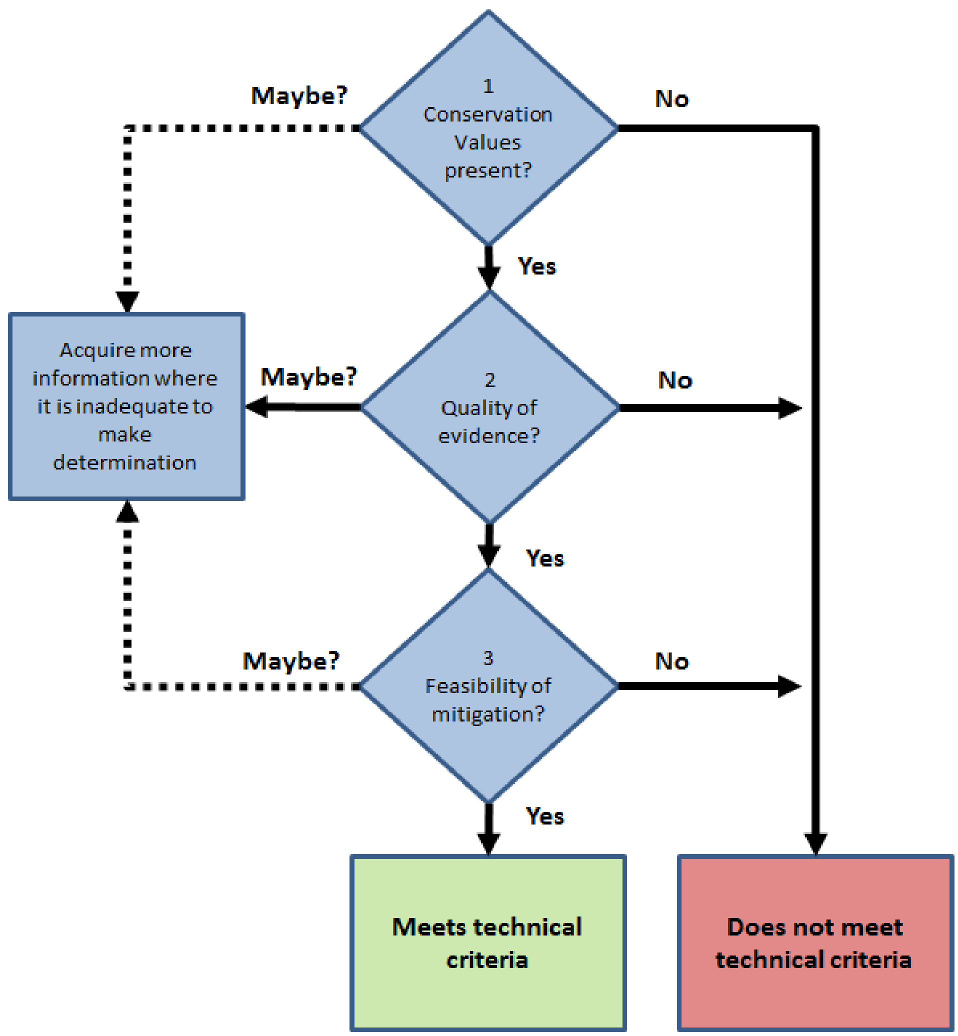

Figure 4. Typical flow of technical criteria evaluation applied to a candidate stream

Professional knowledge and peer review are essential to establishing sufficient quality of evidence in the decision process. Testing whether a particular stream reasonably meets these criteria would be premised on the FRPA results-based framework and professional reliance, both of which form the management paradigm currently envisioned under FRPA (Reader 2006). In other words, professional opinion should be applied to assess (a) actual or potential for biophysical changes, (b) whether these changes represent adverse effects on conservation values, (c) the quality of evidence used to assess these effects, and (d) the feasibility of mitigating potential adverse effects.

Such assessments rely on input both from scientists (fisheries biologists, hydrologists, etc.), and resource managers (e.g., government decision-makers) to confirm that the rationale for designating a stream as temperature sensitive reasonably meets these technical criteria. Given the importance of the technical criteria, the evaluation steps outlined later in this document (see section 2.4) will help ensure that decisions made employing this procedure are made using the best available information and a well-grounded understanding of the resource values under consideration.

2.3 Regulatory tests

The regulatory tests are set out in GAR section 2(1) and apply to all actions taken under GAR. These tests ensure that, as a result of an action, there has been consideration of both (1) benefits to the public, and (2) impacts to the industry as a whole or to directly affected licensees. The four test statements below summarize into categories a longer list of regulatory tests described in GAR (see: B.C. Ministry of Forests, Ministry of Environment, Ministry of Agriculture and Lands, and Ministry of Tourism, Culture, and the Arts 2008; also see Appendix 2):

Test 1: Will "special management" as described in the regulation (GAR s.15 and FPPR s. 53) conserve the intended value?

In the case of a TSS, this test simply means, "Will the added riparian conservation practices provided for in regulation result in a net benefit to maintaining (or recovering) the stream's thermal regime in a way beneficial to fish?"

Test 2: Is the proposed TSS designation consistent with government objectives and direction?

Here, consistency refers to objectives set by government such as high-level goals (Campagnolo 2005) through to direction provided in approved land use plans and other such policy direction. Where there is a reasonable level of consistency, the rationale for designation is can be met.

Test 3: Will a TSS designation unduly impact the provincial timber supply?

Application of this test involves an assessment of timber supply impacts related to the requirements of the TSS order. Because the actual area involved in the designation is negligible compared to the total harvesting land base, it is expected that in most cases this test will be met (see Appendix 2).

Test 4: Does the public benefit arising from the action outweigh impacts to a licensee's viability (operationally, economically, or legally) in relation to activities in the geographic area where the designation will occur?

This test is operationally oriented and, because the determination of impacts is site-specific, the onus is on industry to provide the appropriate information to government during the review and comment period (see Section 2.4, Step 4) that demonstrates the nature and magnitude of potential impacts. Where the technical criteria and all other regulatory tests establish sufficient environmental values and social direction, there is a sound rationale to suggest that the impacts have been accounted for. The final decision, however, rests solely with the delegated decision-maker (DDM) and information presented to the DDM must be balanced and not fetter a determination.

Application of the tests is discussed in the GAR administrative guide entitled *GAR: Policy and Procedures* (B.C. Ministry of Forests, Ministry of Environment, Ministry of Agriculture and Lands, and Ministry of Tourism, Culture, and the Arts 2008). Government staff responsible for administering the tests, and those interested in further information on the topic are encouraged to refer to the guide.

2.4 Procedural steps

Any procedure used to conserve environmental values under GAR must allow appropriate consideration of each specific action's technical criteria and all regulatory tests (B.C. Ministry of Forests, Ministry of Environment, Ministry of Agriculture and Lands, and Ministry of Tourism, Culture, and the Arts 2008). In the procedure outlined below, each step highlights one or more of the necessary tests applicable to the step; however, *all* tests should be considered throughout the procedure, starting with the proposal's initial draft (Step 1), through to the decision (Step 6).

Apart from the technical criteria used to evaluate a stream's temperature sensitivity (considered in Steps 1 and 2), the proposed TSS procedure follows steps similar to those used in the B.C. Procedures for Managing Identified Wildlife (2004) or PMIW. This approach is suited to the TSS designation process because it has a longstanding record and is well understood. The PMIW procedure is used to review, evaluate and, where appropriate, legally designate wildlife habitat areas (WHA) under GAR. It is also mirrored in other procedures used to conserve resource values under GAR. Each step in the TSS evaluation process is shown in Figure 5.

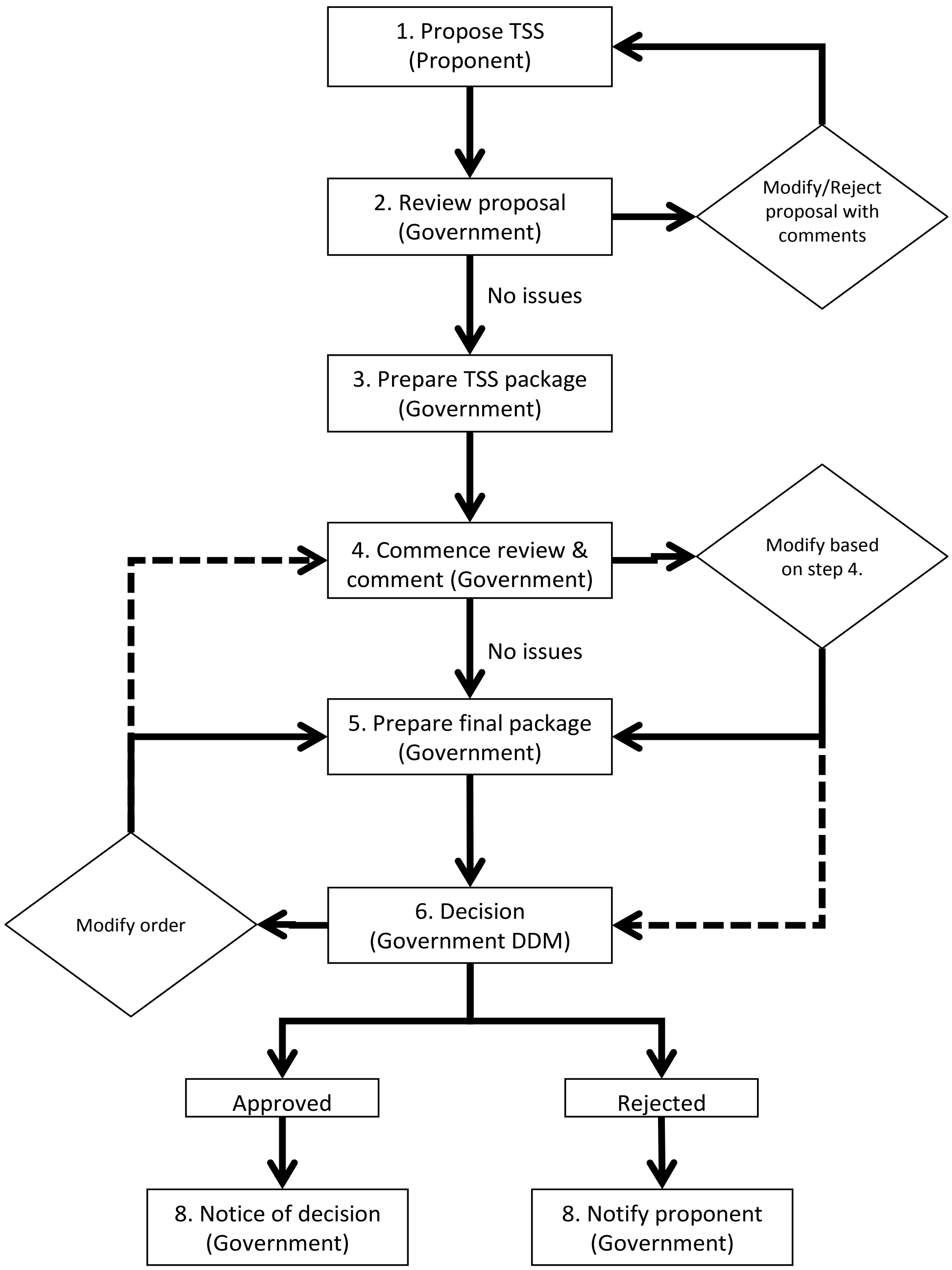

Figure 5. Flow chart depicting required regulatory steps to designating a candidate stream as a Temperature Sensitive Stream

The various roles and responsibilities associated with each step are outlined in **Error! Not a valid bookmark self-reference.** and discussed in detail thereafter. For more information regarding roles and responsibilities of individuals listed in Table 5, refer to the description under each step. Once finalized, a TSS procedure manual, similar to that of the PMIW, will serve as a guide to all parties who may have an interest in a proposed TSS, its evaluation, and the designation process.

Table 5. Proposed steps for designating Temperature Sensitive Streams including related responsibilities, timelines, and FRPA authorities

Step	Task	Responsibility (lead)	Responsibility (support)	Allotted time (# of days)	Regulatory authority
1	Propose TSS	Proponent (anyone)	Government (region)	Unlimited	n/a
2	Review proposal	Government (regional staff)	Government (HQ) & Technical Review Team	20 days	n/a
3	Prepare draft TSS package	Government (regional staff)	Government (HQ)	20 days	GAR s.15 & s.2(1) (1st application of GAR tests)
4	Commence review and comment process	Industry and proponent(s)	Government (region) Government (HQ)	30 days	GAR s.3 with respect to GAR s.15(a) and GAR s.2 and emphasis on s.2(1)(b) and s.2(1)(c)
5	Finalize TSS package	Government (HQ) & Government (regional staff)	Government technical review team	20 days	GAR s.15 and s.2(1)
6	Decision	Delegated decision maker (DDM) & Government (HQ)	As required	10 days	GAR s.2 and s.15
7	Notice of Decision	Government (HQ)	None	30 days	GAR s.4
8a	Manage	Affected licensee(s)	Professionals	n/a	FPPR s.53
8b	Monitor	Government (industry and stakeholders)	Government technical team	n/a	(Quality Assurance –Adaptive Management)

2.4.1 Step 1—Propose a TSS

Step 1 involves development of the initial TSS proposal. TSS proposals can be submitted to government by anyone (referred to here as “the proponent”) including but not limited to individuals, companies, governments, non-profit originations, and institutions. The proponent is advised to include all parties that might be affected by a TSS designation as early as possible in the proposal preparation process. It is recommended that local technical experts employed by government also be included because these individuals may help improve the content and strength of the proposal by providing valuable information and background knowledge. Regardless of who the proponents may be, they are encouraged to contact the province’s regional TSS lead to discuss the proposal early in its development as this will help clarify proposal requirements and minimize the potential for multiple iterations of the proposal, particularly between Steps 1 and 2. Once a proposal is completed it must be formally submitted to the province’s regional TSS lead, at which point Step 2 begins.

The number of streams or stream networks identified in any one proposal is not restricted; however, where there are multiple non-contiguous streams (i.e., not part of the same directly connected stream network) included in a proposal, having a list that is prioritized will assist in completing subsequent steps. In cases where there are important geographic differences and/or species of interest, this may also be a good basis for drafting multiple legal orders. Appendix 3 outlines a method for prioritizing streams based on the technical criteria described earlier.

The proponent is responsible for providing all documentation supporting a proposal. Typically, this will include a technical report and any associated mapping and digital spatial reference files (see Appendix 4 for spatial mapping specifications). The report should describe the background context that addresses the three evaluation questions (see section 2.1) and provide a rationale for proposed TSS designation that is supported by available scientific and background information.

The priority GAR tests that require consideration in Step 1 involve confirming that the basic GAR s.15 technical criteria described in section 2.1, and GAR regulatory test 1 described in section 2.3 are met. Ensuring that the technical criteria have been appropriately applied will, in essence, satisfy this test, i.e., whether there a reasonable likelihood there will be a net thermal benefit to the stream and fish species from the retention of streamside vegetation as described in FPPR s.53 (see Appendix 2).

2.4.2 Step 2—Review the proposal

Step 2 involves a review of the products submitted by the proponent in Step 1. The provincial government is the body with statutory authority to designate a TSS. Accordingly, government staff are responsible for verification of the TSS proposal's suitability. The review of the proposal will determine: (a) if the proposal meets the technical criteria; and (b) whether, predicated on a preliminary assessment, the regulatory tests set out in GAR can be met.

It should be noted that government, in fulfilling a range of its statutory responsibilities, often acts as both a proponent and reviewer of proposals. Regardless of who the proponent is, checks and balances are built in to the evaluation, review, and designation processes (e.g., Step 2 and/or 3 peer review; Step 4 regulatory review and comment process; Step 5 review by the FRPA Implementation Committee; professional reliance) to ensure that information and decisions are balanced. If government is the proponent, Steps 1 and 2 are merged.

In Step 2, the priority GAR requirements are those used to confirm the GAR s.15 technical criteria described in section 2.1 and GAR test 1 (section 2.3) are met. In cases where a TSS proposal is complex, the TSS Technical Review Committee (TTRC) may be asked to assist with the review. The make-up of the TTRC should mirror to some extent other GAR technical committees and include available experts (e.g., qualified ecosystem/ fisheries biologists and/or hydrologists) from the province, federal government, and industry. Completion of Step 2 will result in one of three outcomes:

1. The proposal may be deemed inconsistent with GAR and returned to the proponent with a written rationale for disqualification; or
2. The proposal may be determined to have merit but requiring additional information or revision. Such proposals will be returned to the proponent with a brief description of why the proposal has been returned and recommended actions prior to resubmission; or
3. The proposal may be determined to be consistent with the GAR tests. Such proposals will proceed to Step 3.

2.4.3 Step 3—Prepare TSS package

Step 3 brings together the various pieces of the proposal into a consistently and logically organized TSS package for the purposes of review and comment. This includes ensuring that a timber supply analysis has been completed. The package is to be compiled by government's regional TSS lead.

GAR regulatory tests 2 and 3 are the priority regulatory considerations in this step. GAR test 2 demonstrates the action's consistency with government goals and objectives, including goals reflected in content within land-use or sustainable resource management plans. Other historic actions used to protect a stream's thermal regime may also be important considerations as these may lend weight to meeting this test. Section 1.3.1 provides further discussion around government direction around protection of a TSS. GAR test 3 requires completion of a timber supply impact analysis by the appropriate personnel. We have assumed that, in most cases, the timber supply impact will be negligible because the riparian retention area associated with a TSS designation is typically very small, and because most Timber Supply Reviews used to determine the Chief Forester's annual allowable cut (AAC) allow for retention within the riparian management zone. Nonetheless, this topic requires further investigation and would be best addressed during a pilot test of the TSS procedure and program.

At a minimum, a TSS package should include:

1. a copy of the draft order (see Appendix 4);
2. all mapping associated with the order including GIS files (see Appendix 4);
3. a timber supply analysis; and
4. a copy(s) of the technical report (proposal) describing the TSS's suitability as per the technical criteria and GAR test 1.

Once the package has been completed and vetted by the appropriate government staff the proposal proceeds to Step 4.

2.4.4 Step 4—Commence review and comment process

The review and comment process serves three purposes: (1) it allows key parties interested in the proposal an opportunity to review and comment on the content of the TSS package, including the technical criteria and GAR tests 1 through 3; (2) it completes the mandatory requirement specified in the regulation to conduct such a review with affected *Forest Act* licensees (GAR s3); and (3) it facilitates the acquisition of information from *Forest Act* licensees to help resolve (GAR s3) test 4.

In addition to *Forest Act* licensees, Step 4 enables all affected parties to formally examine and submit their assessment of the proposal by way of written comments regarding the various beneficial or adverse impacts the proposed TSS may have. Affected parties include, but are not limited to government agencies responsible for natural resource management; *Forest Act* agreement holders; permitted petroleum and mining interests; and First Nations. Affected parties may also include local organizations that have a direct interest in the stream or watershed where the stream is located. Government's regional TSS lead is responsible for facilitating step 4. With respect to *Forest Act* licensees, government is also interested in receiving comments regarding potential impacts to: (1) the timber supply, (2) delivered wood costs, and (3) rights held under license. Step 4 not only allows an opportunity for all affected parties to conduct their own analysis of the GAR tests, but also provides an opportunity to improve upon key aspects of the proposed order.

Step 4 will take 30 days to complete. All correspondence and communications during Step 4 will be tracked and documented by the regional TSS lead in a manner that details points of agreement and, where they occur, points of departure, along with attempts to resolve points of departure. The communications record will form an important part of the rationale document supporting completion of the final package in Step 5.

2.4.5 Step 5—Finalize TSS package

The purpose of Step 5 is to ensure that all technical criteria and GAR regulatory tests have been fully considered, and a sound rational for the proposed TSS has been made. Step 5 brings the package together in its final form prior to submission to the delegated decision maker (DDM) [7]. Step 5 also serves as an ***important final quality assurance check*** prior to submission of the proposal to the DDM for consideration. In Step 5, all GAR technical criteria and all GAR regulatory tests must be fully considered and documented prior to finalizing the TSS package.

2.4.6 Step 6—Decision

At Step 6, the TSS package will be brought forward to the DDM along with the required supporting documentation (order for DDM signature, final map, TSS summary report with key elements of the timber supply analysis and affected party comments, etc.). The DDM's consideration of the package and resulting determination of its suitability will involve due consideration of all tests, including undue impacts to the provincial timber supply, and weighing impacts to delivered wood costs and the public benefit arising from the order.

[7] Historically, this authority was delegated to the MOE Deputy Minister, but was transferred to the FLNRO Deputy Minister in 2010.

The determination will typically result in one of three outcomes:

1. Rejection of the package; or
2. Return of package to headquarters/region for additional work (e.g., engagement with an affected party) prior to resubmission; or
3. Approval of TSS order.

If the TSS proposal receives DDM approval, a written rationale for the decision will be prepared by the DDM and added to the TSS package to formalize the record that supports the designation.

2.4.7 Step 7—Notice of Decision

If a TSS legal order is approved, GAR section 4 requires giving notice of the approved order and stipulates that notice must be given by the following means: (a) posting the order on one of government's GAR websites [8], including any supplementary information providing guidance and all related mapping; (b) publishing the approval in the B.C. Gazette; and (c) making the notice, along with any accompanying information that outlines management direction, publicly available at the regional office in which the TSS is located. The spatial information will also be made publically available through the B.C. Geographic Warehouse.

2.4.8 Step 8—Manage and Monitor

While Step 8 addresses (a) managing and (b) monitoring designated temperature sensitive streams (see Table 5), these two activities are not explicit requirements of the TSS designation procedure. However, both tasks are recognized as essential to conserving the intended values that the order aims to protect, and to upholding a results-based management regime. Each of these activities is discussed further in the following two sections.

[8] Government's general FRPA related GAR authorities website: www.env.gov.bc.ca/wld/frpa/index.html

Government's specific GAR related TSS authorities website: www.env.gov.bc.ca/wld/frpa/tss/index.html

2.5 Management strategies

Once legalized, the TSS order becomes a *practice requirement* and is effective immediately. As a practice requirement, there is no obligation on the part of the licensee to amend their Forest Stewardship Plan (FSP) to include TSS content (i.e., to prepare TSS results and strategies that must be added to a FSP). Rather, the requirement is simply to comply with the order. Section 53 of the FPPR sets out the riparian retention requirements for a TSS. Appendix 1 provides a discussion of TSS management specific to GAR, along with elaboration on various regulatory definitions.

2.6 Monitoring strategies

The reasons for developing a monitoring strategy are well established. Monitoring is a foundational element of FRPA (Snetsinger 2009) and its results-based regulatory regime (Coglianese 2003). Monitoring is also essential to ensuring management actions [9] are effective, that the intended values are being protected, and mechanisms for improvement are identified as necessary. Yet monitoring of management actions and evaluation of conservation programs often do not occur (Ferraro and Pattanayak 2006). A failure to monitor, evaluate, and understand the effectiveness of management actions can lead to financial, social, and environmental costs, thus eroding the efficacy and intent of results-based regulatory initiatives (Coglianese 2003).

Monitoring and evaluation are beneficial steps in designating a TSS. Scientists and natural resource professionals benefit because the information gained through monitoring improves their ability of to anticipate effects. Managers in turn benefit from the assurance that management strategies are compliant and effective. Natural resource industries benefit through reduced regulatory burden and costs over time.

Once a procedure for designation has been developed, a more detailed monitoring strategy for TSS will be needed to provide further clarity around four components: (1) purpose of monitoring; (2) sampling design; (3) field protocols; and (4) data management and analysis. The purposes of monitoring will be driven by a need to understand implementation of forest management practices, assess effectiveness of those forest management practices, and validate key relationships of interest (see Kershner 1997).

[9] In this case, management actions include regulations, legal TSS orders, and the resulting forest management practices.

Given these monitoring purposes, the following questions are deemed most relevant to a TSS monitoring strategy (TSS Technical Team pers. comm.) and are discussed in detail below:

4. What forest management practices are being implemented on designated streams?
5. Are forest management practices on designated streams maintaining stream temperatures within desired limits?
6. Are conservation values being protected through forest management practices on designated streams?
7. Has stream temperature been affected by historical forest management practices and, if so, is the thermal buffering capacity of the system recovering?
8. How is climate change affecting stream temperatures (e.g., magnitude of change, trend)?
9. What is the relationship between air and stream temperature?

Question 1 involves implementation monitoring which will be important to accurately characterize the forest management "treatments" to which a designated stream is being subjected (e.g., distinguish between high, moderate, or low levels of riparian protection on designated streams). Questions 2, 3, and 4 attempt to understand the effectiveness of forest management practices on designated streams relative to management goals. Lastly, question 5 is related to validating and improving our understanding about the role of climate change (via changes in air temperature, precipitation, and streamflow) and its influence on measuring cumulative effects as a potential confounding factor when studying temperature in designated streams.

In being clear on the purpose of monitoring, it is also important to describe the target population and sampling unit of interest. In this case, the target population will include smaller streams and rivers, specifically S2, S3, S4, S5, and S6 classes of streams across British Columbia (i.e., fish-bearing and non-fish-bearing streams with a channel widths < 20 m; see B.C. Ministry of Forests and B.C. Ministry of Environment1998) because the effects of resource management activities will mostly be undetectable on larger rivers. The sampling unit will include the reach within a stream or river at which a temperature sensor is deployed in the field (see below).

To answer the proposed TSS monitoring questions, it is necessary to describe in more detail the study design, spatial and temporal boundaries of sampling, relevant predictor and response variables of interest, and related data analyses. Details around these issues have implications for the cost and statistical validity of the final monitoring design. A TSS monitoring strategy should be both cost effective and statistically valid; however, these two objectives can be at odds. A low cost monitoring strategy might not be statistically valid because it has too few sampling locations or too few years of monitoring data to detect the effectiveness of TSS designations. Alternatively, a statistically rigorous monitoring strategy might be able to detect the effectiveness of forest management practices yet impose onerous field sampling costs on government agencies or industry.

One of the most important considerations in providing these details will be a decision on the type of study and associated level of inference of the results (Figure 6; Schwarz 1998). The inferences from some study designs are limited to sampled locations only (e.g., descriptive or observational studies), while other designs allow for much broader inferences across the population of interest (e.g., control-impact studies or designed experiments, or assessments compared against baselines compiled from sound empirical data collected for an area). Given the need to understand the effectiveness of forest management practices, it is expected that a monitoring strategy for TSS will have a high level of inference and, as a result follow the principles of sound experimental or observational design (e.g., stratification, replication, and randomization).

Stratification can be used to focus monitoring on strata of interest and to help reduce variation in temperature among streams in a sampled population and thus improve the statistical power of detecting the effectiveness of forest management practices. Based on the most influential drivers of stream temperatures, strata could be developed on the basis of stream size / stream class, variation in regional hydrology, aspect, and regional long term climate conditions (e.g., define strata into categories of smaller headwater streams and larger downstream rivers, and/or streams in regions with hot and mild summer air temperatures).

Replication of control and treatment streams will be important to appropriately characterize variation among the population of streams, and to detect significant differences among treatment and control groups. A common approach used in stream temperature monitoring is to use pairs of streams for comparison (control and treatment) or sites (upstream and downstream of disturbance) to better detect the effect of forest management practices.

Random selection and random assignment of treatments to streams (reach scale) within the population will be important to ensure that the level of inference of the results from a monitoring strategy is broadly transferrable across the population. Simple random sampling and systematic random sampling are the most common sampling designs. A simple random sample selects an individual from the population based on a random selection process, while a systematic random sample selects an individual from the population at regular interval using a random starting point. Generalized random-tessellation stratified (GRTS) designs combine the strengths of these approaches to develop spatially-balanced probabilistic surveys (Stevens and Olsen 2004). A GRTS design is being used for monitoring Fisheries Sensitive Watersheds in B.C. and would be a valuable framework within which to integrate a temperature monitoring program (Wieckowski et al. 2008; 2009; Pickard et al. 2009)

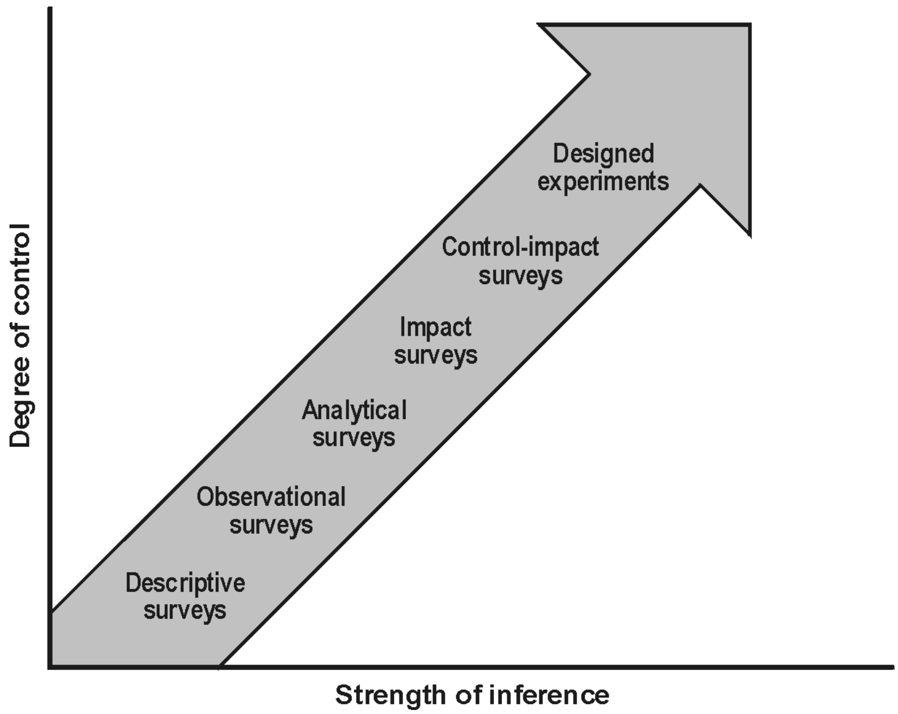

Figure 6. Continuum of monitoring studies aligned according to their degree of control and strength of inference (from Schwarz 1998)
Note: The closer a study is to the upper right-hand quadrant of the graph, the more it is inclined to become a research initiative versus a monitoring exercise.

Accompanying the details for study design are the need to describe the sampling frequency at an individual stream within and across years, and sampling effort across the population (i.e., sample size). Current technologies (see below) allow for affordable spot or continuous monitoring, both of which can provide valuable insights into stream temperature patterns (e.g., Moore 2006; Rex et al. 2012). Given their affordability and ease of deployment, many studies use sensors to monitor temperatures continuously for a number of years prior to and following disturbance. However, alternative designs are available that allow for monitoring across a greater number of samples by rotating sampling events at repeated though interspersed intervals (e.g., monitoring temperatures in a stream every other year; see McDonald 2003). The desired number of streams sampled in a monitoring strategy will be a function of the inherent variation in the population of streams and desired level of statistical power (Peterman 1990) to detect effects of forest management practices on designated streams. At this time, it is difficult to identify the appropriate number of years and samples that would be required for a TSS monitoring strategy. Power analyses are needed to provide this answer, recognizing that an increase in the number of years and samples would improve statistical power of the resulting analyses. As a reference point, Keeley and Walters (1994) recommended sampling eight to 16 streams for four to eight years to assess the effectiveness of restoration actions for the B.C. Watershed Restoration Program.

An important and early task in the process of developing a monitoring strategy will include selecting the appropriate temperature indicators / metrics (i.e., response variables) as well as the natural and human drivers of temperature to monitor (i.e., explanatory variables). Decisions about indicators will have important implications on the questions that can be answered through statistical analyses and how these data will be collected through a monitoring program.

To understand a stream's response to disturbance (i.e., the response variable), a temperature sensor can collect data by the minute, or at hourly, daily, weekly, seasonal, and annual intervals. Depending on the type of data analysis (see below), these raw data may be useful in an analysis on their own, though there may also be a need for temporal aggregations—into daily, weekly, seasonal, or annual metrics—some of which may be highly correlated with each other (e.g., Sullivan et al. 2000; Nelitz et al. 2007b). Decisions around stream temperature metrics and the accompanying analyses are important because they also have implications on the timing of sampling, statistical detection of changes in thermal regimes, and characterization of ecological responses to those changes. For example, forest management practices will have different impacts on summer and winter stream temperatures. Detecting these changes will require monitoring at different times of year, which will have implications for the metric being used in an analysis. Furthermore, different temperature metrics will vary in their biological relevance: changes in diurnal variation, summer temperatures, and winter temperatures will each be associated with different ecological responses. Table 6 provides a summary of potential indicators and metrics that could be used to monitor temperature responses.

Table 6. Alternative indicators and metrics of stream temperature response that could be collected through a monitoring program (adapted from Nelitz et al. 2007b)

Stream temperature indicator	Description of stream temperature metric
Daily stream temperature	Daily minimum temperature
	Daily average temperature
	Daily maximum temperature
Weekly stream temperature	Seven-day average of the daily minimum temperature
	Seven-day average of the daily average temperature
	Seven-day average of the daily maximum temperature
Summer stream temperature	Median value of the daily mean temperature over the summer
	Average of the daily mean temperature over the summer
	Annual maximum of the daily maximum temperature
	Annual maximum of a seven-day average of the daily maximum temperature
	Annual maximum of a seven-day average of the daily minimum temperature
	Annual maximum of a seven-day average of the daily mean temperature
	Value representing the 95th percentile of the daily mean temperature
	Number of days the daily maximum temperature exceeds 19°C
	Number of days the daily maximum temperature exceeds 15°C
	Number of days that a seven-day average of the daily maximum temperature exceeds 18°C
	Date of the maximum of the daily maximum temperature
Winter stream temperature	Accumulated thermal units over the winter
Diurnal fluctuation in stream temperature	Maximum difference between the daily maximum and the daily minimum temperature
	Minimum difference between the daily maximum and the daily minimum temperature
	Summer average of the difference between the daily maximum and the daily minimum temperature
Seasonal rate of change in stream temperature	Average rate of increase (°C/day) from the daily minimum temperature on June 9 to the maximum of the daily maximum temperature
	Average rate of decrease (°C/day) from the maximum of the daily maximum temperature to the daily minimum temperature on September 15

Another important consideration will be to specify the natural and human drivers (i.e., the explanatory variables) that need to be monitored to answer the above questions with the appropriate analyses (see Poole and Berman 2001; Gallo et al. 2005; and Table 7 for natural drivers of stream temperature which include air temperature, surface water and groundwater influences, and upland vegetation). The inherent features of a stream channel and watershed can further insulate or buffer a stream from heating, which include topographic shade, channel width, riparian vegetation, and the influence of lakes / wetlands, among others. Human activities influence stream temperatures through a variety of pathways, including riparian harvesting, water withdrawals, flow management, upslope activities (i.e., roads that intercept subsurface flow or clear-cuts that result in changes to the timing of snow melt), and channel modifications. A subset of these variables will be important to include in a monitoring strategy, either during a field visit or using remote sensed data.

Table 7. Alternative indicators of natural and human drivers of stream temperature that could be collected through a monitoring program (adapted from Poole and Berman 2001; Gallo et al. 2005)

Watershed sub-system	Related process	Sample indicators
Upslope areas	Vegetative succession, growth, and mortality	Vegetation seral stage, harvested area, land use, land cover, natural disturbance (e.g., fire, disease)
	Soil cycle	Road density, land use, land cover
	Hydrological cycle	Snowpack, glaciers, lakes, wetlands
Riparian-floodplain areas	Vegetative succession, growth, and mortality	Vegetation seral stage, riparian condition / buffer (including percent shade over stream), land use, land cover, natural disturbance
	Soil cycle	Road density, stream crossings, land use, land cover
	Hydrological cycle	Channel / subsurface connectivity, wetlands
In-channel	Channel structural dynamics	Channel width, slope, substrate, geomorphology, bank stability
	Energy exchange	Riparian condition, discharge, groundwater exchange, upstream / tributary flow, precipitation, air temperature, wind, solar radiation, shade
	Hydrological cycle	Discharge, groundwater exchange, upstream / tributary flow, water use, precipitation

A more detailed monitoring strategy will also require guidance on field protocols and procedures to ensure the proper collection of data in the field. There are five important considerations in the way a monitoring program is deployed and temperature data are collected that will help ensure the resulting field data are accurate and reliable reflections of thermal conditions in the target population of streams and sampling units of interest (for more information see Dunham et al. 2005; Quilty and Moore 2007; 2010; Isaak et al. 2012):

- selection of an appropriate temperature sensor (e.g., thermometer, mechanical thermograph, thermocouples, or thermistors);
- calibration of temperature sensors to ensure measurements are accurate and reliable;
- verification and correction of stream temperature data to ensure there are no errors in data recordings (e.g., due to dewatering);
- correctly programming temperature sensors to collect data at the appropriate and desired temporal interval; and
- appropriate placement and installation of temperature sensors so they collect data that are representative of the stream of interest (e.g., avoiding locations with direct solar radiation, vulnerable to de-watering, or high potential for natural disturbance).

The management and analyses of field data will also be important to clarify before full deployment of a monitoring program. Currently, across British Columbia stream temperature data are not collected in a coordinated, consistent, or integrated manner among academic, government, industry, and non-governmental organizations (Nelitz et al. 2008). There are valid reasons for this lack of coordination, a key one being that temperature monitoring programs are typically designed to serve tailored needs or answer different questions in a particular stream or watershed of interest. A lack of coordination or consistency, however, makes it cumbersome to use the vast amounts of data being collected to gain broader insights into the effects of climate change, as well as understanding the effectiveness of forest management strategies related to TSS. Given the ecological importance of stream temperature and influence of climate change, a valuable contribution of a TSS monitoring strategy would be to develop standardized data templates, common quality assurance / quality control procedures, and a centralized database for storing data collected through various monitoring programs.

Once a centralized database is available, many different types of analyses could be performed at a reach, watershed, or regional (multiple watersheds or landscape) scale. Among others, relevant types of analyses that have been performed in forested watersheds across western North America include:

- comparison of treatment and control streams to assess the magnitude of change in stream temperature due to contrasting “treatments” which could help answer questions 1, 2, 3, and 4 (e.g., Feller 1981; Mellina et al. 2002; Macdonald et al. 2003; Rex et al. 2012);
- comparisons of stream temperatures before and after a disturbance event (among years or along a watercourse) to assess a stream’s response which could help answer questions 2, 3, and 4 (e.g., Feller 1981; Zwieniecki and Newton 1999; Mellina et al. 2002; Macdonald et al. 2003; Moore et al. 2005; Rex et al. 2012);
- development of multiple regression models to predict stream temperatures (or fish species occurrence) at locations or at times without any monitoring data which could help answer questions 2, 3, 4, and 5 (e.g., Holtby 1988; Stefan and Preud'homme 1993; Lewis et al. 2000; Isaak and Hubert 2001; Dunham et al. 2003; Nelitz et al. 2008); and
- trend analyses to understand the relationship between air temperatures and stream temperatures, or to examine the thermal recovery of a stream (reach) after disturbance, which could help answer questions 4 and 5 (e.g., Feller 1981; Holtby 1988; Johnson and Jones 2000).

There is a potential to collect a lot of data through a temperature monitoring program; however, these data need to be coordinated within a broader monitoring framework to ensure there are informative contrasts and comparisons across space and time. To be effective, such coordination requires a long-term (though not full time) commitment to support the design, reporting, and a sense of responsibility for the program. If a monitoring strategy were developed and deployed in a coordinated way, the results of analyses could then be used to better inform managers about the effectiveness of forest management practices being used on TSS; scientists, managers, and planners about appropriate adaptation strategies in response to climate change; and politicians, policy, and the public about the performance of natural resource regulations and management actions in British Columbia.

3 Next steps: implementation and resolving uncertainties

The forgoing discussion and proposed procedure lays out the context and methods for evaluation and designation of a TSS in B.C.. Although the primary focus of this paper has been on implementation under FRPA, similar scientific, technical, and regulatory principles hold true for providing TSS protection under OGAA, and potentially other statutes as well. It is envisioned that this discussion paper will provide the foundation for a thorough appraisal of the proposed TSS procedure through a pilot application, followed by essential modifications to the procedure discovered during the pilot(s), and finally culminating in the implementation of a provincial TSS program. As with development of any policy and accompanying procedures, it is recognized that some scientific and policy uncertainties exist; however, it has been demonstrated here that sufficient knowledge and understanding of the topic exists to commence the process of establishing a TSS procedure and program. By initiating a pilot, government and those with an interest in TSS designation will have the opportunity to assess and resolve remaining uncertainties. Moving forward with a TSS program is especially relevant now, given the predicted pressures on ecosystems associated with climate change that will affect aquatic environments. Table 8 highlights suggested next steps to complete and implement a TSS procedure.

Table 8. Recommendations for completing and implementing a TSS procedure

Step	Time frame	Recommendations
1	2012/14	Conduct a pilot to establish efficacy of untested portions of evaluation criteria and administrative uncertainties using obvious TSS candidates. Pilot should include a targeted watershed basin (e.g., Nicola River or other similar basin) known for temperature sensitivity, as well as other well-documented TSS candidates across the province.
2	Fall/Winter 2012	Determine specific significance of impacts as per GAR administration tests (e.g., AAC, DWC, impacts to rights under license; see Appendix 2).
3	Spring/Summer 2013	Use the knowledge gained from the above, complete (including interagency review) and finalize TSS designation procedure manual.
4	Winter 2012 to Summer 2013	Engage the Oil & Gas Commission and adapt procedure for use under the Environmental Protection and Management Regulation.
5	2013/15	Develop an effectiveness monitoring component to evaluate efficacy of TSS designations as a regulatory tool (FREP).

4 References

B.C. Ministry of Water, Land and Air Protection. 2004. Procedures for Managing Identified Wildlife. Available from (accessed 11/01/31): www.env.gov.bc.ca/wld/documents/identified/IWMS%20Procedures.pdf

B.C. Ministry of Environment and Government of British Columbia. 2007. Freshwater Fisheries Program Plan. Available from (accessed 12/03/20): www.env.gov.bc.ca/esd/

B.C. Ministry of Forests, Ministry of Environment, Ministry of Agriculture and Lands, and Ministry of Tourism, Culture, and the Arts. 2008. Government Actions Regulation; Policy and Procedures. Available www.for.gov.bc.ca/ftp/hth/external/!publish/Web/frpa-admin/frpa-implementation/gar-guide.pdf (accessed 11/02/02)

B.C. Minstry of Environment. 2009. Ecosystems Program Plan. Available:www.env.gov.bc.ca/esd/ (accessed 12/03/20)

B.C. Ministry of Environment. 2010. Conservation Framework. Available from (accessed 12/03/20): www.env.gov.bc.ca/conservationframework/

B.C. Ministry of Environment. 2011. Priority Setting for Implementation of Fish and Wildlife Habitat Conservation under the Government Actions Regulation. B.C. Ministry of Environment. Available from (accessed 11/02/02): a100.gov.bc.ca/pub/eirs/finishDownloadDocument.do;jsessionid=ccc0e2369ca20fde9d5741ca8a3c8100bec1cc829debfca7122ea72152b74517.e3uMah8KbhmLe3iNb30PbxiRaO1ynknvrkLOlQzNp65In0?subdocumentId=8482

B.C. Ministry of Environment. 2009. Water use reduction order to protect fish populations. Information Bulletin 2009ENV0020-000367 September 18, 2009. Available from: livingwatersmart.ca/news/docs/2009ENV0020-000367.pdf

B.C. Ministry of Forests and B.C. Ministry of Environment Lands and Parks. 1998. Fish-stream Identification Guidebook - Second Edition.

B.C. Ministry of Forests, Lands, and Natural Resource Operations. 2012. 2012/13 – 2014-15 Service Plan. Available from (accessed 12/09/18): http://www.bcbudget.gov.bc.ca/2012/sp/pdf/ministry/flnr.pdf

Battin, J., M.W. Wiley, M.H. Ruckelshaus, R.N. Palmer, E. Korb, K.K. Bartz, and H. Imaki. 2007. Projected impacts of climate change on salmon habitat restoration. Proceedings of the National Academy of Sciences of the United States of America. 104 (16): 6720-6725.

Beschta, R.L., R.E. Bilby, G.W. Brown, L.B. Holtby, and T.D. Hoffstra. 1987. Stream Temperature and Aquatic Habitat: Fisheries and Forestry Interactions. Pages 191-232 in E.O. Salo and T.W. Cundy (eds). Streamside Management: Forestry and Fishery Interactions. University of Washington - Institute of Forest Resources. Seattle, Wa. 469 pp.

Bisson, P. 2008. Salmon and trout in the Pacific Northwest and climate change. (June 16, 2008). U.S. Department of Agriculture, Forest Service, Climate Change Resource Center. Available at (accessed 12/09/18): www.fs.fed.us/ccrc/topics/salmon-trout.shtml

Brazner, J.C., Tanner, D.K. Detenbeck, N.E., Batterman, S.L., Stark, S.L., Jagger, L.A., and V.M. Snarski. 2005. Regional, watershed, and site-specific environmental influences on fish assemblage structure and function in western Lake Superior tributaries. Canadian Journal of Fisheries and Aquatic Sciences. 62: 1254-1270.

Brett, J.R. 1952. Temperature tolerance in young Pacific salmon, genus Oncorhynchus. Journal of the Fisheries Research Board of Canada 9(6): 265-323.

Brett, J.R., W.C. Clarke, and J.E. Shelbourn. 1982. Experiments on Thermal Requirements for Growth and Food Conversion Efficiency of Juvenile Chinook Salmon, Oncorhynchus tshawytscha. Prepared by Department of Fisheries and Oceans. Canadian Technical Report of Fisheries and Aquatic Sciences 1127. 29 pp.

British Columbia. 1997a. Fish Protection Act. [SBC 1997] CHAPTER 21 Queens Printer's web site. Available from (accessed 11/02/04): www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/00_97021_01

British Columbia. 1997b. Fish Protection Act. Ministry of Environment web site. Available from (accessed 11/02/04): www.env.gov.bc.ca/habitat/fish_protection_act/act/documents/act-theact.html

British Columbia. 2002. Timber Harvesting and Silviculture Practices Regulation. s.15(1). B.C. Reg. 352/2002). Available from: (accessed 11/01/31): www.for.gov.bc.ca/tasb/legsregs/archive/fpc/fpcaregs/thspr/thspr.htm#section15

British Columbia. 2008a. Oil and Gas Activities Act. [SBC 2008] CHAPTER 36. Available from (accessed 11/02/04): www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/00_08036_01

British Columbia. 2008b. Living Water Smart: British Columbia's Water Plan. Available from: www.livingwatersmart.ca/docs/livingwatersmart_book.pdf

British Columbia. 2010. Environmental Protection and Management Regulation. s.28. B.C. Reg. 200/2010. Available from (accessed 11/02/04): www.bcogc.ca/OGAA/regulations.aspx

Caissie, D. 2006. The thermal regime of rivers: A review. Freshwater Biology. 51: 1389-1406.

Coglianese, G., J. Nash, and T Olmstead. 2003. Performance-based regulation: prospects and limitations in health, safety, and environmental protection. Administrative Law Review 55: 705-728.

Cooke, S.J., S.G. Hinch, A.P. Farrell, M.F. Lapointe, S.R.M. Jones, J.S. Macdonald, D.A. Patterson, M.C. Healey, and G. Van Der Kraak. 2004. Abnormal migration timing and high en route mortality of sockeye salmon in the Fraser River, British Columbia. Fisheries 29(2): 22–33.

Dunham, J., B. Rieman, and G. Chandler. 2003a. Influences of temperature and environmental variables on the distribution of bull trout within streams at the southern margin of its range. North American Journal of Fisheries Management 23: 894-904.

Dunham, J., G. Chandler, B. Rieman, and D. Martin. 2005. Measuring stream temperature with digital data loggers: a user's guide. U.S. Department of Agriculture, U.S. Forest Service, Rochy Mountain Research Station. Fort Collins, Colorado. General Technical Report RMRS-GTR-150. Available from (accessed 12/04/02): www.fs.fed.us/rm/boise/publications/fisheries/rmrs_2005_dunhamj001.pdf

Dunham, J., Schroeter, R. and B. Rieman. 2003b. Influence of maximum water temperature on occurrence of Lahontan cutthroat trout within streams. North American Journal of Fisheries Management. 23: 1042-1049.

Dunham, J.B., A.E. Rosenberger, C.H. Luce, and B.E. Rieman. 2007. Influences of Wildfire and Channel Reorganization on Spatial and Temporal Variation in Stream Temperature and the Distribution of Fish and Amphibians. Ecosystems.

Eheart, J.W., and H. Park. 1989. Effects of Temperature Variation on Critical Dissolved Oxygen. Water Resources Research 25(2): 145-151.

Farrell, A.P., S.G. Hinch, S.J. Cooke, D.A. Patterson, G.T. Crossin, M. Lapointe, and M.T. Mathes. 2008. Pacific salmon in hot water: Applying aerobic scope models and biotelemetry to predict the success of spawning migrations. Physiological and Biochemical Zoology. 81(6): 697–708

Feller, M.C. 1981. Effects of clearcutting and slashburning on stream temperature in southwestern British Columbia. Water Resources Bulletin 17(5): 863-867.

Ferraro, P.J., and S.K. Pattanayak. 2006. Money for Nothing? A Call for Empirical Evaluation of Biodiversity Conservation Investments. PLoS Biology 4(4): 482-488. Available from: www.plosbiology.org/article/info:doi/10.1371/journal.pbio.0040105

Foreman, M.G.G., D.K. Lee, J. Morrison, S. Macdonald, D. Barnes, and I.V. Williams. 2001. Simulations and retrospective analyses of Fraser Watershed Flows and Temperatures. Atmosphere-Ocean 39(2): 89–105.

Fryer, J.L., K.S. Pilcher, J.E. Sanders, J.S. Rohovec, J.L. Zinn, W.J. Groberg, and R.H. McCoy. 1976. Temperature, Infectious Diseases and the Immune Response in Salmonid Fish. Prepared by Oregon State University - Microbiology Department. Prepared for U.S. Environmental Protection Agency. EPA-600/3-76-021.

Gallo, K., S.H. Lanigan, P. Eldred, S.N. Gordon, and C. Moyer. 2005. Northwest Forest Plan—the first 10 years (1994-2003): Preliminary assessment of the condition of watersheds. Gen. Tech. Rep. PNW-GTR-647. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 133p.

Gomi, T., R.C. Sidle, and J.S. Richardson. 2002. Understanding processes and downstream linkages of headwater systems. BioScience. 52(10): 905-916.

Goniea, T.M., M.L. Keefer, T.C. Bjornn, C.A. Peery, D.H. Bennett, and L.C. Stuehrenberg. 2006. Behavioral Thermoregulation and Slowed Migration by Adult Fall Chinook Salmon in Response to High Columbia River Water Temperatures. Transactions of the American Fisheries Society. 135: 408–419.

Grozier, K. 2000. Operations Report on Temperature Sensitive Streams in British Columbia. Ministry of Forests.

Hauer, F.R., J.S. Baron, D.H. Campbell, K.D. Fausch, S.W. Hostetler, G.H. Leavesley, P.R. Leavitt, D.M. McKnight, and J.A. Stanford. 1997. Assessment of climate change and freshwater ecosystems of the Rocky Mountains, USA and Canada. Hydrological Processes 11: 903-924.

Hawkins, C.P., J.N. Hogue, L.M. Decker, and J.W. Feminella. 1997. Channel morphology, water temperature, and assemblage structure of stream insects. Journal of the North American Benthological Society 16(4): 728-749.

Heino, J. 2002. Concordance of species richness patterns among multiple freshwater taxa: a regional perspective. Biodiversity and Conservation. 11: 1347-147.

Hodgson, S., and T.P. Quinn. 2002. The timing of adult sockeye salmon migration into fresh water: adaptations by populations to prevailing thermal regimes. Canadian Journal of Zoology 80: 542-555.

Hokanson, K.E.F., C.F. Kleiner, and T.W. Thorslund. 1977. Effects of constant temperatures and diel temperature fluctuations on specific growth and mortality rates and yield of juvenile rainbow trout, Salmo gairdneri. Journal of the Fisheries Research Board of Canada 34: 639-648.

Holt, R.A., J.E. Sanders, J.L. Zinn, J.L. Fryer, and K.S. Pilcher. 1975. Relation of water temperature to Flexibacter columnaris infection in steelhead trout (Salmo gairdneri), coho (Oncorhynchus kisutch) and chinook (O. tshawytscha) salmon. Journal of the Fisheries Research Board of Canada 32(9): 1553-1559.

Holtby, L.B. 1988. Effects of logging on stream temperature in Carnation Creek, British Columbia, and associated impacts of coho salmon (Oncorhynchus kisutch). Canadian Journal of Fisheries and Aquatic Sciences 45: 502-515.

Hyatt K., M. Stockwell, and P. Rankin. 2003. Impact and Adaptation Responses of Okanagan River Sockeye Salmon (Oncorhynchus nerka) to Climate Variation and Change Effects During Freshwater Migration: Stock Restoration and Fisheries Management Implications. Canadian

Irvine, J.R. 2004. Climate change, adaptation and ‘endangered’ salmon in Canada. In T.D. Hooper (ed). Proceedings of the Species at Risk 2004 Pathways to Recovery Conference. March 2-6, 2004. Victoria, B.C.

Isaak, D.J., and W.A. Hubert. 2001. A hypothesis about factors that affect maximum summer stream temperatures across montane landscapes. Journal of the American Water Resources Association 37(2): 351-366.

Isaak, D.J., C.H. Luce, B.E. Rieman, D.E. Nagel, E.E. Peterson, D.L. Horan, S.Parkes, and G.L. Chandler. 2010. Effects of climate change and wildfire on stream temperature and salmonid thermal habitat in a mountain river network. Ecological Applications 20: 1350-1370.

Isaak, D., D. Horan, and S. Wollrab. 2012. A Simple Method Using Underwater Epoxy to Permanently Install Temperature Sensors in Mountain Streams. Version 3.12. Prepared by U.S. Forest Service, Rocky Mountain Research Station, Air, Water, and Aquatics Program – Boise Aquatic Sciences Lab. Available from (accessed 12/04/02): www.fs.fed.us/rm/boise/AWAE/projects/stream_temp/downloads/RMRS_StreamSensorEpoxyProtocol_3_12.pdf

Johnson, D. H. 1999. The Insignificance of Statistical Significance Testing. J. Wild. Mgmt. 63:763-772

Johnson, S.L., and J.A. Jones. 2000. Stream temperature response to forest harvest and debris flows in western Cascades, Oregon. Canadian Journal of Fisheries and Aquatic Sciences. 57 (Suppl. 2): 30–39.

Keeley, E.R., and C.J. Walters. 1994. The British Columbia Watershed Restoration Program: Summary of the Experimental Design, Monitoring and Restoration Techniques Workshop. Prepared for B.C. Ministry of Environment Lands and Parks and B.C. Ministry of Forests - Watershed Restoration Program. WRP Management Report No. 1. 32 pp.

Kershner, J.L.K. 1997. Chapter 8 – Monitoring and Adaptive Management. In J.E. Williams, C.A. Wood, and M.P. Dombeck (eds). Watershed Restoration: Principles and Practices. American Fisheries Society. Bethesda, Md.

Lapointe, M.F., S.J. Cooke, S.G. Hinch, A.P. Farrell, S. Jones, S. Macdonald, D. Patterson, M.C. Healey, and G. Van Der Kraak. 2003. Late-run sockeye salmon in the Fraser River, British Columbia are experiencing early upstream migration and unusually high rates of mortality: what is going on? In Proceedings of the 2003 Georgia Basin/Puget Sound Research Conference pp. 1–14.

Leach, J.A., and R.D. Moore. 2008. Stream temperature response to riparian wildfire: lessons from Fishtrap Creek. Streamline Watershed Management Bulletin 12(1): 11-16

Leung, L.R. and Y. Qian. 2003. Changes in seasonal and extreme hydrologic conditions of the Georgia Basin/Puget Sound in an ensemble regional climate simulation for the mid-century. Canadian Water Resources Journal 28 (4): 605–631.

Lewis, T.E., D.W. Lamphear, D.R. McCanne, A.S. Webb, J.P. Krieter, and W.D. Conroy. 2000. Regional Assessment of Stream Temperatures Across Northern California and Their Relationship to Various Landscape-Level and Site-Specific Attributes. Prepared for Humboldt State University Foundation Forest Science Project. Arcata, Ca. 420 pp.

Macdonald, J.S., E.A. MacIsaac, and H.E. Herunter. 2003. The effect of variable-retention riparian buffer zones on water temperatures in small headwater streams in sub-boreal forest ecosystems of British Columbia. Canadian Journal of Forest Research 33: 1371-1382.

MacDonald, S., M. Foreman, T. Farrell, I. Williams, J. Grout, A. Cass, J. Woodey, H. Enzenhoffer, C. Clarke, R. Houtman, E. Donaldson and D. Barnes. 2000. The influence of extreme water temperatures on migrating Fraser River sockeye salmon (Oncorhynchus nerka) during the 1998 spawning season. Canadian Technical Report of Fisheries and Aquatic Sciences. 2326.

Magnuson, J.J., L.B. Crowder, and P.A. Medvick. 1979. Temperature as an ecological resource. American Zoologist. 19(1): 331-343.

McDonald, T.L. 2003. Review of Environmental Monitoring Methods: Survey Designs. Environmental Monitoring and Assessment. 85: 277-292.

Mellina, E., R.D. Moore, S.G. Hinch, J.S. Macdonald, and G. Pearson. 2002. Stream temperature responses to clearcut logging in British Columbia: The moderating influences of groundwater and headwater lakes. Canadian Journal of Fisheries and Aquatic Sciences 59: 1886–1900.

Merritt, W.S., and Y. Alila. 2004. Chapter 7. Hydrology. Pages 63-88 in S. Cohen, D. Neilsen, and R. Welbourn (eds.) Expanding the dialogue on climate change and water management in the Okanagan Basin, British Columbia.

Merritt, W.S., Y. Alila, M. Barton, B. Taylor, S. Cohen, D. Neilsen. 2006. Hydrologic response to scenarios of climate change in subwatersheds of the Okanagan basin, British Columbia. Journal of Hydrology 326: 79–108.

Moore, R.D. 2006. Stream temperature patterns in British Columbia, Canada, based on routine spot measurements. Canadian Water Resources Journal 31(1): 41-56.

Moore, R.D., D.L. Spittlehouse, and A. Story. 2005. Riparian microclimate and stream temperature response to forest harvesting: A review. Journal of the American Water Resources Association. 813-834.

Moore, R.D., P. Sutherland, T. Gomi, and A. Dhakal, 2005. Therma Regime of a Headwater Stream Within a Clear-Cut, Coastal British Columbia, Canada. Hydrological Processes. 19 (13): 2591–2608.

Morin, A. W. Lamoureux, and J. Busnarda. 1999. Empirical Models Predicting Primary Productivity from Chlorophyll a and Water Temperature for Stream Periphyton and Lake and Ocean Phytoplankton. Journal of the North American Benthological Society. 18 (3): 299-307.

Morrison, J., M.C. Quick, and M.C.G. Foreman. 2002. Climate change in the Fraser River watershed: Flow and temperature projections. Journal of Hydrology 263: 230-244.

Murray, C.B., and J.D. McPhail. 1988. Effect of incubation temperature on the development of five species of Pacific salmon (Oncorhynchus) embryos and alevins. Canadian Journal of Zoology 66: 266-273.

Naiman, R. J., H. Décamps, and M. E. McClain. 2005. Riparia: ecology, conservation and management of streamside communities. Elsevier, San Diego, California, USA.

Naughton, G.P., C.C. Caudill, M.L. Keefer, T.C. Bjornn, L.C. Stuehrenberg, and C.A. Peery. 2005. Late-season mortality during migration of radio-tagged adult sockeye salmon (Oncorhynchus nerka) in the Columbia River. Canadian Journal of Fisheries and Aquatic Sciences. 62: 30–47.

Nelitz, M.A., E.A. MacIsaac, and R.M. Peterman. 2007a. A science-based approach for identifying temperature-sensitive streams for rainbow trout. North American Journal of Fisheries Management. 27: 405–424.

Nelitz, M., K. Wieckowski, D. Pickard, K. Pawley, and D.R. Marmorek. 2007b. Helping Pacific salmon survive the impacts of climate change on freshwater habitats: Pursuing proactive and reactive adaptation strategies. Final report prepared by ESSA Technologies Ltd., Vancouver, B.C. for the Pacific Fisheries Resource Conservation Council, Vancouver, B.C.

Nelitz, M., K. Wieckowski, M. Porter, K. Bryan, F. Poulsen, and D. Carr. 2010. Evaluating the vulnerability of freshwater fish habitats to climate change and identifying regional adaptation strategies in the Cariboo-Chilcotin. Report prepared for Fraser Salmon and Watersheds Program by ESSA Technologies Ltd. Available from: www.thinksalmon.com/fswp_project/item/evaluating_the_vulnerability_of_pacific_salmon_to_effects_of_climate_change/

Nelitz, M.A., R.D. Moore, and E. Parkinson. 2008. Developing a Framework to Designate 'Temperature Sensitive Streams' in the B.C. Interior. Final report prepared by ESSA Technologies Ltd., University of British Columbia, and B.C. Ministry of Environment for B.C. Forest Science Program, PricewaterhouseCoopers, Vancouver, B.C.

Nordin, L.J., D.A. Maloney, and J.F. Rex. 2009. Detecting effects of upper basin riparian harvesting at downstream reaches using stream indicators. B.C. Journal of Ecosystems and Management. 10 (2): 123–139.

O'Neal, K. 2002. Effects of Global Warming on Trout and Salmon in U.S. Streams. Prepared by Abt Associates. Prepared for Defenders of Wildlife and Natural Resources Defense Council. 46 pp.

Oliver, G.G., and L.E. Fidler. 2001. Towards a water quality for temperature in the province of British Columbia. Prepared by Aspen Applied Sciences Ltd. Prepared for Ministry of Environment Lands and Parks.

Peterman, R.M. 1990. Statistical power analysis can improve fisheries research and management. Canadian Journal of Fisheries and Aquatic Sciences 47: 2-15.

Peterman, W.E., and R.D. Semlitsch. 2009. Efficacy of riparian buffers in mitigating local population declines and the effects of even-aged timber harvest on larval salamanders. Forest Ecology and Management 257: 8-14.

Pickard, D., M. Porter, K. Wieckowski, and D. Marmorek. 2009. Workplan to Pilot the Fisheries Sensitive Watersheds (FSW) Monitoring Framework. Prepared for B.C. Ministry of Environment.

Pike, R.G., D.L. Spittlehouse, K.E. Bennett, V.N. Egginton, P.J. Tschaplinski, T.Q. Murdock, and A.T. Werner. 2008. Climate change and watershed hydrology Part I – Recent and projected changes in British Columbia. Streamline Watershed Management Bulletin. Vol. 11. No 2.

Pike, R.G., K.E. Bennett, T.E. Redding, A.T. Werner, D.L. Spittlehouse, R.D. Moore, T.Q. Murdock, J. Beckers, B.D. Smerdon, K.D. Bladon, V.N. Foord, D.A. Campbell, and P.J. Tschaplinski. 2010. Chapter 19 – Climate Change Effects on Watershed Processes in British Columbia. Pages 699-747 in R.G. Pike, T.E. Redding, R.D. Moore, R.D. Winker, and K.D. Bladon (editors). Compendium of forest hydrology and geomorphology in British Columbia. B.C. Ministry of Forests and Range, Forest Science Program, Victoria, B.C. and FORREX Forum for Research and Extension in Natural Resources, Kamloops, B.C. Land Management Handbook 66. www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh66.htm

Poole, G.C., and C.H. Berman. 2001. An ecological perspective on in-stream temperature: Natural heat dynamics and mechanisms on human-caused thermal degradation. Environmental Management 27: 787-802.

Pritchard, G., L.D. Harder, and R.A. Mutch. 1996. Development of aquatic insect eggs in relation to temperature and strategies for dealing with different thermal environments. Biological Journal of Linnean Society 58: 221-244.

Ptolemy, Ron. 2010. Provincial-scale resolution of flow sensitive landscapes. Presentation made at the MOE B.C. Fisheries Program Meeting.

Quilty, E. and R.D. Moore. 2007. Measuring stream temperature. Streamline Watershed Management Bulletin 10(2): 25-30.

Quilty, E., and R.D. Moore. 2010. Chapter 17 – Watershed Measurement Methods and Data Limitations – Physical Water Quality – Stream Temperature. Pages 606-612 in R.G. Pike, T.E. Redding, R.D. Moore, R.D. Winker, and K.D. Bladon (editors). Compendium of forest hydrology and geomorphology in British Columbia. B.C. Ministry of Forests and Range, Forest Science Program, Victoria, B.C. and FORREX Forum for Research and Extension in Natural Resources, Kamloops, B.C. Land Management Handbook 66. www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh66.htm

Rand, P.S., S.G. Hinch, J. Morrison, M.G.G. Foreman, M.J. MacNutt, J.S. MacDonald, M.C. Healey, A.P. Farrell, and D.A. Higgs. 2006. Effects of river discharge, temperature, and future climates on energetics and mortality of adult migrating Fraser River sockeye salmon. Transactions of the American Fisheries Society. 135: 655–667.

Reader, R. 2006. The Expectations That Affect The Management Of Public Forest and Range Lands In British Columbia – Looking Outside The Legislation; A discussion paper prepared for the Ministry of Forests and Range and the Ministry of Environment. Province of B.C. Available from (accessed 11/03/27): www.for.gov.bc.ca/code/training/frpa/looking.html

Rex, J.F., D.A. Maloney, P.N. Krauskopf, P.G. Beaudry, and L.J. Beaudry. 2012. Variable-retention riparian harvesting effects on riparian air and water temperature of sub-boreal headwater streams in British Columbia. Forest Ecology and Management. 269: 259–270.

Richter, A., and S.A. Kolmes. 2005. Maximum temperature limits for chinook, coho, and chum salmon, and steelhead trout in the Pacific Northwest. Reviews in Fisheries Science 13: 23-49.

Roberts, R.J. (ed) 1978. Fish Pathology. Balliere Tindall. London, UK. 318 pp.

Schindler, D.W. 1997. Widespread Effects of Climatic Warming on Freshwater Ecosystems in North America. Hydrological Processes 11: 1043-1067.

Schindler, D.W. 2001. The cumulative effects of climate warming and other human stresses on Canadian freshwaters in the new millennium. Canadian Journal of Fisheries and Aquatic Sciences 58: 18-29.

Scholz, J.G. 2001. The variability in stream temperatures in the Wenatchee National Forest and their relationship to physical, geological, and land management factors. M.S. Thesis, University of Washington, Division of Forest Management and Engineering, College of Forest Resources.

Schwarz, C.J. 1998. Studies of Uncontrolled Events. Pages 19-39 in V. Sit and B. Taylor (eds). Statistical Methods for Adaptive Management Studies. B.C. Ministry of Forests. Victoria, B.C.. 157 pp. Available from: www.for.gov.bc.ca/hfd/pubs/docs/lmh/lmh42.htm

Selong, J.H., T.E. McMahon, A.V. Zale, and F.T. Barrows. 2001. Effect of temperature on growth and survival of bull trout, with application of an improved method for determining thermal tolerance in fishes. Transactions of the American Fisheries Society 130: 1026-1037.

Shuter, B.J. and J.R. Post. 1990. Climate, population viability, and the zoogeography of temperate fishes. Transactions of the American Fisheries Society. 119(2): 314-336.

Smith, B.J., P.E. Davies, and S.A. Munks. 2009. Changes in benthic macroinvertebrate communities in upper catchment streams across a gradient of catchment forest operation history. Forest Ecology and Management 257: 2166-2174.

Snetsinger, J. 2009. Considerations for forest and range stewardship under the Forest and Range Practices Act. FREP Chief Forester's Report. Available from (accessed 11/02/04): www.for.gov.bc.ca/ftp/hfp/external/!publish/frep/reports/CFReport_20091019.pdf

Stahl, K., R. D. Moore, J. M. Shea, D. Hutchinson, and A. J. Cannon. 2008. Coupled modelling of glacier and streamflow response to future climate scenarios, Water Resources Research. 44.

Stefan, H.G., and E.B. Preud'homme. 1993. Stream temperature estimation from air temperature. Water Resources Bulletin 29(1): 27-45.

Stefan, H.G., and E.B. Preud'homme. 1993. Stream temperature estimation from air temperature. Water Resources Bulletin 29(1): 27-45.

Stevens, D.L., and A.R. Olsen. 2004. Spatially balanced sampling of natural resources. Journal of the American Statistical Association. 99 (465): 262-278.

Sullivan, K., D.J. Martin, R.D. Cardwell, J.E. Toll, and S. Duke. 2000. An Analysis of the Effects of Temperature on Salmonids of the Pacific Northwest with Implications for Selecting Temperature Criteria. Prepared for Sustainable Ecosystems Institute. Portland, Or. 120+ pp.

Tschaplinski, P. J., D. L. Hogan, and G. F. Hartman. 2004. Fish-forestry interaction research in coastal British Columbia: The Carnation Creek and Queen Charlotte Islands studies. *In* Fishes and Forestry: Worldwide Watershed Interactions and Management. Chapter 18. pp. 389 – 412. *Edited by* G. F. Hartman and T. G. Northcote. Blackwell Press, London, UK 789 pp.

Tschaplinski, P.J., and R. G. Pike. 2010. Chapter 15 – Riparian Management and Effects on Function. Pages 479-525 in R.G. Pike, T.E. Redding, R.D. Moore, R.D. Winker, and K.D. Bladon (editors). Compendium of forest hydrology and geomorphology in British Columbia. B.C. Ministry of Forests and Range, Forest Science Program, Victoria, B.C. and FORREX Forum for Research and Extension in Natural Resources, Kamloops, B.C. Land Management Handbook 66. www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh66.htm

Tyedmers, P., and B. Ward. 2001. A Review of the Impacts of Climate Change on B.C.'s Freshwater Fish Resources and Possible Management Responses. Prepared by The Fisheries Centre - University of British Columbia. Vancouver, B.C.. Fisheries Centre Research Reports 2001 Volume 9 Number 7. 15 pp.

U.S. Environmental Protection Agency (US EPA). 2003. EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards. Prepared by EPA - Region 10 Office of Water. Seattle, Wa. EPA 910-B-03-002. 57 pp.

U.S. Environmental Protection Agency (US EPA). 2008. Climate change effects on stream and river biological indicators: A preliminary analysis. Global Change Research Program, National Center for Environmental Assessment, Washington, DC; EPA/600/R-07/085. Available online: cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=190304

Vannote, R.L., and B.W. Sweeney. 1980. Geographic analysis of thermal equilibria: A conceptual model for evaluating the effect of natural and modified thermal regimes on aquatic insect communities. American Naturalist 115(5): 667-695.

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell, and C.E. Cushing. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences 37: 130-137.

Velsen, F.P.J. 1987. Temperature and Incubation in Pacific Salmon and Rainbow Trout: Compilation of Data on Median Hatching Time, Mortality and Embryonic Staging. Prepared by Department of Fisheries and Oceans - Fisheries Research Branch Pacific Biological Station. Nanaimo, B.C. Canadian Data Report of Fisheries and Aquatic Sciences No. 626. 58 pp.

Webb, B.W., D.M. Hannah, R.D. Moore, L.E. Brown, and F. Nobilis. 2008. Recent advances in stream and river temperature research. Hydrological Processes. 22: 902-918.

Wehrly, K.E., M.J. Wiley, and P.W. Seelbach. 2003. Classifying regional variation in thermal regime based on stream fish community patterns. Transactions of the American Fisheries Society 132: 18–38.

Welsh, H.H. Jr., Hodgson, G.R., Harvey, B.C. and M.R. Roche. 2001. Distribution of juvenile coho salmon in relation to water temperatures in tributaries of the Mattole River, California. North American Journal of Fisheries Management. 21: 464-470.

Wenger, S.J., D.J. Isaak, C.H. Luce, H.M. Neville, K.D. Fausch, J.B. Dunham, D.C. Dauwalter, M.K. Young, M.M. Elsner, B.E. Rieman, A.F. Hamlet, and J.E. Williams. 2011. Flow regime, temperature, and biotic interactions drive differential declines of trout species under climate change. Proceedings of the National Academy of Sciences. 108 (34): 14175-14180.

Whitfield, P.H. Wang, J.Y., and Cannon, A.J. 2003. Modelling future streamflow extremes—Floods and low flows in Georgia Basin, British Columbia. Canadian Water Resources Journal. 28(4): 633–656.

Wieckowski, K. D. Pickard, M. Porter, D. Robinson, and D. Marmorek, and C. Schwarz. 2008. A Conceptual Framework for Monitoring Fisheries Sensitive Watersheds (FSW). Prepared for B.C. Ministry of Environment.

Wieckowski, K. M. Porter, D. Marmorek, and D. Pickard. 2009. A Framework for Monitoring Fisheries Sensitive Watersheds (FSW). Prepared for B.C. Ministry of Environment.

Wipfli, M.S., J.S. Richardson, and R.J. Naiman. 2007. Ecological linkages between headwaters and downstream ecosystems: transport of organic matter, invertebrates, and wood down headwater channels. Journal of the American Water Resources Association 43:72-85.

Young, K.A. 2000. Riparian zone management in the Pacific Northwest: Who’s cutting what? Environmental Management. 26(2): 131-144.

Zwieniecki, M.A., and M. Newton. 1999. Influence of streamside cover and stream features on temperature trends in forested streams of western Oregon. Western Journal of Applied Forestry 14(2): 106-113.

Appendix 1—Explanation of the forest management practice requirements set out in FRPA regulations

1. Spatial extent of stream network requiring management

As discussed earlier, Section 53 of the FPPR requires the following practice:

"An authorized person…must retain…[riparian vegetation] sufficient to prevent the temperature of the temperature sensitive stream from increasing to an extent that would have a material adverse impact on fish".

To determine the spatial extent of the protection several key definitions described in the FPPR, and that apply to both the GAR and FPPR, must be understood. The first is "fish stream" as used in the GAR. The FPPR defines a fish stream in one of two ways; a watercourse that:

> "(a) is frequented by any of the following species of fish:
>
> > (i) anadromous salmonids;
> >
> > (ii) rainbow trout, cutthroat trout, brown trout, bull trout, Dolly Varden char, lake trout, brook trout, kokanee, largemouth bass, smallmouth bass, mountain whitefish, lake whitefish, arctic grayling, burbot, white sturgeon, black crappie, yellow perch, walleye or northern pike;
> >
> > (iii) a species identified as a species at risk;
> >
> > (iv) a species identified as regionally important wildlife, or
>
> (b) has a slope gradient of less than 20%, unless the watercourse
>
> > (i) does not contain any of the species of fish referred to in paragraph (a),
> >
> > (ii) is located upstream of a barrier to fish passage and all reaches upstream of the barrier are simultaneously dry at any time during the year, or is located upstream of a barrier to fish passage and no perennial fish habitat exists upstream of the barrier".

Therefore, the spatial extent of the designation is first defined in GAR (s.15) by both, the known distribution of fish, or the physical parameters that restrict the movement of fish throughout a stream network. The FPPR classifies fish streams as one of four possible stream classes (S1, S2, S3, or S4) and, by way of the GAR designation, requires retention of stream side vegetation. Because the FPPR clearly requires riparian retention on all S1 through S3 streams, regardless of the stream's temperature sensitivity, these streams receive riparian buffering by default. However, the GAR extends this buffering requirement to S4 streams.

Like an S4 stream, normally, the remaining stream classes (S5 and S6) do not necessarily require streamside vegetation retention as the option is provided to a *Forest Act* agreement holder to retain an amount along these streams between 0% and 100%. Under TSS management requirements however, it is along S5 and S6 streams that the practice requirements are also increased (see Table 9). The FPPR (section 53) does this by additionally requiring forest management activities to retain stream side vegetation along "direct tributary" streams to a TSS (i.e. a S1 to S4 stream). To understand how this would be translated to the stream network the term direct tributary requires examination. The FPPR defines this term as a portion of a tributary stream that:

"(a) is a minimum of 100 m in length, and

(b) has the same stream order as the most downstream reach of the tributary"

In this way, the spatial distribution of the stream network is limited to fish streams and direct tributaries and accordingly in many cases headwater streams will be omitted. Table 9 helps describe the interpretation of the TSS stream-network using the FPPR defined term "direct tributary". Figures 7 and 8 illustrates the application of GAR s.15 and the FPPR s.53 to a stream network at multiple and single watershed levels respectively. Note that in all examples below, if the direct tributary were less than 100m long, it would not require any additional management.

Table 9. FPPR base-case riparian management versus TSS management

Areas requiring increased management under a TSS designation, particularly for S4, S5, & S6 streams.

Stream Class	Stream Channel Width	Fish?	Reserve Zone	Management Zone	Size of Total Management area
S1-A	≥100m	Yes	none	100	100
S1-B	>20m	Yes	50	20	70
S2	≥5m to <20m	Yes	30	20	50
S3	1.5m to <5m	Yes	20	20	40
S4	<1.5m	Yes	none	30	30
S5	>3m	No	none	30	30
S6	≤3m	No	none	20	20

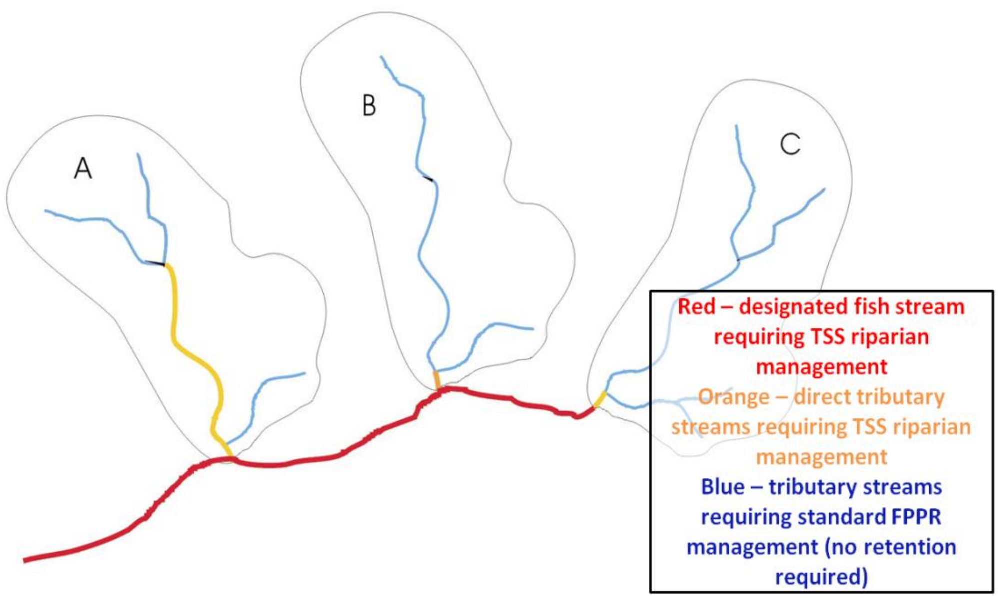

Figure 7. Application of GAR s.15 and the FPPR s.53 to three different stream networks in three similar sized watersheds

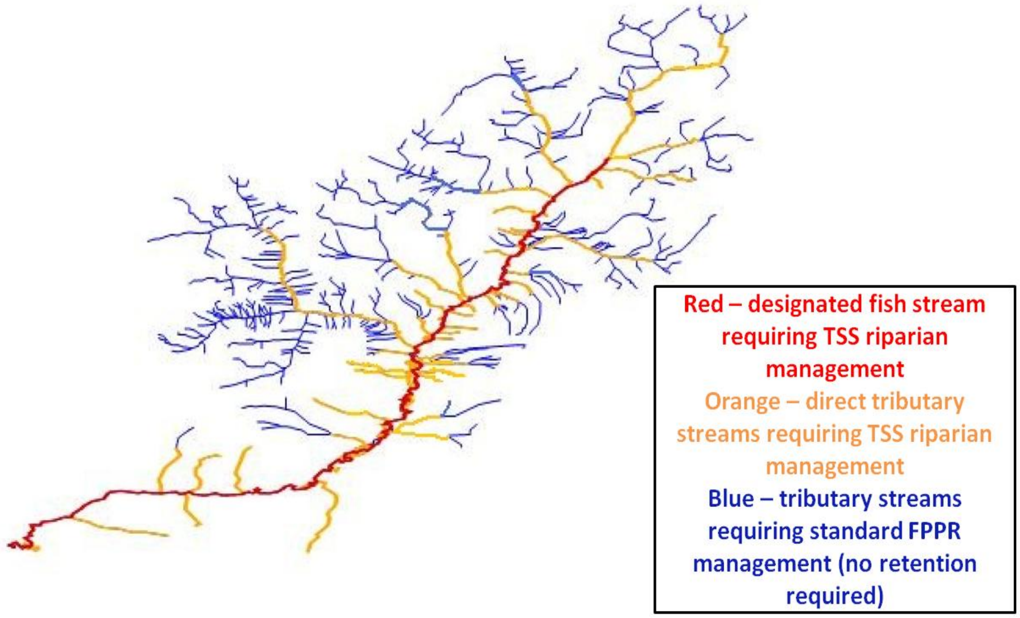

Figure 8. Application of GAR s.15 and the FPPR s.53 to a stream network at the watershed level

2. Regulatory focus; habitat or species?

A TSS designation is habitat management, rather than species, oriented. However, where any fish species of interest resides within the habitat types as defined in the FPPR as a “fish stream”, the fish species can benefit from a TSS designation. The reason for this is twofold. First, the habitat defined under “fish stream” is described in two distinct ways: (i) using categories of known distributions of FPPR defined fish species (i.e. anadromous, salmonid, listed “species-at-risk”, and regionally important) that utilize some part of a stream during their lifecycle; and (ii) using parameters describing essential fish-stream physical features (e.g., gradient <20%, barriers, stream types or fish species residing above barriers). Second, the FRPA definition of “wildlife” includes all freshwater and anadromous “fish” species found in B.C. (...interestingly, crustaceans and mollusks are also included in the same FRPA definition of fish). As a TSS designation is intended for the protection of fish as per s.15(b) of the GAR, even though a species is not explicitly listed in the FPPR definition, as long as the habitat parameters that these FRPA defined fish species utilize falls within that described under a “fish stream”, the TSS designation may provide some level of benefit.

3. Windthrow protection

Buffering streamside riparian vegetation from the effect of wind and windthrow may require retention of an amount greater than that described in the GAR or FPPR. Although the basic requirement is for retention of riparian vegetation sufficient to prevent temperature increases in a stream, an additional amount may be required to protect vegetation from impacts of wind. In the case of S4, S5, and S6 streams this may involve retention of at least the entire management zone. In the case of S1, S2, and S3 streams, this may require retention of the entire amount in the management zone adjacent to the reserve zone. The amount will vary based on site-conditions and it is the responsibility of the qualified professional to determine the amount required to provide a thermal benefit and the additional amount necessary to protect the streamside buffering vegetation from windthrow over time.

4. Restoration and recovery

Historically, streams were harvested to their streambanks regardless of fish values and any temerpature senstivity. Depending on the harvest age and hydrological nature of the stream, many of these areas will be in some phase of natural recovery. The dynamic characteristics of streams can make these areas difficult to rehabilitate. Where there is reasonable science based evidence that a TSS that has been affected by historic streamside harvesting may benefit from riparian area restoration treatments this should be considered.

Appendix 2—Regulatory tests under GAR

A list summarizing considerations in GAR regulatory tests is provided in Table 10 (from Anonomous 2008). A person preparing, reviewing, and making the final decision regarding the approval/rejection of a TSS order must consider each of these tests. For more detailed discussion of these tests please refer to Anonomous 2008.

Table 10. Summary of considerations in meeting GAR tests

GAR test	Summary of considerations in meeting tests
Criteria for individual GAR actions	• Is the delegated decision-maker satisfied that the proposed order meets the criteria specified in the relevant section of the regulation (e.g. fisheries sensitive watersheds, temperature sensitive streams)?
Special management (Test 1 -chapter 5.1)	• Do FRPA provisions for protection of other values also provide the special management that can be relied on to conserve the value in the area(s) of concern? • Do other enactments conserve the value in the area(s) of concern? • Do existing government actions provide the special management for this value in this location?
Consistent with established objectives (Test 2 - chapter 5.2)	Is the proposed action consistent with: • Land use objectives • Objectives in regulation • Other objectives established under authority of the GAR • Grand-parented objectives
Not unduly reduce the supply of timber of BC forests (Test 3-chapter 5.3)	• Is the action consistent with government's timber supply impact policies? • Is the action consistent with the timber impact policy associated with the government approved land and resource use decisions?
Public benefits (part of Test 4 - chapter 5.4)	• What are the public benefits that may be derived from the order to conserve/protect a public resource value such as water, fish, wildlife, cultural heritage? • How does the order address public and First Nation interests in the area of the action?
Material adverse impacts on delivered wood costs (part of	• Has the information acquired through consultation with affected agreement holders been considered? • Are the impacts on delivered wood costs considered to be *material*

Test 4)	and *adverse*? And, if so, to what extent? • What changes to the action have been undertaken to address identified, material adverse impacts on delivered wood costs?
Undue constraint on the ability of an agreement holder (part of Test 4)	• Has the information acquired through consultation with affected agreement holders been considered? • Are the constraints on the ability of the agreement holders to exercise rights under the agreement considered to be *undue*? And, if so, to what extent? • What changes to the action have been undertaken to address identified, undue constraints on the ability of the agreement holder to exercise their rights under agreement?
Public benefits outweigh any material adverse effects and undue constraints (Test 4)	• Describe why it is believed that public benefits outweigh any material adverse impact on delivered wood costs and undue constraint on the ability of agreement holders to exercise their rights.

Appendix 3—Prioritizing streams for designation using technical criteria

Once a TSS procedure is implemented, establishing regional priorities for the designation of candidate streams will be an important consideration. Prioritizing TSS will assist with work planning (e.g., B.C. Ministry of Environment 2011) processes when compiling lists of potential temperature sensitive streams and provide some insight around cost benefit analysis. Using components of each technical criterion (i.e. section 2.1 and descriptions below) it is possible to rank each stream using a simple formula:

$$\frac{(CV + EICV + FM) = \text{Rank}}{3}$$

Values for each criterion used with this formula are normalized ranging from 0 to 1. Table 11 describes the overall priority level based on the rank using the above formula and ranks assigned by criterion are described in the corresponding Tables 12 through 14 below. The intent here is that all streams receiving a ranked score of ≥ 0.5 could be considered TSS candidates, but that the highest ranking would be addressed first.

Table 11. TSS priority determination

	Rank	**Priority**
a)	≥ 1.0	Very high
b)	≥ 0.9	High
c)	≥ 0.8	Moderately high
d)	≥ 0.75	Moderate
e)	≥ 0.7	Moderately low
f)	≥ 0.5	Low
g)	<.5	None

Technical criterion 1 – Conservation values (CV)

Table 12. Fish species/community temperature priority ranking

	Priority rank	Vulnerability	Description of vulnerability
a)	1.0	Very high	At least one known salmonid or fish species at risk is known to utilize the stream during a critical stage in its life cycle
b)	0.75	High	An assemblage of species (community) will undergo a shift (or has undergone a shift) as a result of water temperatures reaching a known threshold.
c)	0.50	Moderate	A fish species is known to utilize the stream network during a specific period in its life cycle when the fish is vulnerable.
d)	0.25	Low	At least one fish species is known to utilize the stream network but is not temperature sensitive relative to occupancy, life cycle susceptibility, and the (seasonal) stream conditions.
e)	0	n/a	No fish currently or historically utilized the stream network

Technical criterion 2 – Evidence of impacts to conservation value (EICV)

Table 13. Quality of evidence

Priority rank	Description
1.0	Any combination of information described in the two Yes boxes below provides very high strength and consistency of evidence
0.5	Calibrated/validated localized models Publically available peer reviewed reports or publications
	Fish kill & temperature data Generalized (encompassing large areas) models & temperature data Temp stress & temperature data Behavior & temperature data
0.0	Anecdotal information Professional opinion Suspected temp related fish kills Suspected temp stress related to behavior observations

Technical criterion 3 – Feasibility of mitigation (FM):

Stream restoration and recovery requirements are important factors when considering stream designation priority. Assessing restoration and recovery requires consideration of two fundamental questions: (1) will improving the riparian condition improve the thermal buffering capability for affected species currently residing in the stream, and (2) will improving the habitat condition potentially recover species that historically resided in a stream? In either of these cases, the feasibility (e.g., cost and likelihood of success) of these efforts is a critical consideration and will have an important bearing on whether to pursue a TSS designation. Table 14 serves to differentiate priority rankings for various proposed streams. While restoration and recovery may provide some important benefits in the long term, the initial focus and emphasis around TSS designation should seek to protect currently functioning riparian areas as the highest priority. Accordingly, Table 14 does not consider streams that require restoration and recovery, and where this is deemed a local priority these streams can be evaluated separately.

Table 14. Priority ranking for habitat based on condition

	Priority		**Description of habitat condition**
a)	High	1.0	Conserving existing riparian thermal buffering capability
b)	Moderate to Low	0.5	Restoring disturbed riparian areas to improve the thermal buffering capacity for vulnerable species (or communities) currently utilizing the stream network.
c)	Low to Very Low (or n/a)	0.25	Restoring disturbed riparian areas to improve the thermal buffering capacity for a vulnerable species (or community) that historically utilized the stream network during a period in their life cycle when the fish species is vulnerable.

Appendix 4—GIS specifications and content of a TSS order

Legal orders under the GAR use mapping and spatial digital references to illustrate the area where the order applies. In the GIS environment this is done using polygons, lines, and points to depict an locations of interest. Because all spatial information used in the provincial spatial database must conform to a consitent standard, a single GIS specification must be adopted which best suites the application.

In the case of a TSS the immediate choice might be to use lines that represent the stream network. However, provincial GIS stream network databases do not accurately represent the the actual location or the extent of the real-world stream network occuring on the landbase. Furthermore, fish inventories and the FRPA stream classification system, both necessary to determine the extent of the riparian management stipulated in the FPPR, are not tied (linked) to GIS stream networks and must be determined in the field or through field-based inventories and mapping exercises. Therefore, using linear stream-network spatial databases is not suitable for describing a TSS nor providing the intended protection.

Points and polygons provide a better approach to identifing a TSS stream network. Points have an advantage in that they are simple to aquire and place in the GIS environment, and they put the onus of identifing the affected stream network, and associated management requirements upstream of the point, on (forest) managers conducting operational activities in and around these streams. Like the spatial acurracy considerations surrounding linear stream-networks databases, and compounded by a fluvial stream-network's tendency to migrate over time, the accuracy of a single point relative to the actual location of the stream, may introduce inaccuracies and questions surrounding to which stream the TSS point may apply.

Polygons will also require the acquisition of a GPS point (upstream of which the order would apply) in order to creat a watershed based polygon. While management requirements would be the same as those for a point, the advantage that a watershed polygon will have over a point is it clearly illustrates the area within which the order applies. A consideration in using polygons for TSS designation is that in provincial analyses of conservation measures, TSS polygons may be inadvertently miss interpreted (e.g., they may be seen as representing much larger areas than the actual area requiring a modified form of management). Another consideration is that forest licensees may argue that in the designation process, the outer limit of the polygon should be based on actual operational requirements as specified in the FPPR and, in so doing, attempt to shift the responsibility to government for delineating the actual area (and thus the actual streams) requiring TSS management.

Due to provincial database acrchiectural constraints, when the TSS procedure is finalized only one of the two prefered methods can be used. In the specification outlined below polygons are used as an example to illustrate the TSS GIS specification and define the TSS stream-network because, as the forgoing discussion has illustrated, polygons better represent the full extent of the streams the regulation is aiming to protect and allows for the actual identification of TSS' in an operational context.

The format that the TSS order will take will be straightforward and require about a single page of information including: a standard legal preamble referencing the TSS spatial information for the particular order, a schedule pointing to the FPPR s.53 management requirements, and the decision maker's (DM) signature block. Like other GAR orders, the package making up a TSS order will be made up of: 1) a written order (signed by the DM), 2) a hard copy map (signed by the DM), 3) a rational (signed by the DM), 4) associated digital files as referenced in the written order, and 5) all other related or supporting summary and detailed reporting.

Summary of spatial data standards for submission of TSS

Defining and mapping a TSS requires the selection of a single point representing the downstream location along the stream network of interest. This point will be used to indicate the downstream limit of the TSS and to define the watershed polygons encompassing the stream network (using the outer boundary of an aggregate of Freshwater Atlas polygons). Where the point occurs somewhere within the boundary of the farthest downstream watershed polygon, this polygon may need to be modified to adjust the downstream extent of the overall TSS polygon area. Where private lands occur within a TSS polygon, these areas should be removed.

The preferred digital format for submission of TSS definitions is an ArcInfo polygon coverage or, at minimum, a polygon shape file with associated TSS attributes as specified below. Although these specifications follow a standardized GAR format some minor details may change and the current version of the TSS procedure should be sought to confirm actual specifications.

Table 15. Description of attributes

Column Name	Output Width	Type	Number of decimals
AREA	16	Number	0
PERIMETER	12	Number	3
TSS_TAG	14	Character	-
FEAT_NOTES	254	Character	-

FCODE	50	Character	-
TSS_POINT	50	Character	-
WS_CODE	45	Character	-
GAZE_NAME	30	Character	-
LOCAL_NAME	30	Character	-

TSS_TAG – Alpha-numeric string identifying the TSS polygon. TSS_TAG numbers must be lower case with dashes, e.g., t-5-0001, where ‘t’ is constant, ‘5’ is the MOE region number, and ‘0001’ is the unique 4 digit TSS_TAG number identifying the TSS polygon associated with a particular region.

FEAT_NOTES – An optional description or notation associated with the TSS. The farthest downstream 1:50k Watershed Atlas alphanumeric code can be recorded here.

FCODE – A 10 digit code identifying the TSS polygon as a Temperature Sensitive Stream referenced in the MOE feature code database.

- The TSS code value is ____(TBD)________

TSS_POINT – The UTM coordinates of a single downstream point, that most closely define the stream network at its most downstream extent. The UTM_POINT is to be recorded as follows: Z[2 character number]N[7 character number]E[38 character number].

WS_CODE – Feature code derived from the B.C. Watershed Atlas, 1:50,000 scale; identifies a watershed polygon at the farthest downstream point in its relationship to associated polygons containing the TSS stream network.

GAZE_NAME – Name of watercourse legally named in the B.C. Gazette at the farthest downstream point where the TSS_POINT is assigned.

LOCAL_NAME – Local name of watercourse at the TSS_POINT. Name may be the same as the gazetted name unless there is a common locally know/used name.

Spatial Data Projection – The projection must be in B.C. Albers.

Sending the Data – ArcInfo coverages must be sent as e00 files, uncompressed (i.e., exported with NONE compression option). Shapefiles are also acceptable.