Tamed Rivers

A Guide to River Diversion Hydropower in British Columbia



Watershed Watch Salmon Society
Watching Out for BC's Wild Salmon

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Watershed Watch Salmon Society – October 2012

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Executive Summary

The looming consequences of global climate change have created a strong imperative to move away from fossil fuels and to develop more sources of renewable energy. Though British Columbia already boasts abundant supplies of hydroelectricity, growing demand and a shift in provincial policy has generated hundreds of new hydroelectric projects and project proposals.

Since 2002, most new renewable electricity projects in British Columbia (BC) are built and owned by private developers. Most projects are river diversions – commonly known as "run-of-river" or "small hydro." While it is often assumed that these projects have smaller environmental impacts than traditional hydropower dams, the impacts of river diversion projects can be severe, especially when multiple projects are clustered within single valleys. The sheer number of river diversions approved and proposed, combined with a lack of land-use planning to ensure appropriate siting, are threatening some of BC's fish and wildlife populations, and reducing their ability to cope with stresses caused by climate change, urbanization, resource extraction, pollution and other threats. Impacts to social and cultural values are also an issue.

The practice of diverting rivers for hydroelectricity is relatively new in BC, and many of the potential impacts are still not well understood or considered. *Tamed Rivers* was thus prepared by Watershed Watch to: i) provide a comprehensive, technically-referenced guide to the known and potential impacts of river diversion hydropower, and, ii) to offer constructive solutions to improve BC's current approach to electricity production, particularly with respect to hydroelectricity.

Impacts to aquatic ecosystems

Typically, river diversion projects in BC divert most of a river's flow into a pipe, often for a distance of several kilometers. The piped water is then put through an electricity-generating turbine and returned to the original river channel. Compared to natural flows, only a small amount of water may be left in the "diversion reach" (the length of river from which the water is diverted). In many projects, instream flows in the diversion reach can drop to as little as 2-5% of natural flows. Operational issues at some projects have even led to dried-out diversion reaches and other incidents of fish mortality.

Even when instream flow releases are done according to licence requirements, extremely reduced flows can cause severe, interconnected impacts to the aquatic environment. The most obvious is a

Damien Gillis

Construction of the Fire Creek diversion, near Harrison Lake

reduction in total amount of habitat available to fish and other organisms, due to severe reductions in the width, depth, and velocity of water left behind in the diversion reach. The habitat that remains is usually degraded because of the unnatural flow regime. This is due to reduced high flows (that normally maintain the channel), accumulation of fine sediments, and altered seasonal timing of flows. Water temperature also changes, further affecting habitat quality. All this can lead to impairment of the aquatic food web, including the production of important prey items for fish.

In addition, the diversion dam may interrupt the supply of channel-forming elements (such as gravels and large woody debris), and create a migration barrier for fish. Other infrastructure, including the powerhouse, water intake, roads, and head pond/reservoir, usually cause habitat loss in important riparian areas, while the head pond or reservoir often converts high value riffle habitat into low value pond habitat.

While the majority of the river diversions that have been approved in BC are upstream of anadromous (ocean-migrating) salmon habitat, most are in areas used by other fish, including resident trout and char. Some river diversions have been approved to divert water from stretches of river where adult salmon and steelhead are known to spawn and where juvenile salmon are known to rear. Whether a river diversion is in salmon habitat or trout habitat, the damage to the aquatic environment is similar.

River diversions may also affect high-value salmon habitat below the diversion reach. The most obvious of these downstream effects is the rapid fluctuation in flows that can result from electricity generation, particularly when the project operator is trying to maximize profits. These fluctuations cause repeated drying of shallow stream margins which can strand and kill juvenile fish and wreak havoc on their habitats. In fact, fluctuating flows – in the diversion reach as well as downstream – may be the greatest problem associated with river diversions in the aquatic environment. This problem is amplified when project operators fail to adhere to requirements or best practices for the maximum rate of change of flow.

Impacts to terrestrial ecosystems

Terrestrial ecosystems can be seriously affected by river diversion hydropower projects, particularly when projects are in remote locations requiring the construction of long transmission lines and new or upgraded roads. Roads and transmission lines cause habitat loss and habitat fragmentation. They are also a common cause of erosion and landslides – events that can often harm aquatic ecosystems as well. Roads also affect terrestrial species in more subtle ways, by presenting a migration barrier to some animals and by killing others through collisions with vehicles. Some wildlife species – for example grizzly bears, moose and wolves – may change their behaviour around roads, or avoid roaded areas altogether. Transmission lines have similar impacts, as the vegetation must be routinely cut in the transmission line rights-of-way, creating a new and less desirable habitat type. An additional problem caused by transmission lines is death or injury of bats and birds, as a result of collisions or electrocution.

Mountain goat

The diversion dam, head pond/reservoir and powerhouse cause additional habitat losses in biologically valuable streamside areas. These important habitats are affected by vegetation clearing and by reduced flows in the diversion reach. Reduced flows also impact or eliminate "spray zones" – unique, rare, and sensitive ecosystems that rely on the moist, cool conditions around waterfalls and cascades.

Marbled murrelet, grizzly bear and mountain goat are some of the terrestrial species most affected by river diversions, and there are many more plant and animal species – including species at risk – that are likely to be affected and that should be considered in project plans.

Ongoing uncertainty and risk

The practice of diverting rivers for hydroelectricity is relatively new, and the impacts are still under study. A lack of data can make it very difficult and expensive to understand and address potential terrestrial and aquatic impacts in a timely fashion. As a result, proponents typically promise research and adaptive management to address problems that might be discovered after project construction. This approach has been sufficient to obtain project approvals in many instances. However, in some cases development impacts simply cannot be mitigated, and the wisest approach is to leave an area undeveloped. While improved individual project planning could enhance outcomes in some cases, strategic planning is the most effective way to designate areas that are appropriate for development and areas that should be left undeveloped to protect sensitive species and ecosystems.

Damien Gillis

BC's mountainous terrain provides many potential opportunities for river diversion hydropower

Strategic planning to minimize cumulative impacts

Cumulative effects – also known as cumulative impacts – refer to the accumulation of human impacts over time, from all sources. If enough impacts accumulate, this can push ecosystems or individual species past ecological "tipping points" from which they may not recover. The localized environmental impacts of individual river diversion projects can be lower than the impacts of traditional hydropower dams, so river diversions can appear relatively benign. However, this comparison does not account for the cumulative impacts from neighbouring hydro projects. Nor does this one-off approach consider the relative impact per mega-watt of electricity produced, or whether the project will serve as a gateway to other development by providing key infrastructure such as roads and transmission lines. If done properly, cumulative effects assessment will take into account other land uses such as forestry, mining, urbanization and agriculture, in addition to the sum of impacts from existing and proposed hydropower development in an area.

Environmental assessments for individual river diversions usually include cumulative effects assessments, but these almost always conclude that cumulative impacts will not be a problem. This outcome is a direct result of the narrow scope of investigation possible within an approval process designed for individual diversions. Cumulative effects from proposed and existing development would be more accurately understood by scaling the analysis up to a larger area and to a timeframe where human activity can be proactively managed. Land use planning can then be employed to limit the damage caused by human activity.

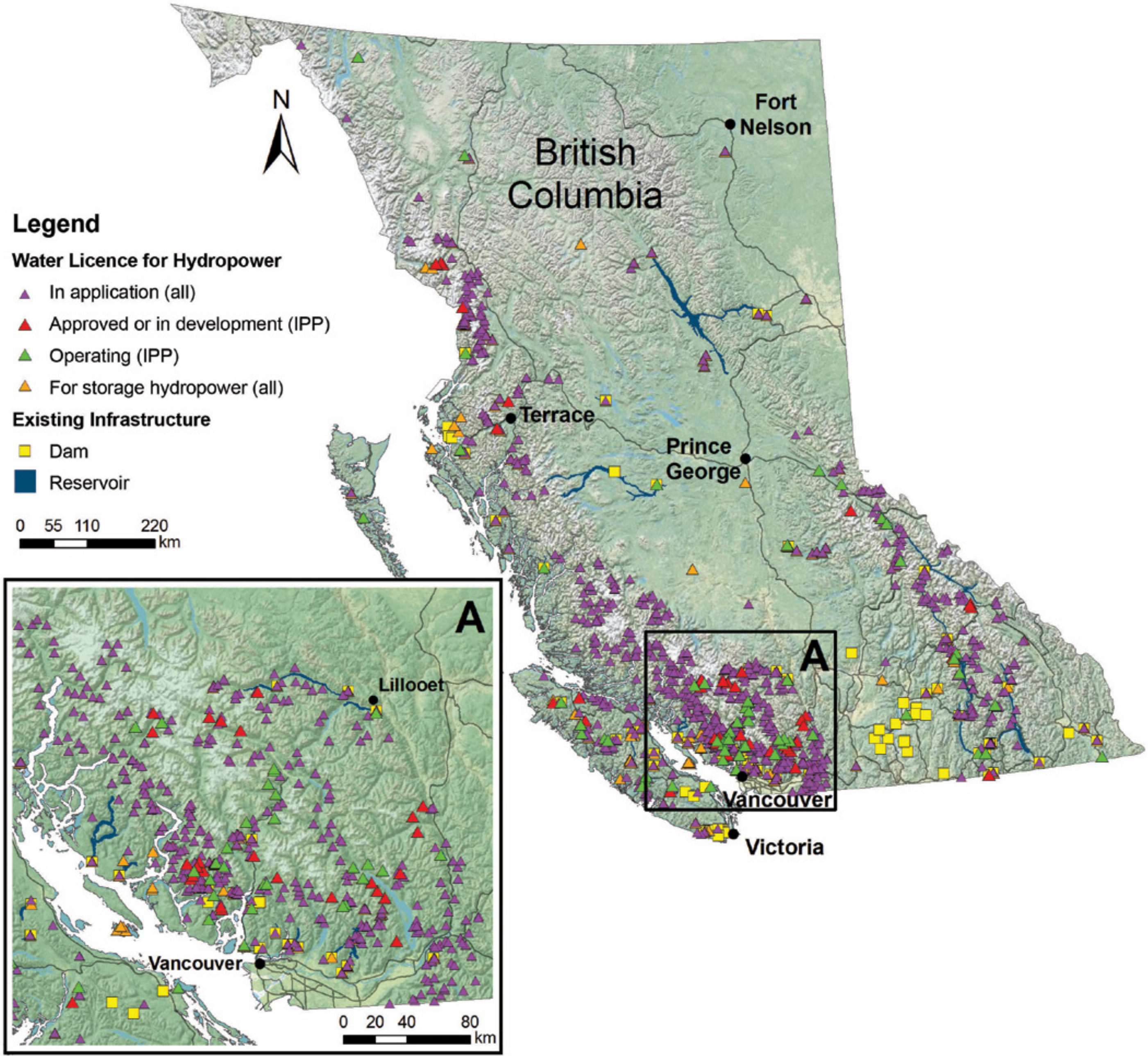
Many river diversion projects have met fierce opposition over concerns for fish, wildlife, tourism, and cultural and recreational values. Many citizens are frustrated by the lack of public input into the large land-use changes brought about by river diversions in BC. Improved public participation in decision-making would therefore be a key element in effective planning for renewable energy development in BC.

To effectively manage cumulative and individual project impacts through an inclusive public process, Watershed Watch proposes a strategic planning process similar to that developed by the Canadian Council of Ministers of the Environment for these types of land use issues. This process is done at a regional or landscape scale – the scale that matters for the protection of ecosystems and species – and would involve British Columbia's resource ministries as well as First Nations, communities and stakeholders. The following steps would be required:

- ***Gather information and examine the options.*** This would include information about areas of high ecological and social/cultural value. This information would then be used in a rigorous analysis of the impacts of different development scenarios.
- ***Use scenarios for public land use planning.*** A good planning process would generate several future scenarios to choose among, and the chosen scenario would be used to guide land management decisions into the future. A well-researched understanding of the cumulative effects of each scenario will be important for making final land management decisions. Public participation, including that of stakeholders and First Nations, would ensure that final decisions represent the broad public interest. Some areas will be deemed appropriate for development, others may be appropriate depending on project plans, and some will simply be inappropriate for any form of river diversion or other renewable energy development.
- ***Monitoring and adaptive management.*** Project impacts must be monitored so that they can be properly understood and mitigated. The on-the-ground outcomes of land use frameworks must be monitored as well, so that a course correction can be made if impacts are greater than expected.

Getting it right with renewable energy development in BC

British Columbia enjoys remarkable potential for most forms of renewable energy. To date there has been no comprehensive planning to make the most of it. River diversion hydropower is best planned within a framework that includes large storage dams as well as wind, tidal and geothermal power. Energy conservation is also critical, as reducing demand allows us to avoid the environmental damage inevitably linked to new electricity development. The best outcome for BC would be a coordinated set of regional plans that include all the renewable energy options, to help us develop the most energy for the least amount of environmental, social and cultural impact. We can be global leaders in sustainable energy development if our government works with concerned citizens, experts and First Nations to manage our resources in a precautionary, strategic and forward-thinking manner.



Independent Power Producers (IPPs) have staked hundreds of BC rivers and streams for potential development. As of September 1, 2012, there were approximately 1100 approved or in-application water licences for hydro power generation in BC. As of April 1, 2012, BC Hydro was buying power from 60 operating facilities and 42 additional facilities were either approved or in development with an Electricity Purchase Agreement from BC Hydro.

The Taming of BC's Rivers

The looming consequences of global climate change have created a strong imperative to move away from fossil fuels and to develop more sources of renewable energy. Though British Columbia (BC) already boasts abundant supplies of hydroelectricity, growing demand and a shift in provincial policy has made BC a global testing ground for "run-of-river" hydroelectricity. Yet these kinds of hydropower projects (more correctly described as "river diversions") are controversial, as are the policies promoting their development.

Public concerns over provincial hydroelectricity policy escalated in 2002, when the provincial government released an Energy Plan directing BC Hydro to purchase new electricity from private developers.[1] These policies were confirmed and updated in 2009,[2] and in 2010 the *Clean Energy Act* cemented them into law.

Damien Gillis

Ashlu River diversion under construction

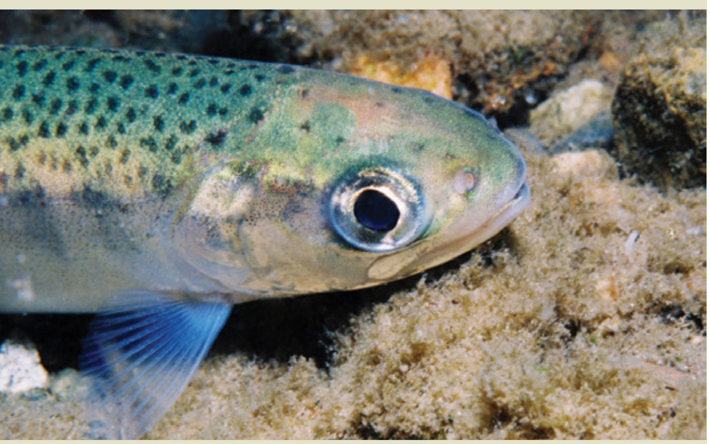
Since 2002 there have been over 800 water licence applications for hydropower development in BC's streams and rivers. More than one hundred of these have been developed into bids in response to BC Hydro's "clean power calls." Most of these bids were for river diversion hydropower, and 53 were subsequently awarded Electricity Purchase Agreements. Problems with this approach were immediately apparent, however, as the placement of river diversions was not tied to any land use planning. Though BC Hydro conducts planning in deciding which bids to reward with Electricity Purchase Agreements, that process is not transparent, nor does it consider environmental factors. No planning process designates areas best suited for energy development or best preserved for other values.

How many river diversion projects are in fish-bearing waters?[3]

For 42 existing and proposed river diversions that have public information on fish presence:

- 72% have confirmed or suspected fish presence;
- 21% have unknown status with respect to fish presence;
- 7% are confirmed to have no fish present.

The species living in diversion reaches are usually resident (non-ocean-going) fish: rainbow trout, cutthroat trout, and/or bull trout. Two approved projects have salmon present through all or most of the diversion reach. Four proposed diversions have a suspected salmon presence. However, salmon are present or suspected to be present in the lowermost part of the diversion reach or just downstream of the diversion reach for many more projects.



Roger Tabor USFWS

Rainbow trout are found in the majority of river diversion sites

BC's energy policy has created unintended consequences. Extensive hydropower developments are now proposed, approved or constructed in many valleys, and healthy ecosystems and fish and wildlife populations are under threat. Even from an energy generation standpoint, this scattershot approach does little to ensure that British Columbians will get an optimal suite of projects for their electricity needs.

Not surprisingly, many proposed river diversion projects have met fierce opposition over concerns for fish, wildlife, tourism, and recreation values. Proposed and approved developments in the Upper Pitt River watershed, Glacier-Howser Creeks, Ashlu River, Bute Inlet, Sedan Creek, Kokish River, and the Klinaklini River were (and remain) among the most contentious. Likewise, provincial policies supporting these projects have drawn strong criticism. At the root of these criticisms are concerns over a lack of land use planning, restricted or futile public participation, and inadequate environmental assessment processes. The nature of private sector-led development has led to further concerns about the ability to monitor and manage environmental impacts, particularly given the dwindling capacities of the agencies involved. Another issue for many citizens is long-term financial impacts to BC Hydro and BC's ratepayers that may result from the privatization of electricity generation.

Within this context, Watershed Watch offers *Tamed Rivers: A guide to river diversion hydropower in British Columbia* in order to: i) provide a comprehensive, technically-referenced guide to the known and potential impacts of river diversion hydropower, and, ii) to offer constructive solutions to improve BC's current approach to electricity production, particularly with respect to hydroelectricity.

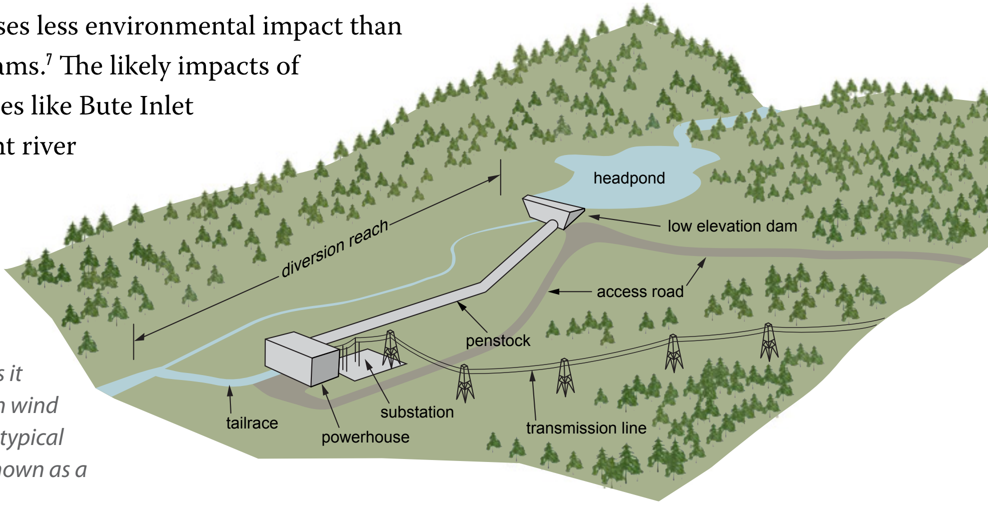
All forms of electricity generation cause environmental impacts. Developers and government alike should aspire to generate the most electricity of the highest quality (reliability) for the least amount of environmental damage. This balancing act requires careful consideration of the ecological limits to development as well as the potential impacts to social and cultural values. It also requires increased energy conservation, so that we develop the minimum number of new projects to sustain our needs.

What is river diversion hydropower?

Penstock being laid for the 2003 Rutherford Creek river diversion project near Pemberton, BC

River diversion hydropower is more commonly known as "run-of-river" hydropower. The term "run-of-river" can give the mistaken impression of a water wheel placed directly in an open stream or river channel. Here in BC, run-of-river simply means that water is not stored behind a dam for more than 48 hours.[4] Even very large facilities such as BC Hydro's proposed Site C dam are technically run-of-river. Watershed Watch prefers the term "river diversion" (as used by the World Commission on Dams)[5] to more accurately convey what is entailed. This term also includes projects that augment water available for electricity generation by storing water in an alpine lake or a reservoir. A defining feature of a river diversion is the piping of water out of the river and into turbines at a downstream location. Just how this is done depends on the local site, but it almost always entails most of the flow being diverted from a long stretch of river.

River diversions are often perceived as environmentally friendly, since they can be built on a much smaller scale than typical hydropower dams and do not require a large reservoir. In fact, depending on site-specific factors, short river diversions can be the very best and greenest choice. But according to a recent paper,[6] the perception that "small hydro" (another popular term for river diversion power) is "green" is driving a surge of interest in its development all over the world – and creating a suite of unintended consequences when networks of these projects are developed. When viewed as impact per mega-watt of power generated, there is no reason to believe that extensive development of small hydro causes less environmental impact than large, centralized hydropower dams.[7] The likely impacts of clustered river diversions in places like Bute Inlet (a proposed cluster of 17 adjacent river diversions on BC's south coast) provide a case in point.



River diversion hydropower is the predominant kind of renewable energy proposed by private developers in BC, as it is usually less expensive to produce than wind or solar power. This diagram shows the typical components of a river diversion (also known as a run-of-river) project.

Hydroelectricity in BC

Approximately 78% of BC's electricity is produced by hydroelectric facilities within BC, and of this, about 90% is from BC Hydro's large dams.[8] As of December 2011, 51 private power projects were generating hydroelectricity, contributing about 10% of BC's total electricity supply, or 12% of BC's total hydroelectricity.[9] River diversion projects account for about half of this amount, with the remainder from a few large dams: Rio Tinto Alcan's massive Kemano project on the Nechako River, the dams managed by the Columbia Basin Trust, and the Waneta Dam near Trail.

The relative contribution from private power projects is set to increase as at least 35 additional private hydro projects have received electricity purchase agreements from BC Hydro. These projects are still in development or under construction with the majority being river diversion projects. While some may not proceed, these projects would represent about 8% of BC's current supply. By contrast, the proposed Site C BC Hydro dam represents about 2% of BC's current supply.

Large dams will likely remain the most important part of BC Hydro's energy portfolio, as hundreds of new river diversions would be required to replace them. Wind, solar or tidal power may become more important in the future, but at this time these options are less available and more expensive than hydroelectricity. All forms of intermittent electricity, including river diversions and wind, require "firming" from stable electricity sources like large hydro dams.

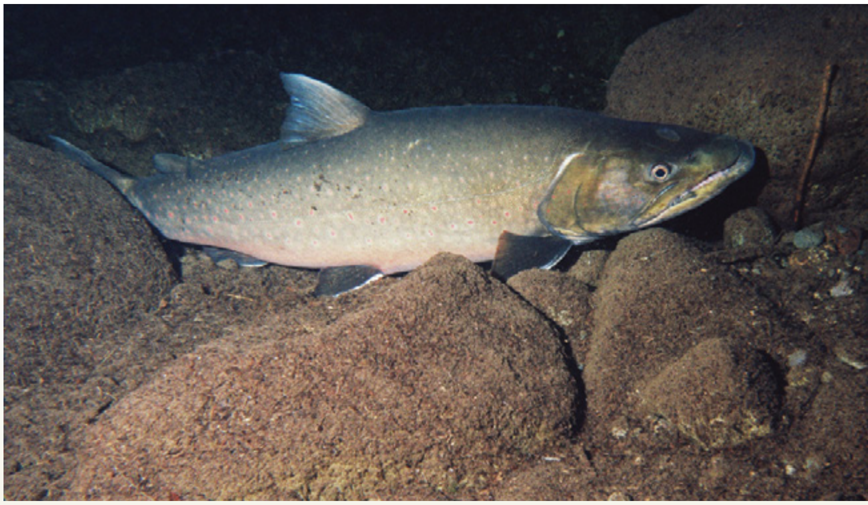
Damien Gillis

River diversion construction at Tipella Creek near Harrison Lake

Aquatic impacts of river diversion

In a nutshell: River diversion impacts on aquatic ecosystems

River diversion projects affect the aquatic environment by dramatically reducing flows through the "diversion reach" – a stretch of river that can be five or more kilometers long. Other impacts result from the footprint of the project itself: the streamside roads and power lines, the powerhouse, and the diversion dam. Day-to-day operations are also very important, and rapid changes to flows within and below the diversion reach are serious problems that can be difficult to address.



Roger Tabor, USFWS

Adult bull trout

Because everything is connected, changes in flows affect not only the quantity and quality of aquatic habitat, but also streamside vegetation, food web components (such as insects), and the shape of the channel itself. Even temperature can change, both in the diversion reach and downstream.

The diversion reach and the diversion dam can be barriers to fish migration. In most cases these will be situated above the range of migrating salmon, but will still divide resident fish populations in two.

The practice of diverting rivers for hydroelectricity is relatively new, and the impacts are still under study. In some cases these developments can provide truly low-impact renewable energy, but they can also generate extensive and profound negative effects. Care must be taken to ensure that river diversion projects are done well, and in appropriate locations. This includes strategic planning for renewable energy in BC, to minimize the impacts per mega-watt-hour of electricity generated.

A warning from Norway

Because river diversion hydropower is a new technology for BC, we lack conclusive data on its full environmental impacts. However, results are in from Norway, where steep terrain supports thousands of hydropower plants that supply 99% of Norway's electricity.[10] Hydropower is the most widespread cause of problems for salmon in Norway, affecting more wild Atlantic salmon stocks than any other human-related cause, including ocean harvesting, sea lice and other parasites, acid rain, and other forms of habitat destruction. In fact, hydropower projects have resulted in the loss of entire populations (19 extinctions to date) and significant reductions in the productive capacity of salmon rivers.[11] Millions of dollars are being spent to mitigate the negative effects, and Norway is even considering removing some river diversions.[12] While Norwegian conditions are not identical those in BC, and include older facilities which have operated with less stringent standards, we should take warning from the Norwegian experience.

River diversions affect aquatic ecosystems by lowering instream flows, by causing fluctuations in flow, and through direct habitat loss. Temperature changes below the diversion reach can also be a problem.

Tamed Rivers focuses on river diversion projects because they are the predominant form of new hydropower development in British Columbia. While most are run-of-river, some river diversions use stored water from alpine lakes or small storage reservoirs to generate additional and more consistent power.

For river diversion projects in BC, water licences specify how much water can be diverted, as well as how much must be left in the stream or river. The amount that must be left instream is called the *instream flow requirement*, and is nearly always a small fraction of natural flows (see Table 1). Most of the year, the instream flow requirement is all that will be left in the river between the diversion and the point at which the flow is returned. Instream flows will increase beyond this amount only during times of high run-off, such as spring snow melt, when the amount of water available for diversion exceeds the amount that can be diverted.

Most (but not all) river diversion projects are built just upstream of anadromous (ocean-migrating) salmon and steelhead habitat, though resident (non-ocean-going) fish populations are present in most sites. Resident fish in BC include rainbow trout, cutthroat trout, and bull trout (a species of char), among others.

Reduced instream flows

The amount of water that must be left instream has a major effect on the financial viability of any river diversion project. When more water is diverted more electricity can be generated, and the project becomes more profitable. In order to be profitable, the majority of available flows must usually be diverted.[13] This creates a strong incentive to leave the lowest possible amount for instream needs.

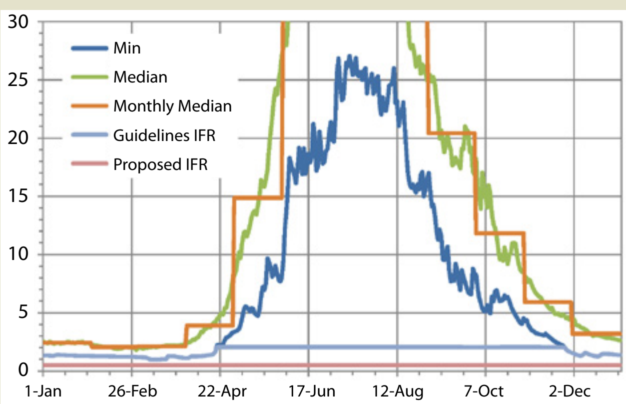
The provincial government has a procedure for determining instream flow amounts for fishless and for fish-bearing streams,[14] but this procedure results in thresholds for fish-bearing streams that are often deemed too high for river diversion projects to be financially viable.[15] These guidelines were developed to be used as a "coarse filter" for reviewing water licence applications in BC, and project proponents supplement these guidelines with their own studies to determine the minimum instream flows necessary to protect aquatic life. This is a difficult task to do well,[16] particularly as there are little to no existing hydrological data for most rivers and streams proposed for development. While various methods can be used to understand and model instream flows,[17,18,19,20,21] these methods necessarily make some broad

Table 1: Instream flow releases and diversion flows for existing and proposed river diversions[22]

Project	Stream Name	Capacity (MW)	Diversion Flow (m^3/s)	Instream flow requirement (m^3/s)	% Water Diverted (maximum)
East Toba-Montrose (existing project)	Montrose	73	20.26	0.25	99
	East Toba	123	28.89	0.71	98
Upper Toba (approved project)	Dagleish Creek	30	5.70	0.18	97
	Jimme Creek	55	16.40	0.64	96
	Upper Toba	45	20.80	1.01	95
Bute Inlet (proposed project)	Scar Creek	88	28.60	1.24 – 3.1	89 – 96
	Coola Creek	23	13.40	0.58 – 1.45	89 – 96
	Whitemantle Creek	83	22.30	0.78 – 1.21	95 – 97
	Brew Creek	103	37.80	1.64 – 3.69	90 – 96
	Jewakwa River	79	39.70	1.38 – 2.16	95 – 97
	Heakamie River	52	34.80	1.21 – 1.89	95 – 97
	Gargoyle Creek	40	6.90	0.30 - 0.75	89 – 96
	Bear River	46	58.00	2.52 – 5.67	90 – 96
	Elliot Creek	70	14.70	0.51 – 1.12	92 – 97
	Icewall Creek	71	22.10	0.77 – 1.44	93 – 97
	Raleigh Creek	51	17.50	0.61 – 1.33	92 – 97
	Southgate River 1	143	39.20	1.20	97
	Southgate River 2	28	9.40	0.25	97
	Alaire Creek	67	22.20	0.58	97
	North Orford River	18	10.20	0.42 - 0.91	91 – 96
	East Orford River	35	13.10	0.46 - 1.00	92 – 97
	Algard Creek	29	14.80	0.65 - 1.46	90 – 96
Upper Harrison (existing)	Tipella Creek	16.7	7.20	0.35	95
	Upper Fire Creek	5.9	1.74	0.10	94
	Lamont Creek	28	8.67	0.50	94
	Upper Stave River	33.5	43.80	2.60	94
	NW Stave River	18.1	31.50	1.30	96
Glacier-Howser (proposed project)	Glacier Creek	44.5	13.00	0.65	95
	Howser Creek	55	20.00	0.95	95
Kwoiek (under construction in 2012)	Kwoiek Creek	50	13.50	0.55	96
Kokish (approved project)	Kokish River	45	23.33	3.00	87
Cascade Heritage (existing project)	Kettle River	25	90.00	1.00	99
Iskut Cluster (under construction/ approved project)	Forrest Kerr	195	252.02	5.00	98
	McLymont Creek	66	30.70	0.50	98
Pingston (existing project)	Pingston Creek	25	5.40	0.30	94
Nascall (proposed project)	Upper Nascall River	40	65.00	2.24	97
	Lower Nascall River	31	75.00	3.14	96
Europa (proposed project)	Europa Creek	102	18.08	0.18	99
Tyson (existing project)	Tyson Creek	9.3	1.30	0.07	95
Ashlu (existing project)	Ashlu Creek	49.9	29.30	2.42	92

How much water is left instream?

The East Toba-Montrose project near Powell River consists of two linked river diversions. At the East Toba site, the flow that can be diverted is 30.7 cubic meters per second (m^3/s), and the instream flow release is 0.70 m^3/s. Thus, up to 98% of the flow can be diverted, depending on flow conditions. The instream flow requirement is only exceeded about 20% of the time, when excess flow is allowed to spill down the diversion reach. The numbers are similar for the Montrose site, where the flow that can be diverted is 22.8 m^3/s and the instream flow release is 0.52 m^3/s. Another way to understand the remaining quantity of water in the diversion reach is to determine how often flows would naturally drop to this level. For the East Toba site, pre-diversion flows (based on limited data) would be at this level only about seven days per year. For the Montrose site it would be even less – under natural conditions, flows would equal the instream flow requirement for perhaps three to four days per year.[23]



McLymont Creek, in northwestern BC, is another stream proposed for diversion. In June 2012 this project received an Environmental Assessment Certificate and was still waiting for water licence and land tenure approvals. This annual hydrograph[24] shows the great difference between natural flows and the small instream flows that would be left after diversion. The proposed instream flow release (pink line) is less than half that recommended by government guidelines (blue line)[25] and is vastly smaller than natural flows.

assumptions (such as the application of a single guideline to diverse geographical regions, or the use of a standard percentage of flow). Even the most detailed and onerous assessment methods have many limitations.[26]

Until recently, the effects of river diversions were not well studied in BC. The Province of BC now requires river diversion proponents to complete extensive monitoring of fish and fish habitat. Unfortunately, definitive results from many recently constructed projects are not yet available, leaving little real-world data to evaluate the likely impacts of dozens of river diversion proposals pending in BC. If unacceptable impacts to fish and fish habitat or other values are discovered, it is possible to amend the project's water licence to increase the instream flow requirement. In reality, making an adjustment to a water licence would require significant proof of harm based on solid monitoring results, since increases to instream flows could result in substantial financial losses. Several years of monitoring will likely be required to better understand the environmental effects of river diversion in BC.

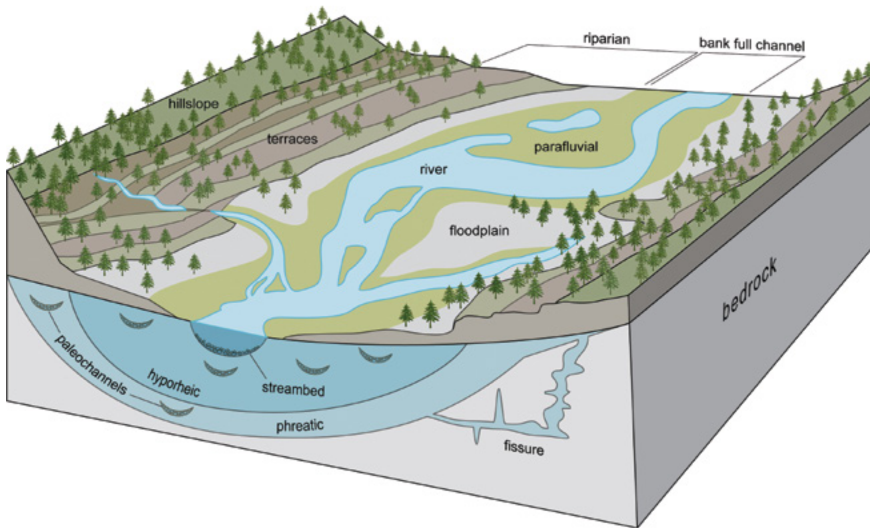
Less habitat, and changes to the remaining habitat

Healthy, natural stream habitats and food webs are maintained by complex factors that include high flows during spring snowmelt or winter rains, the downstream movement of gravel and woody debris, and interactions between the stream and the surrounding vegetation. While the full effect of dramatic flow reductions is impossible to quantify, this section describes some of the better-known effects of reduced and regulated flows.

River floodplain ecosystems can be described as "shifting habitat mosaics."[27] These mosaics of aquatic and riparian habitat will shift in time and space in response to naturally varying flows, including floods. Dams and diversions cause predictable harm to the mosaic, because of their distinctly un-natural flow regime. Over time the structure of the channel will change and thus the shifting habitat mosaic becomes simplified with great loss of aquatic and riparian biodiversity.[28]

River channels below dams and diversions experience long-term changes in their habitat structure and value (and sometimes size) because of interconnected reasons, chiefly:

i. reductions in width, velocity and depth, altering the amount, character and value of stream habitats;
ii. reduced high flows that eliminate the cut and fill processes that maintain natural channel networks;
iii. accumulation of fine sediments that fill in pool habitats and clog up gravels; and,
iv. an interrupted supply of channel-forming elements, including gravels, other sediments, and woody debris.



In lower gradient rivers, the floodplain can be described as a "shifting habitat mosaic." The form and extent of the mosaic is changed below dams or diversions, due to a lack of channel-forming and channel-shifting flows. Without these flows there is a loss of lateral and vertical exchange of surface and groundwater, which is a primary source of biodiversity and productivity.[29]

Reductions in width, velocity and depth

River diversion projects dramatically reduce the amount of water in long stretches of river. Reducing the "wetted width" of a stream will reduce the amount of fish habitat. It will also change the depth and velocity, key factors that determine the value of fish habitat as well as its suitability for other life forms. Different fish species prefer different velocities and depths, so assessments must be based on which species are present. Hydrological modeling can predict depth and velocity changes at a coarse level by looking at the channel shape and at the normal flows throughout the year. The degree of change to velocities and depths will depend on the shape and size of the channel. Modeling will generally show that small streams will need to retain a greater proportion of their flow than larger streams, in order to retain the preferred velocities and depths for fish.[30]

Damien Gillis

The diversion reach at Rutherford Creek, showing very low instream flows and poor fish habitat

Environmental impacts of big hydropower dams

Large hydro dams have well-recognized environmental impacts, which have become clear since their widespread construction began in the 1950s.[31] These include:[32]

- **Flooding of high-value habitats** such as low elevation forests, wetlands, and salmon streams, and the elimination or displacement of the wildlife populations that depend on them;
- **Release of methane** (an extremely potent greenhouse gas) and carbon dioxide due to flooding of vegetated areas – in some cases making the energy from large dams little better than fossil fuels when it comes to greenhouse gas emissions;[33]
- **Changes to nutrient levels** (e.g., eutrophication) due to leaching from flooded soils and sequestration of nutrients associated with suspended sediments;
- **Increased siltation** (behind dams), impacting bottom-dwelling organisms, and loss of suspended sediments downstream of dams, reducing the natural deposition of sediments – an essential component of healthy floodplain ecosystems;
- **Increased concentrations of mercury** (a potent neurotoxin) in high trophic-level fishes and birds, due to bio-accumulation, as naturally occurring mercury is released from decomposing organic matter;
- **Displacement of human settlements** and loss of traditional land uses;[34] and,
- **Barriers to fish migration** upstream and downstream, often leading to the fragmentation or even the extinction of unique fish populations.

Other common impacts[35] of large dams are similar to those of river diversions, and can be even more serious:

- **Dramatic changes to downstream flow patterns**. This includes reductions in habitat quality and quantity due to reduced flow, and the loss of the natural processes of erosion and sedimentation that occur in healthy floodplains as a result of flooding. Less flooding means a reduction in channel migration, and a loss of the shifting habitat mosaic that supports aquatic and terrestrial biodiversity.[36] This includes the dewatering of smaller side channels due to a drop in the water table.[37] The lack of natural floods also leads to altered streamside (riparian) vegetation, with negative impacts to the riparian food web, including the wildlife and plants adapted to live there. Some of these impacts can be more severe for lower gradient channels with established floodplains[38] – the type of channels most common below large dams;
- **Problems with rapid changes in flow** (ramping rates), leading to fish stranding;
- **Entrainment of fish** and other aquatic life in power turbines;
- **Aquatic ecosystem impacts** caused by changes to temperature, sediment and large woody debris patterns;
- **Deforestation and other direct habitat loss** caused by the project's terrestrial footprint (i.e., power lines, roads, and dams), with associated CO_2 emissions and potential harm to sensitive species;
- **Fragmentation of important habitats** due to the linear infrastructure of power lines and dams – a particular concern for projects in remote areas; and,
- **Construction impacts** such as spills, erosion, siltation, noise pollution, carbon dioxide emissions and human disturbance of wildlife.

While flows downstream of large dams can be less natural than flows below river diversion projects, large dams can provide precise flow releases to support aquatic life downstream, including augmented flows during low-flow times of year.

River diversion projects are sometimes seen as "greener" than large hydro dams because water is more quickly returned to the channel, and because they don't necessarily flood large areas of land to create reservoirs. However, when all the various impacts are examined, there is little reason to believe that river diversion projects are less harmful than big dams.[39] That said, comparisons between river diversions and large dams can be difficult to make, given that "run-of-river" power is intermittent while large dams can provide stable year-round power. In fact, British Columbia's large dams provide an essential power-storage service for the "non-firm" power from river diversion projects and wind turbines.

Damien Gillis

An access road for the Tipella Creek river diversion project, near Harrison Lake

Occasionally, reduced flows may actually increase the habitat suitability for fish and other organisms (for example, through increases in temperature that might lead to increased growth[40]), but this must be weighed against other consequences, such as the loss of rare "spray zones" associated with steep and turbulent stretches of river (see page 12), as well as other long-term changes to habitat quality.

Reduced high flows

Floods that happen only occasionally (e.g., every one to two years) are described as "channel maintenance flows."[41] In BC these flood flows are defined by their size relative to the average annual flow (>400% of mean annual discharge, occurring over a period of days.[42]) These channel-maintaining floods define and maintain the channel banks, and move boulders, gravels, and woody debris into new configurations. While this can cause some destruction, it is also a form of renewal. Floods provide a critically important ecological function in all rivers. In environments undisturbed by human impacts, river floodplains are dynamic environments that support a great amount of biodiversity.

In lower gradient channels, a *lack* of change in the channel's location on the floodplain is a notable result of flow regulation by a hydropower facility.[43] Generally, low gradient channels (below gradients of 1.5%[44]) experience greater problems as a result of dams or diversions. River diversion projects are by necessity in higher gradient stretches of river, though portions of the diversion reach may be at much lower gradients. In any case, harm to the diversion reach is still unavoidable given the dramatic reductions in flow through the diversion reach.

The majority of river diversion projects can rely only on the severely reduced natural flows overtopping the dam to provide high flows for channel maintenance. In other words, there is no ability to actively manage high flows, since there is little storage in head ponds. Based on an analysis of several existing and proposed projects, the frequency of channel maintenance flows is typically reduced by more than half.[45] In addition, the magnitude of floods will be reduced by the amount of water flowing through the penstock. The floods that still occur may be enough to maintain the channel in its natural condition; however, there is insufficient information to confirm that this is the case.

Life in the spray zone: impacts of river diversions on rare riparian ecosystems

– by Jim Pojar and Patrick Williston[46]

Flathead Lake Biological Station

Waterfalls, cataracts, cascades, and wet canyons are striking physical features that are among the hallmarks of British Columbia. But they are more than water and rock. The constant spray and perpetually moist, shady and cool conditions result in unusual ecosystems with a rich assemblage of moisture-loving organisms. These features are small but significant nodes of diversity and specialization, especially in our mountainous forested landscapes.

Although small and generally overlooked, particularly noteworthy are the non-vascular plants. These diminutive plants, which reproduce via spores, include the mosses, liverworts, and lichens. They thrive on the wet rocks, drip faces, and mist-drenched trees and logs of waterfall spray zones and humid canyons. These habitats shelter many rare species of such plants and are critical habitat for several species endemic to our part of the planet. We suspect that many specialized invertebrates also live in these habitats, in addition to better-known vertebrates such as the dipper and tailed frog.

Current environmental assessments of river diversion projects do not effectively address these sensitive ecosystems and species, because:

- These small, obscure organisms are not usually included in environmental assessments, which emphasize impacts on vertebrates—especially fish and mammals;
- Even when they are documented in areas proposed for development, these organisms are not effectively protected by existing legislation and development plans are seldom changed to accommodate them;
- If these sensitive species and ecosystems do happen to get noticed, "mitigation" is typically prescribed. But in these circumstances mitigation would mean re-creating the waterfall or wet canyon and its microclimate—which isn't going to happen; and,
- The current process promotes progressive erosion of key habitats for rare and regionally endemic species.

Accumulation of fine sediments

When a major amount of flow is removed, fine sediment (silt and sand) can build up in the channel.[47,48] While healthy rivers and streams contain a mix of fine and coarse sediments, it's well known that too much fine sediment can clog the river-bed gravels that fish use for spawning, reducing the survival of overwintering eggs and embryos.[49,50,51,52,53] Benthic invertebrates (bottom-dwelling insects) that live in these gravels may also be adversely affected,[54,55] or experience shifts in community structure (the relative proportions of different species and groups of species). This can affect juvenile fish through removing their prey.[56]

A recent study showed that channels downstream of diversion dams contain significantly more fine sediment and slow-flowing habitat than in similar unaffected areas.[57] In nature, "flushing flows" move this fine sediment downstream, and eventually out to a lake or the sea.[58] One way of describing flushing flows is by their size relative to the annual average flow – about 200% of mean annual discharge[59] – though "flushing flows" are defined in different ways and are sometimes treated as interchangeable with "channel maintenance flows" (discussed above).[60,61]

Damien Gillis

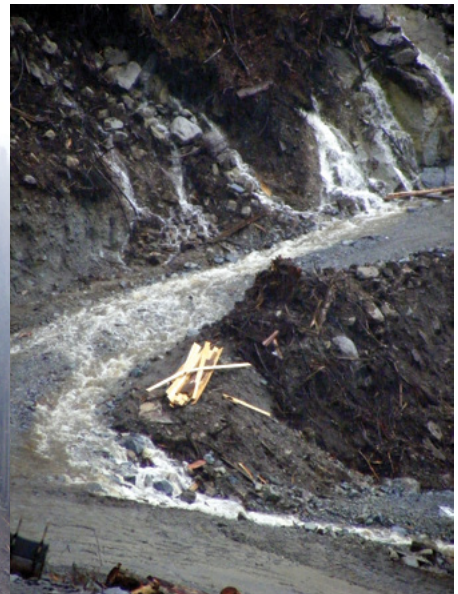
Ashlu River powerhouse under construction

Conventional hydro projects often plan for the special release of flushing flows to clean out fine sediments. In the case of river diversion projects, flushing flows occur when the diversion dam is overtopped during seasonal high flows (e.g., during spring melt and winter rains). However, the frequency of flushing flows will be significantly reduced from natural conditions. Based on an analysis of several proposed and existing projects, the frequency of flushing flows will be reduced up to 10-fold, and the magnitude of the flushing flows will also be reduced.[62] For BC's diverted rivers, there are no completed studies to indicate whether this reduced frequency might create problems with sediment accumulation between "flushes."

Interrupted supply of sediment and large woody debris

The structural elements of streams – large woody debris and sediment – are partly delivered from upstream reaches.[63] Large woody debris (LWD) is simply the trees, roots and branches that fall into the stream channel. Sediments are cobbles, gravels, and finer grained sands, silts, and clays that make up the stream bottom.

The importance of LWD for fish habitat is well documented,[64] and channels lacking LWD tend to provide poor fish habitat. LWD bolsters complexity in channels, stabilizes channels, maintains pools, and provides hiding cover for fish. LWD is usually lost as a result of streamside logging. LWD is so important to stream



Sunshine Coast Conservation Association

The Tyson Creek river diversion project on the Sunshine Coast, showing (left) the steep clearing for the above-ground penstock, and (right: inset photo) surface runoff causing erosion and potential slope stability problems.

structure that habitat restoration projects commonly involve the difficult and expensive practice of placing large logs in the stream,[65] as well as planting coniferous trees to assure long-term LWD supply.[66] In addition to providing stream structure, large woody debris habitat also supports invertebrate (insect) populations, which in turn are food for fish and other life forms.[67]

Sediment supply is a difficult issue below traditional hydro dams. While excessive fine sediment can accumulate, it is also true that too little sediment of all sizes is available to maintain the channel form and provide quality spawning sites for fish. This is due to sediment being trapped behind the dam.

River diversion projects without storage reservoirs will have fewer problems with trapped sediment than traditional hydro projects. The low dams typical of most river diversions are overtopped every year, allowing some sediment to move downstream. Some diversion dams also incorporate the ability to flush the head pond of accumulated sediments, using sluice gates or deflatable rubber sections. However, some head ponds are predicted to hold as much sediment as is moved during 5 to 50 year flood events,[68] and could release all this sediment at once during manual flushing presenting a potential problem downstream. Facilities that do not have this flushing ability will trap sediment on a permanent basis. Although this is not likely a problem during higher flow months, during drier months the flow in diversion reaches may well be starved of sediment which could increase erosion,[69,70] or cause other negative changes to channel shape or habitat quality.

Stockpiled LWD not transported by high flows will probably need to be manually moved over the dam, as is the plan for at least one river diversion project.[71] Questions remain about whether there are negative effects related to the timing of sediment and LWD movements downstream. And because a substantial amount of the stream flow will still be diverted into the penstock – even at peak flows – it is unclear whether the reduced magnitude of the peak flows will be sufficient to move LWD downstream.

Ongoing uncertainty regarding the impacts of flow reduction

The extent of damage to BC's rivers is not well understood, because river diversion projects have become common only in recent years and little research has been completed.[72] Some rivers will be more vulnerable than others, and higher gradient stream channels vary considerably in their responses to flow depletion.[73]

Recommendations for minimum instream flows are usually based on standardized calculations developed to avoid excessive physical and biological impacts to stream life. However, such methodologies (such as the BC-modified Tennant method) may not fit the wide diversity of streams in BC.[74,75,76] Other more detailed methods, such as the Instream Flow Incremental Methodology (IFIM) and its component Physical Habitat Simulation (PHABSIM), require an immense amount of work, and are not broadly applicable across many streams. While these more intensive methods are useful in quantifying habitat for a given fish species at a specific life stage, they are difficult to apply across the full ecological spectrum present in most aquatic habitats affected by river diversions.[77] To fully understand the effect of flow reduction on habitat quality and quantity, much work is needed at an extremely fine scale – something not usually feasible for streams with complex channel geometries.[78] Generally speaking, hydraulic modeling does not reveal flow patterns at scales that are important to fish survival,[79] and as such can't provide the kind of biological understanding necessary to understand how reduced flows will likely affect fish populations.[80] Consequently, no matter what method is used to determine instream flow requirements, an accurate prediction of the changes to the quantity and quality of the remaining habitat is not likely, and may not be possible within the constraints of a development project. In any case, the full impacts of river diversion on physical, chemical and biological conditions may take decades or centuries to become apparent.[81,82]

Eulachon and coastal hydropower

Eulachon are herring-sized fish that are important to coastal ecosystems as well as to First Nations.[83] Coast-wide there has been an estimated 90% decline[84] in their numbers, which may be due to warming environments as well as fisheries by-catch and freshwater habitat loss.[85] Due to this decline, major BC eulachon populations are listed as endangered (Fraser River and Central Coast populations) or threatened (Skeena/Nass populations).[86]

Eulachon spawn in the lower reaches of some coastal rivers,[87] and use estuaries for rearing.[88] Changes to flow or sediment as a result of hydropower development could put additional pressure on these threatened and endangered populations. For instance, eulachon can be affected by increases in fine sediment in their spawning gravels,[89] and by changes to flow patterns caused by upstream dams or diversions.[90] For those rivers that support eulachon populations, extra care will be needed to understand and monitor the downstream impacts of proposed river diversions.

Watershed Watch Salmon Society

A male eulachon in spawning colors.

Changed seasonal timing of flows

Fish and other organisms respond to seasonal cues for parts of their life cycles. For example, salmon migration and spawning are often triggered by fall rains. According to an analysis done by Watershed Watch, many diversion reaches will experience a significant delay in the onset of seasonal high flows, and a consistent reduction in the magnitude of peak flows compared to natural conditions.[91]

Damien Gillis

Water leaving the powerhouse on Rutherford Creek

It's difficult to predict the ecological effects of delaying and reducing high flows over the life of a power project. In some years, important flushing flows might not happen in time to clean spawning gravels in the diversion reach. Changes to flow timing could also affect the food web – for instance, changing the time at which fish fry emerge from their spawning gravel relative to the availability of their prey, with consequences to the health or size of the local fish population(s).

For river diversions in fish-bearing habitat, the provincial and federal governments typically require increased instream flows during certain times of the year in order to maintain critical fish habitats. For example, flows would be increased in spring and summer to maintain spawning and rearing habitat for trout, and increased flow would also be required to support fall spawning habitat for salmon and char (bull trout). Less flow would be required over the winter months to support overwintering habitat. Whether these flows are sufficient to maintain healthy fish populations remains to be seen. Monitoring of fish populations and fish habitat is generally carried out by project proponents, based on requirements negotiated with the Province prior to receiving a water licence. Conclusive monitoring results are not yet available.

Changes to temperature

Water temperature directly affects habitat quality and quantity for fish and other aquatic organisms. Reductions to flow will affect temperature in both winter and summer. Reduced flow will allow the remaining water to heat up in summer and may help fish grow faster and larger. In cold coastal streams this can increase their probability of survival and shorten time to maturity. However, this can have other effects: in one study the benefits of warmer waters led to earlier migration to sea, which then resulted in reduced marine survival.[92] If summertime waters heat up too much as a result of reduced flows, fish can suffer stress or even death. Lethally high temperatures for fish are a common result of water extraction in BC's interior streams,[93] and may soon occur more often in cooler coastal streams as a result of BC's warming climate.[94]

In winter, reduced flow could increase the possibility of harmful ice formation. Ice can form on the bottom of the stream (called anchor ice) or can form in slushy crystals called frazil ice. Frazil ice can harm fish

Fish kills discovered at BC river diversions

The province does very little inspection of operating river diversions. Instead, detailed information on flows is provided on an annual basis to the Ministry of Forests, Lands and Natural Resource Operations, plus any non-compliance must be reported as it occurs. This lack of field presence means that problems on the ground are sometimes revealed by chance alone. This is exactly what happened when Fisheries and Oceans Canada (DFO) officials were doing swift water rescue training on the Mamquam River near Squamish in 2010. They were dismayed to notice wildly fluctuating flows, and saw young steelhead getting stranded along the river margins.[95]

University of Montana

Juvenile rainbow trout

Freedom of Information requests made by the Vancouver Sun and the Wilderness Committee have revealed that repeated water flow fluctuations are stranding and killing juvenile fish in the Mamquam River and in Ashlu Creek, which is another Squamish tributary.[96] As of April, 2012, neither operator had been charged; they had only been sent warning letters. The released documents state that DFO has seen considerable non-compliance with instream flow requirements at other projects, too. Provincial officials are on record as being frustrated with the "hand-holding" and the repeated problems that are occurring as they try to bring project proponents into compliance.[97]

Better operating practices must be developed for flow ramping, but these are only likely to be effective with better oversight.

directly through scraping their gills, or even cause suffocation.[98] In general, when ice forms it displaces fish from favourable habitats. Ice sometimes creates dams, which can cause some areas to flood and others to dewater. When dams break, they can crush fish and cause downstream erosion.[99] Not enough is known about ice formation in rivers affected by flow diversions, nor its effects on fish and other aquatic life.

Changes to riparian vegetation

The vegetation that grows along stream banks and lake edges is called "riparian" vegetation. Riparian "zones" typically provide high value terrestrial habitat while influencing river ecosystems in profound ways.[100] For example, riparian vegetation provides nutrients to food webs, and also provides important fish food directly through terrestrial "insect drop."[101,102] It provides shade, protects river banks from erosion, and helps provide river structure through "woody debris" – the trees that fall into a river channel and help shape its form, and provide hiding cover and pool habitat for fish.[103] Riparian vegetation can also filter runoff containing harmful sediment or pollutants before it reaches a stream or lake.

Riparian vegetation and ecosystems may be affected by reduced moisture levels due to reductions in instream flows. This can be a problem when rare plant communities rely on stream moisture, for example in high-gradient stream reaches that give off a lot of mist (see *Life in the Spray Zone* on page 12). Conversely, changes to riparian vegetation can affect the stream; a concern when riparian vegetation

Emergency shutdowns of connected projects

Where multiple projects share a transmission line, it is possible that these projects will be shut down all at once due to problems with the line. In such cases, problems with quick drops in flow (i.e., extreme ramping rates) can be additive, causing major problems downstream.

In the case of the Forrest Kerr river diversion project now under construction in northwest BC, and the adjacent, proposed McLymont Creek project, simultaneous shutdowns could result in decreases in water depths of almost ten times the site-specific recommended rates, even though the project tailraces are located 10 km from each other.[104] Similar issues could occur in other proposed projects (e.g., Bute Inlet and Holmes River) where multiple adjacent diversions would share a single transmission line.

As is the case for the Forrest Kerr and McLymont Creek projects, most river diversion projects in BC are located just upstream of lower-gradient salmon spawning and rearing habitat, which leaves fish more susceptible to stranding due to flow ramping. Flow by-passes that allow some or all of the project flow to be continued through the powerhouse without energy production can mitigate these effects, but only if properly implemented and managed.

is removed to make way for dams, roads, powerhouses and power lines. As discussed in the *Terrestrial impacts of river diversion* section of this document, riparian areas also provide essential habitats for terrestrial species.

Changes to the food web

Capital Regional District

Crayfish

Aquatic food webs are likely to be affected by the reduced habitat quality and quantity caused by river diversions. Benthic invertebrates are the most recognized part of the food web, because they are a primary food source for fish[105] and are essential for the healthy functioning of aquatic ecosystems.[106] Benthic invertebrates include the larvae of insects such as caddisflies, dragonflies, and mayflies. They live on the stream bottom, and cycle nutrients by eating algae, leaf litter, or other insects. In addition to providing fish food, the types and densities of invertebrates reflect conditions in the stream, which is one reason they are used as a monitoring tool. The presence or absence of sensitive species is a good indicator of habitat quality and of changes over time.[107]

Studies in other jurisdictions have found benthic invertebrate densities dropping by 50% or more as a result of stream diversions.[108,109,110] Similar studies have shown dramatic changes in the types of

Hydropower mishaps

Emergency shutdowns, mechanical malfunctions, lax oversight, and the challenges of operating in rugged, remote locations will occasionally cause mishaps that can dry up rivers or damage fish habitat. The diversion reaches at both the Miller Creek Hydroelectric Project near Pemberton[111] and Rutherford Creek Hydro Project near Whistler have run dry, due to equipment malfunction or lack of onsite management. Likewise, Freedom of Information requests made by the Wilderness Committee revealed that the Akolkolex River near Revelstoke dried out below the intake for a period of three days in 2005, and had further problems that continued until 2006.[112] Other incidents are likely to have occurred without public knowledge. Incidents like these demonstrate that while good planning and infrastructure may be in place, short-lived, unforeseen events can cause devastating fish kills and damage to fish habitat.

Environmentally devastating incidents can also happen at storage hydropower projects. In spring 2011, a failure in the second of two turbines at a TransAlta hydroelectric facility near Canmore, Alberta (the first was undergoing scheduled maintenance) was followed by unusually large rainfall and snowmelt events.[113] Pent-up water led to flows that were about 50 times normal volumes, likely causing the extermination of westslope cutthroat trout residing in the Spray River.[114] Sediment released during this event may also have affected bull trout in the Bow River, more than 40 km downstream. Likewise, an unexpected sediment release from the lake-storage river diversion at Tyson Creek near Sechelt affected the Tzoonie River in 2010, only months after resuming operations following a previous shutdown. In this case, unbeknownst to operators, a large sediment deposit was mobilized when the lake level was drawn down by 10 meters, releasing a large plume of fine sediment into Tyson Creek, the salmon-bearing Tzoonie River and Narrows Inlet.[115] This event was noticed by members of the public after the sediment plume had already reached the Tzoonie River estuary and Narrows Inlet.

invertebrates below dams.[116,117,118] River diversion proponents in BC usually collect benthic invertebrate data prior to project construction as part of their environmental assessment. These projects have not yet produced conclusive monitoring results so it is not yet known whether this type of monitoring will further our understanding of river diversion impacts on the food web.

Downstream impacts

River ecosystems are complex, and river diversions cause problems even downstream of where diverted water is returned to the river. To date, downstream effects have received little attention (other than the effects of flow fluctuations due to "ramping," which are increasingly acknowledged as problematic). This lack of attention is not surprising, considering it would take a significant amount of research to properly understand the issue. Locally relevant research is not available, in part because river diversion projects are only recently becoming common. However, a great deal is known about the ecological connections between "headwater" streams and the lower gradient river systems that they feed.

Within river ecosystems, downstream communities are dependent – at least in part – on upstream processes.[119] Water from smaller streams provides a continual source of essential food and nutrients that support life downstream. These include dissolved nutrients,[120] organic matter (i.e., from plants), as well as drifting aquatic and terrestrial insects.[121,122] The elements that shape streams – large woody debris and sediment – are also partly provided by upstream reaches.[123,124,125] A river diversion can interrupt the supply of sediment and large woody debris. It can also release large amounts of sediment into fish-bearing waters when alpine lakes are used for storage, as happened at Tyson Creek in 2010.[126] In the diversion reach, low flows can affect the nutrients and food matter delivered downstream. For instance, the production of aquatic insects (benthic invertebrates) in the diversion reach will likely be reduced due to a reduction in available habitat. Fewer insects together with seriously reduced flows will reduce the "drift" of insects that would typically be available to downstream fish populations.

Changes to temperature in the diversion reach may also be seen downstream. Downstream temperature changes may result from cold upstream waters being discharged from the penstocks. In Norway, river diversions connected to alpine reservoirs have caused dramatically lower temperatures in at least some downstream waters, causing fish to grow more slowly and have higher mortality. This has led to decreased production of adult salmon and trout.[127]

Concerns about downstream effects are amplified when multiple adjacent tributaries of the same river are diverted. The effects of multiple diversions on river ecosystems may well be greater than the sum of the individual impacts.[128] This is a major issue given the many constructed, approved, and proposed diversion projects clustered within single BC watersheds.

An instream flow release guidance document developed for BC's provincial government has this to say: *"At present, existing data are not sufficient to know with reasonable certainty where the bulk of biological productivity originates in different systems, the extent to which productivity at different sites is interdependent, and what effects hydrologic changes have on that productivity."*[129] In other words, not enough is known about the connections between upstream and downstream environments, or how changes to flow in one site will affect another. This means that it is difficult to predict how reduced flows will affect the aquatic ecosystem downstream of the powerhouse(s).

Effects of project infrastructure and project operations

The environmental impacts of reduced flows are a major focus for regulators and for citizens concerned with preserving river ecosystems. However, the day-to-day operation as well as the design and location of the facilities are equally important.

Daily and hourly fluctuations in flow (peaking and ramping)

Fluctuations in flow due to project operation (called "ramping" and "peaking") can cause fish kills. In fact, flow ramping is one of the biggest sources of environmental damage caused by river diversion projects.

The "ramping rate" is the rate of change in flow through a diversion or a dam. "Peaking" refers to short-term increases in the amount of water diverted, in order to meet power demands or to maximize profits. Flow through the turbines will need to be "ramped up" when peaking is desired, and "ramped down" afterwards. Changes to the amount of water diverted will also happen in response to changing water availability, or because of a shut-down or start-up of the power plant. Flow levels will drop in the diversion reach (i.e., between the intake and the powerhouse) when flows through the penstocks are increased. Conversely, decreasing flows can be a serious problem for the downstream reach (downstream of where flow is restored to the river channel) when flows through the penstocks are decreased or when diverted flows cease altogether. These problems in the downstream reach are due to the differences in travel time between the water flowing in the penstocks (which moves very rapidly), and the slower-moving water flowing down the diversion reach.

Natural floods provide warning signals that allow organisms to anticipate and adjust to changing water levels.[130] However, the unnatural schedules of power production happen too fast for stream life to adapt,[131] causing a "zone of death" along the shallow margins of the stream channel.[132,133] Shallow stream margins are exactly where many insects must emerge to complete life cycles and are also prime rearing habitat for fishes.[134] With flow ramping, fish are stranded here, and their insect prey also experience catastrophic "drift" downstream.[135]

The downstream reach is typically lower gradient habitat where fish stranding and fish kills are more likely. Flow ramping is a serious concern here, as water levels will immediately drop in response to reductions in diverted flow. This issue is one that has not yet been properly addressed in BC.

In addition to the negative effects on stream life, unnatural fluctuations in water levels can also affect water quality, water temperature, and the shape of the channel itself.[136] The consequences of excessive fluctuation in water levels are fewer aquatic species, and shifts in the types and diversity of aquatic species.[137]

Best practices must be developed and implemented in order to avoid serious harms. When diverted flows are decreasing, the ramping rate must be slow to ensure that water levels don't drop too suddenly. The ramping rate must be adapted to the local fish species, the water temperature, season, and time of day, so that fish can react by moving into deeper waters.[138,139,140,141] More independent monitoring is also required to ensure that river diversions are not causing excessive harm as part of their daily operations.

Water use planning

BC Hydro was instructed to undertake water use planning in 1998, to be more responsive to the needs of aquatic life and other non-power uses of dammed waterways and watersheds. According to consultants working on the plans, this was arguably the largest public planning trade-off process in the province's history, and the planning has won numerous sustainability and community-based planning awards.[142]

Water Use Plans cover most of BC Hydro's facilities, and these plans balance the need to produce electricity with other competing uses, such as the need to provide seasonally appropriate flows to the fish populations downstream, as well as recreation, domestic water supply, wildlife and heritage uses.[143] Improved flows will not fully restore these dammed rivers, but many of the remaining fish populations are healthier as a result.[144] Monitoring and adaptive management are ongoing and will result in future management decisions about optimal flow regimes.[145]

BC Hydro had the mandate, the expertise, and the capacity to engage with the public in exercises such as water use planning. Sadly, this progressive planning process is not available with the dozens of private operators now providing BC's new electricity supply. Watershed Watch does not normally focus on the relative merits of public vs. private ownership of hydroelectric infrastructure. However, in this instance, public ownership has provided clear benefits with respect to public accountability and managing for multiple resource uses.

Roger Tabor USFWS

Juvenile rainbow trout

Direct harm to fish through entrainment

Projects must be designed so that fish and other aquatic organisms are not pulled against a penstock's intake screen, or pulled into the penstock itself, thus drawing them into the turbines. This is particularly the case where small fish such as juvenile trout and salmon are present, and especially when juvenile salmon are migrating out to sea. Good intake design will ensure that juvenile fish can avoid being pulled into harm's way. This will generally be the case for newer river diversion projects.

Migration barriers

The low dam built to create the "head pond" is often a barrier for fish, depending on its height and on flow levels. In many cases the dam will divide the local population in two.[146] Long-term negative impacts – like declining populations and loss of genetic diversity – can result from the lack of connection and migration between upstream and downstream areas. Studies in other jurisdictions have proven this to be the case. For example, population decline of bull trout has been seen in Montana above a dam after loss of connectivity with downstream populations,[147] and westslope cutthroat trout above migration barriers have lower genetic diversity than downstream populations.[148] It is well known that habitat fragmentation results in smaller animal populations with lower genetic diversity, decreasing their prospects for long-term survival.[149]

Habitat conversion

The head pond can convert high-value riffle habitat into lower-value pond habitat. Also, the presence of the dam, tailrace, powerhouse, and roads means that valuable riparian vegetation, often including old-growth forests, has been permanently lost. While old-growth forest management areas are protected from logging, these areas are not off limits to river diversion projects.

Terrestrial impacts of river diversion

In a nutshell: River diversion impacts on terrestrial ecosystems

River diversion projects put permanent industrial infrastructure into remote areas, removing some areas of wildlife habitat permanently and diminishing the quality of remaining habitat. Roads and transmission lines have significant impacts on terrestrial ecosystems, and their effects on wildlife can be profound.[150] Roads and transmission lines fragment habitat, create barriers for some species, change species' behaviour, and directly kill some animals through collisions with vehicles or power lines. Unpaved roads can be a major source of sediment to nearby streams, and cause landslides when not properly maintained. Roads and construction projects also bring people – including hunters – into formerly inaccessible areas, causing disturbance and wildlife-human conflicts. Invasive plant species are easily spread by project construction and through the use of roads.

The diversion dam, head pond/reservoir and powerhouse cause additional habitat losses in biologically valuable streamside areas. These important habitats are affected by vegetation clearing and by reduced flows in the diversion reach.

Marbled murrelet, grizzly bear and mountain goat are some of the terrestrial species most affected by river diversions, and there are many more plant and animal species – including species at risk – that are likely to be affected and that should be considered in project plans. Little information is available about many of the species and habitats that will be affected by river diversion projects in BC. This lack of data can make it very difficult and expensive to understand and address the potential terrestrial impacts in a timely fashion. In some instances development impacts simply cannot be mitigated, and the wisest approach would be to leave an area undeveloped. Strategic planning is the best way to manage the unavoidable impacts of electricity generation in BC.

Charlie Nott

Grizzly bear fishing for salmon

Wildlife trees

Worker safety regulations require that dangerous trees be addressed when there is a risk of injury to workers. In practice, this usually means that dead, dying or diseased trees are cut down when they are near work sites, including power lines and roads.[151] Many of these lost trees have high wildlife value, particularly when they are old and large in diameter. Large trees with heart rot (hollow trees) are particularly important for species that use tree cavities, such as bats, birds, and bears.[152] The removal of all wildlife trees in and around a project's footprint is a loss that is difficult to compensate for. Guidance is available on how to safely retain wildlife trees.[153] However, the only recent audit of a river diversion project showed that commitments to leave wildlife trees were not achieved, due to worker safety concerns.[154]

Tanis Gower

wildlife tree

For some hydro developments, disruption and damage to forests, wildlife and plant communities can exceed the harm done to aquatic life. For instance, large dam projects flood entire valley bottoms, which are among the most endangered landscapes on earth.[155] River diversion projects can also have major impacts to forests and wildlife, due to the extensive "footprint" of the hydropower infrastructure, including the access roads and transmission lines that connect the site to population centres. Many projects are made up of two or more linked diversions. With other existing or proposed projects nearby, this means that cumulative impacts can be severe.

Permanent infrastructure

River diversion projects consist of a low dam and a pipeline (penstock) to bring water to a powerhouse at lower elevation. The powerhouse can be several kilometers away, requiring extensive construction to install the connecting penstock, which can be above ground, buried, or tunneled through bedrock. The powerhouse is connected to a power substation and to a "tailrace" channel to convey water back to the stream.

Most BC river diversion projects will need long roads and power lines to connect them to the towns, cities, and remote industrial sites (e.g. mines) where the electricity is used. Unlike forestry roads, which are often deactivated after logging is finished, hydropower access roads need to remain open and be maintained indefinitely. The permanent infrastructure associated with hydropower projects will change the character and habitat value of the surrounding area.

Habitat loss through permanent vegetation clearing

All hydropower projects require vegetation clearing for project infrastructure and for roads and transmission lines. Vegetation clearing disturbs and fragments ecosystems and harms the species that live there.[156,157] For common ecosystems and species, this may not be cause for alarm. However, for rarer ecosystems or

Species at risk


Grizzly bear

BC has high biodiversity and contains a number of North America's biodiversity hotspots.[158] BC supports tens of thousands of known plant and animal species including countless insects (more than 35,000 species identified) and other invertebrate species, many of which remain undiscovered or unstudied. Many of BC's species are considered "at risk" of becoming rarer, endangered or extinct. In fact, BC has more species at risk than any other province in Canada.[159] The risk that a species might be lost can increase when species are found only in a small area; when species are particularly sensitive to human use; when species reproduce slowly; or when species have been subject to large habitat loss.[160] The disruption caused by climate change is also a critical issue that may contribute to the loss of species at risk.

Species at risk are not well protected in BC, and the way they are managed can be confusing to project proponents and to the public. The high species diversity in BC makes it difficult to build a project that identifies and avoids significant impacts to species at risk. Inventory and research are critical,[161] since many locations of rare and endangered species have not been studied. The huge species diversity and the lack of existing inventories mean that project proponents cannot be expected to find every species that occurs in a project area. Nonetheless, a lack of information is not an excuse to assume that species at risk are not present or that the impacts of a project can be mitigated. Unfortunately, even if rare species are known to be in the path of development they can still be legally harmed, as legal protection for BC's species at risk is not particularly effective.

Requirements for assessments and inventories of at-risk species are less stringent for hydroelectric projects with a capacity of less than 50 mega-watts (MW). Even the larger projects (> 50 MW) subject to a formal environmental assessment have included unenforceable commitments to protect species at risk.[162] More care is required to ensure that species at risk are accurately identified and protected.

for ecosystems that support sensitive species, changes to even small sites may be devastating.[163] Some species and communities highlighted in *Tamed Rivers*, such as grizzly bear, marbled murrelet and rare plant communities, may be particularly affected by river diversions or other remote energy projects. Populations of species at risk are particularly vulnerable to changes to habitats, especially those species that have already been victims of large habitat loss.

Vegetation will need to be cleared along the stream bank (part of the "riparian zone") to allow for some of the necessary infrastructure. Riparian vegetation is essential not only for the health of the stream ecosystem, but also for many terrestrial wildlife species. Riparian areas frequently contain the highest number of plant and animal species found in forests, and provide critical habitats, home ranges, and travel corridors for wildlife. Biologically diverse, these areas maintain ecological linkages throughout the forest landscape, connecting hillsides to streams and upper headwaters to lower valley bottoms. There are no other landscape features within the natural forest that provide the natural linkages of riparian areas.[164] Vegetation clearing in riparian areas will affect many species, and project plans should always minimize the amount of riparian vegetation to be cleared.

Healthy ecosystems require predators

Predators are a crucial part of healthy ecosystems, because they have major influences on many other species.[165,166,167,168,169] Despite British Columbia's generally healthy predator populations, the province faces significant challenges in sustaining them.[170] Large predators survive in BC mostly because the province contains large, relatively inaccessible wilderness areas.[171] Elsewhere, populations of grey wolves, grizzly bears, black bears and cougars have been eliminated or greatly reduced. Since 1840, wolf populations in North America have declined by 40%,[172] and grizzlies by 98% (50% in BC).[173] As the province develops new land uses, it is important to consider the risk to large predators. Losing any of the remaining predator populations could affect genetic diversity, making the species less resilient to impacts like climate change.[174]

Grey wolf

Studies to understand large predators are expensive and require years to complete, so quality baseline (pre-project) information about local populations is not usually available. This means that projects will usually be approved without extensive study on impacts to predators, leaving many questions unanswered. A common approach is to proceed with assurances that problems will be identified and fixed as required. This assumes that post-project monitoring can detect problems, which is not necessarily true without knowledge about pre-project conditions. In many cases, problems could only be fixed by removing the project itself, something that is very unlikely. A more cautious approach is warranted. In some cases this will mean better pre- and post-project monitoring and adaptive management, whereas in others it will mean accepting that the cost of development is simply too high.

The impacts of roads and transmission lines

Roads and transmission lines connect dam and diversion sites to population centres. For remote river diversion projects, these "linear disturbances" can form the greatest part of the project's footprint. Roads have serious, well-documented impacts[175,176] that include habitat fragmentation, habitat loss, barriers to movement and migration, wildlife-vehicle collisions, changes to habitat use, and changes to the way that predators interact with their prey. Increased hunting pressure, increased human-wildlife conflicts, erosion and drainage problems, and landslides are also common outcomes.

Transmission lines and other linear corridors have most of the same impacts as roads, because vegetation is cleared and managed differently, creating a new habitat type. These habitat changes benefit some species at the expense of others. The impacts particular to transmission lines are electrocution, and collisions of birds and bats with the power lines.[177,178] Some species, like the marbled murrelet – a threatened sea bird that nests on large, mossy tree limbs – are particularly prone to injury and death due to collisions with power lines.

Habitat fragmentation from roads and transmission lines

Primary forces like wind, fire, and insect infestations are the natural disturbances that define ecosystems in different areas of the province. These disturbances influence the size, shape, age and distribution of different ecosystem types like old-growth forests or grasslands.[179] The species that live in these ecosystems are adapted to the typical patterns, or "patch sizes" found on the landscape because of natural disturbance. For example, many coastal wildlife species are dependent on large, continuous patches of older forest, which exist on the coast where fire and windstorms are relatively rare. Roads and other corridors cut these patches into smaller, disconnected fragments. For some species – such as grizzly bear, mountain caribou, northern goshawk and wolf – survival and reproduction are adversely affected when habitat is fragmented.[180,181,182]

Forest Practices Board

Transmission line near Freda Lake in the Sunshine Coast

The presence of roads and other corridors can also change the behaviour of different species. For instance, wolves have been shown to use the corridors created by power lines and logging roads to improve their hunting success, although they also appear to avoid areas with moderate or high road densities.[183,184,185,186]

Using roads

Roads bring people to nature, and this leads to conflict with wildlife. For example, roads give hunters access to species like deer and moose. Bringing people into wilderness areas can also cause the death of species like grizzly bear and wolves, due to conflicts with people.[187,188] Some animals can also be attracted to salt, seeded grass, and changes to vegetation cover next to roads, increasing their visibility to hunters and predators and making vehicle collisions more likely.[189]

Damien Gillis

Road building and blasting for the Tipella Creek river diversion near Harrison Lake

Some animals change their behaviour around roads, even if traffic volume is low.[190,191,192,193] Controlling the numbers of people allowed to use the road can be effective in reducing road impacts to grizzly bears,[194] and could mitigate impacts for other species too. Road access can be controlled using gates, signs, legal road closures, road deactivation, and other barriers, but there are few regulations that support road closures in British Columbia, especially when a history of public road use develops.[195] Road closures are rarely popular with the public and are largely unenforceable.

Wildlife death rates on roads are determined by the speed and frequency of vehicles and the proximity of habitat cover and wildlife movement corridors.[196] Wildlife species commonly killed by vehicles include snakes,[197] amphibians,[198] and ungulates such as deer and moose.[199] The density of some species like amphibians and small mammals has been shown to decline when roads increase.[200] The problems caused by roads can be addressed for some species, whereas other species remain vulnerable. For example, where roads cross traditional migration paths for frogs or toads, attempts to divert these animals have not been very successful.[201]

Ungulates need special management

Ungulates are hoofed animals; the ungulates native to BC include deer, moose, elk, caribou, mountain goat, mountain sheep, and bison. Most are managed to provide hunting opportunities,[202] and mountain caribou – a sub-species of caribou that live in BC's interior – receive special management because they are a species at risk.[203] Even relatively common ungulate species like elk and moose are sensitive to habitat changes and to roads that make them more visible to hunters. Moose have been found to avoid rural road networks even when these roads are not frequently used.[204] Similarly, elk and mule deer are known to avoid feeding sites near roads, even in seasons when hunting is not permitted.[205,206] Collisions with vehicles are also a concern. Where new river diversion projects are planned, roads can be designed to reduce the likelihood of vehicle collisions with ungulates and other wildlife.

Roosevelt elk

Ungulate winter habitats should also be located and protected from development. Ungulate winter habitat – referred to as "winter range" – consists of forested locations with special attributes that allow the animals to feed and survive over the winter when food is scarce and many ungulates die of starvation.[207,208,209,210]

Mountain goats are particularly sensitive to disturbance associated with blasting, road use, and helicopters. Avoiding spring disturbance during kidding season is important.[211,212] Like large predators, ungulates are difficult and expensive to study, but each population has specific land use patterns that may be affected by proposed projects. Gathering this baseline information is critical to ensuring that project impacts can be minimized.

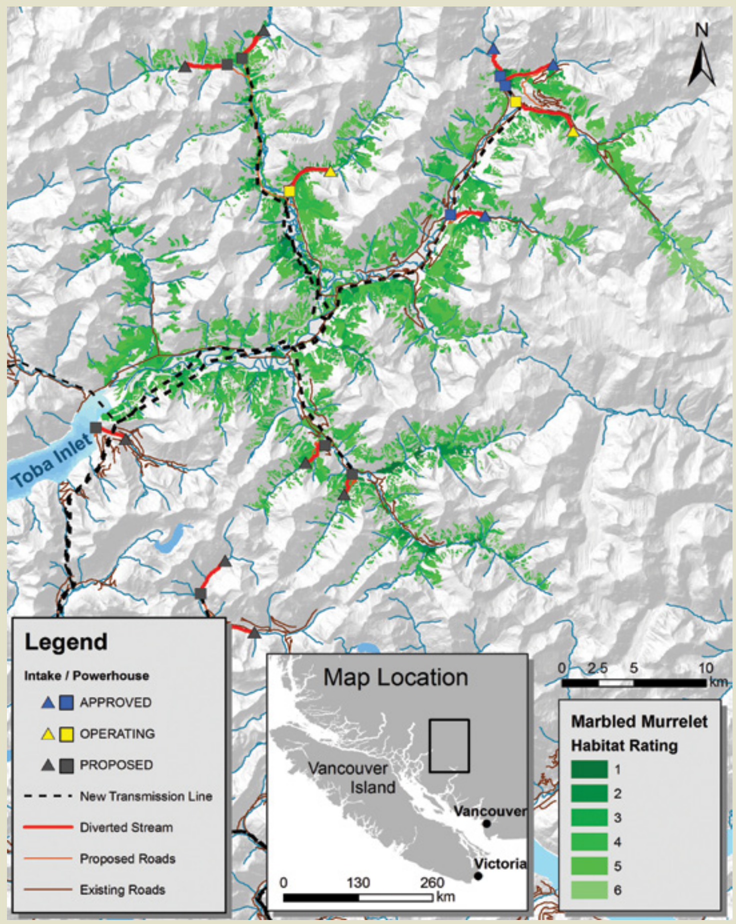
Likely impacts of proposed transmission lines on marbled murrelets nesting on the South Coast of British Columbia

– by Dr. Alan Burger[213]

Alan Burger

Marbled murrelet

Hydroelectric power projects pose a significant threat to the marbled murrelet, a threatened species in Canada which is also covered by the federal *Species at Risk Act* and is provincially "blue-listed." Marbled murrelets are dependent on old-growth forest for nesting, and on BC's southern mainland these seabirds have been severely impacted by habitat loss due to forestry and urbanization. South coast watersheds staked for hydropower development – such as Bute Inlet – are known to support some of the highest concentrations of nesting marbled murrelets on the southern mainland. Loss of nesting habitat through logging of old-growth forests is the primary threat to the marbled murrelet across its range. The many proposed power projects on the south coast pose three new levels of threat to this species. First, the roads, power-line corridors and construction camps remove large swaths of important and irreplaceable nesting habitat. Second, the fragmentation of the forest increases the risk of nest predation by crows, ravens and jays which are known to be important nest predators along forest edges. Third and most alarming is the risk of murrelet collisions with powerlines. Murrelets fly fast and awkwardly during twilight hours when coastal forests are often dark and misty. For these reasons the risks of fatal collisions with power lines are high. There is no known way to mitigate the risk of murrelet collisions with power lines, nor can forest fragmentation and removal be reversed, at least not while the power project is operating. Environment Canada and the Province have not implemented the recommendations of the Marbled Murrelet Recovery Team on this issue.



Proposed transmission and existing transmission lines in marbled murrelet habitat

Erosion and roads

Roads built to access river diversions are usually unpaved and need to cross steep and rugged terrain. If not carefully managed, runoff from these roads can cause soil erosion and deliver sediment into streams.[214] Landslides are another risk. Until recently, unpaved roads built in most of BC's valleys were for forestry purposes only, and had to be built to high standards to avoid typical problems with runoff. These standards are not required for hydropower projects. Even so, proponents may promise to meet these standards. In the only public audit of a river diversion project, the roadwork generally met forestry standards, with the exception of spur roads to access transmission towers. These roads were eroding in many locations and at least one landslide was noted.[215]

Spreading invasive species

Roads create disturbances that allow invasive plants to grow, and vehicles travelling these roads then inadvertently help to move the plant from place to place.[216] A small, new infestation can be the beginning of a costly future problem with implications for the health of local ecosystems and species.[217] At one multi-site river diversion project, investigators noted opportunities for more prompt re-vegetation of disturbed areas and recommended ongoing monitoring to reduce the risk of both soil erosion and the spread of invasive plants.[218]

During construction

The construction phase lasts a few years and human presence and disturbance can be intense. There may be soil erosion, landslides, and accidental spills. There will be chainsaws used to clear vegetation, large machines used to build or improve roads, and rock blasting for roads or penstocks, leaving behind large "spoil sites." Major construction activity is required for the dam, penstocks and powerhouse and the noise associated with this activity can be very disruptive to mountain goats and other wildlife species.[219]

Many people will be on site, and in some cases they will be housed in large field camps. The behaviour of wildlife can be altered around people[220] with some species becoming displaced and others being attracted to garbage. For example, bears that develop a history of scavenging garbage risk being killed because they become a real or perceived danger to humans.[221,222,223]

Ongoing uncertainty and risk

Environmental impact assessments identify some of the above impacts and propose measures to reduce them. However, the impact of river diversion projects cannot be fully addressed for some species like grizzly bear, marbled murrelet, and rare plants. Little information is available about many of the species and habitats that will be affected by river diversion projects in BC. As a result, projects will proceed based on many assumptions, and problems won't be discovered until after the fact, assuming that project monitoring is effective. Project proponents promise research, adaptive management, and to make new efforts to reduce impacts if problems are discovered. By this point however, the only remedy might be to remove the roads, power lines and other infrastructure that are the cause of the problems. BC's interests would be better served by adopting the precautionary principle and by undertaking strategic planning to minimize the impacts per mega-watt-hour of electricity generated.

Climate change considerations

According to the provincial government,[224] British Columbians will see the following consequences of climate change within this century:

- Average annual temperature may increase by 1°C to 4°C;
- Average annual precipitation may increase by 10 to 20 percent;
- Sea level may rise by up to 88 centimetres along parts of the BC coast;
- Many small glaciers in southern BC may disappear;
- Some interior rivers may dry up during the summer and early fall;
- Salmon migration patterns and spawning success are likely to change; and,
- The mountain pine beetle — a pest that kills vast tracts of trees — may expand its already massive range.

These and other predicted effects of climate change will likely exacerbate the local impacts of river diversions. Conversely, climate change may affect river diversions, too: water will likely be less available during some times of the year, which may make river diversions less financially attractive. These water shortages also increase the potential for conflict between power needs and the needs of instream life.

Climate change impacts to BC's rivers and streams

Climate change is putting stress on many species and ecosystems. Rapid shifts in the geographic ranges of some species are already occurring[225] and these shifts will continue. In the Rocky Mountains, for example, cutthroat trout have been displaced by non-native brook trout and brown trout, which can withstand warmer temperatures.[226]

More and more, salmon and trout are under threat from low flows and increased temperatures during the summer months. These conditions can be very stressful – or lethal – for fish.

The Fraser River is BC's largest salmon-bearing watershed, and its average summertime water temperatures have warmed by approximately 2.0°C over the past 60 years.[227] Over the past 20 years, BC's iconic Fraser River sockeye salmon have been suffering from unfavourable temperatures in their marine and their freshwater environments. This poses major challenges to their survival at almost all life stages. Forecasts are for reduced survival and lower productivity if the climate continues to warm.[228] Other salmon species and other salmon rivers will be affected by climate change to varying degrees depending on their location.

Damien Gillis

Shrinking glaciers, reduced snowpacks and warmer summers are already stressing many salmon runs, and this trend is expected to worsen as the climate continues to warm

Such climate-related stress is made much worse by excessive water withdrawal for agricultural, industrial and domestic demands.[229] River water warms up more quickly whenever flows are depleted by human uses. In many streams, salmon and trout survive through the summer through cooling inputs of groundwater,[230] but in addition to being depleted by human uses, groundwater is expected to warm due to increases in average air temperatures.[231] As a result, the southern range of salmon and trout will likely shrink, while expanding further north and to higher altitudes.[232]

A reduced snowpack, earlier melting and reduced glacial melt will result in extended low flows in the summer.[233,234,235] Indeed this is already happening.[236,237] Summer low-flow periods are growing longer[238,239] due to warmer temperatures, glacial retreat and changes to the timing and size of spring floods.[240,241] Conversely, winter flows are predicted to increase for many BC rivers[242] due to changes in precipitation patterns caused by global warming: more rain will fall in winter and flow into the stream instead of being captured as snow. These changes may cause increased flooding which can harm spawning grounds,[243] reducing the egg-to-fry survival rates.[244]

During the early phases of glacier shrinkage, extra melt water is available, followed in later years by reductions in flow.[245,246] In most of BC, it appears that the initial phase of increased melt has already passed, and future reductions in summer stream flow are almost certain.[247,248]

It is difficult to predict exactly what climate change will mean in the long term for BC's fish, but one study forecasts that increased temperatures and increased winter flooding will bring about a massive (47%) reduction in habitat for resident trout by 2080.[249] As salmon habitat overlaps with trout habitat, salmon would be affected too.

A full cost accounting of greenhouse gases

Climate change is one of the most pressing issues of our time. It is exceptionally important to use clean energy, in order to reduce and avoid dangerous changes to our planetary life support systems.

Project proponents state that river diversion power projects produce zero greenhouse gas emissions over very long project lives. While it's true that greenhouse gases are not released when water is run through a turbine, this statement doesn't count the fossil fuels that are used to construct and maintain the facilities, and to eventually decommission them.[250]

Actual greenhouse gas emissions from river diversion projects[251,252,253] vary, and can be greater than emissions from Canada's large hydropower dams.[254] Life-cycle emissions depend on local factors, so some projects can have greater impacts than others.[255] For a mid-sized diversion such as that on Ashlu Creek (49 MW), the life cycle emissions would average out to over 2,500 tonnes of carbon annually (roughly equal to the emissions of 500 cars), a far cry from zero.[256] Using the same calculations, the combined lifetime emissions of all river diversion projects now operating in BC will roughly equal those of about 8,750 cars.[257]

Smaller projects will generally produce more emissions for every unit of energy they generate, as the relative inputs for construction and maintenance will be higher.[258] On average, project construction and construction materials account for about 60-70% of greenhouse gas emissions. Part of this is due to the use of concrete for dams, intakes, and powerhouses. Concrete manufacturing is the third largest source of greenhouse gases worldwide.[259]

Carbon dioxide is permanently released when vegetation is cleared for roads, transmission lines, and the project site.[260] This issue can be especially significant when long roads are built – heavy equipment is required, many trees are removed, and fossil fuels are used for road maintenance. The kinds of forested ecosystems where most river diversion projects are proposed store 300 – 500 tonnes of carbon per hectare (about 100 tonnes of which is in vegetation),[261] and these ecosystems are net carbon sinks. This means that they are capturing additional carbon every year. In fact, every hectare of forest captures about three tonnes of carbon per year, equal to about 60% of the emissions of the average car.[262] Therefore, the carbon consequences of removing forests for roads and other project infrastructure should be weighed against the climate benefits of proposed hydropower projects.

Methane emissions are a serious issue usually associated with the flooding of reservoirs for large hydro dams.[263] Methane is a potent greenhouse gas, with effects far worse than carbon dioxide. River diversion projects can also produce significant methane, depending on site conditions.[264]

Full cost accounting should be applied to river diversion projects so that the greenhouse gas implications are more thoroughly understood. It is also important to look beyond the individual project footprints to what any new "clean" electricity will be used for. For example, the BC government has a goal of supplying three new liquefied natural gas plants with clean energy, including that supplied by private power projects and the proposed Site C dam.[265,266] While it would be nearly impossible to supply the massive power requirements of three LNG plants with new hydroelectricity, it is still important to account for the environmental costs of developing new river diversion projects for this purpose.

Adding to the impacts of river diversions

For waterways already affected by river diversions, climate change-related shifts in temperature and flow might act cumulatively or synergistically with the stressors caused by the project. In the diversion reaches of hydro projects, extended low flows and increases in temperature will further reduce habitat quality and habitat quantity. Moreover, the inherent conflict between water for instream flows and water for power production will be exacerbated during the extended low flow times of year. Studies on hydropower and climate change in the U.S. Pacific Northwest – a landscape similar to British Columbia – have predicted increased future conflict between power production and instream flow requirements.[267,268] This could have significant implications for river diversion projects in BC. In fact, without water stored in glaciers, bigger storage dams may be more appropriate than river diversions for our future climate.[269]


Aaron Hill

Up in smoke? One of hundreds of piles of trees along the right-of-way being cleared for the new Northwest Transmission Line. These piles will likely be burned on the spot in open fires, rather than being used to produce lumber, paper, or "biomass" energy for human use. Full cost accounting of greenhouse gases for renewable energy projects could allow a better understanding of the consequences and necessity of burning large amounts of usable wood.

Species in terrestrial environments such as forests and alpine meadows are also massively affected by climate change, and reducing other stressors will help these species survive into the future. Moving northward (or to a higher elevation) is an important adaptation strategy for species at the edge of their temperature range, though many species can't migrate very fast. Therefore, intact natural ecosystems are essential to support native species through climate stresses, and for providing migration corridors to allow plants and animals to make a gradual north-ward shift.[270,271] Like other roads and transmission lines, those constructed for river diversion projects cause ecosystem fragmentation. They will deplete the health of some plant and animal populations, and affect the migration corridors important for long-term species survival. Good planning is of the utmost importance to minimize these risks.

Of course, factors besides climate change and hydropower development are affecting BC's aquatic and terrestrial ecosystems. Watershed Watch is devoting attention to climate change in this document because human-caused climate change and excessive consumption of greenhouse gas-producing fossil fuels are often (and justifiably) invoked in arguments for increased renewable energy development in BC. While increased renewable energy development is imperative, it's still important to take a big-picture approach in deciding how and where to construct renewable energy developments, to ensure that the environmental benefits will outweigh the costs.

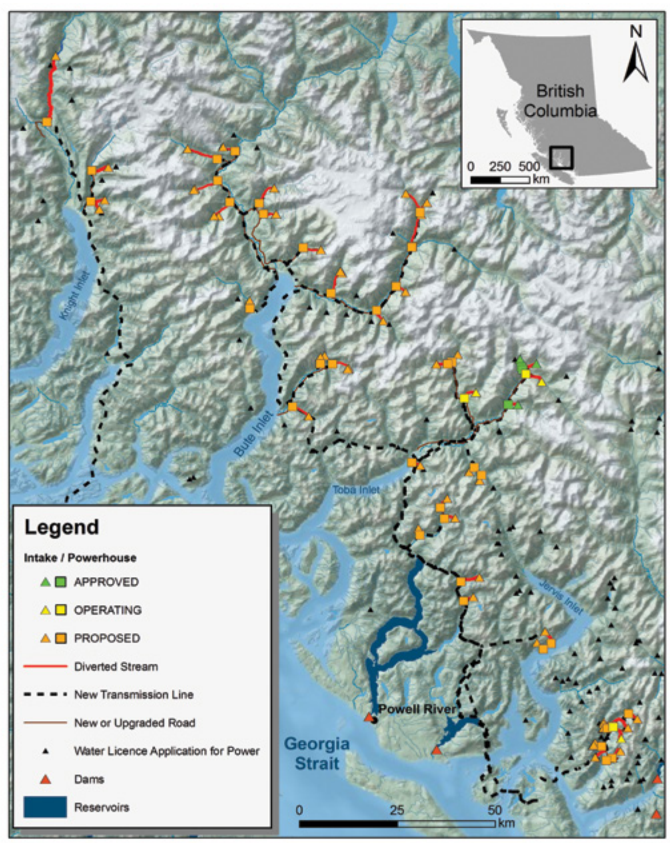
Assessing the cumulative impacts of river diversions and other land uses

The terms “cumulative impacts” and “cumulative effects” refer to the accumulation of human impacts over time, from all sources. Simply put, it is necessary to understand and minimize cumulative environmental impacts in order to prevent “death by a thousand cuts.”

All places on Earth experience some degree of human impact. Even in remote areas without human presence, climate change is affecting the distribution and life cycles of many species. British Columbia is blessed with extensive “wilderness” areas where ecosystems are relatively intact. Even so, most of these areas are within the forestry land base, and have changed considerably from their pre-European-contact state. Even areas within parks are affected by human influences such as fire suppression.

All places on Earth experience some degree of human impact

The local environmental impacts of individual river diversion projects will be lower than the impacts of traditional hydropower dams, so river diversions can appear relatively benign. However, this comparison does not account for the sum of impacts from neighbouring hydro projects and other past and likely future impacts from other land and water uses such as forestry, mining, agriculture, and



Existing and proposed BC south coast hydropower infrastructure urbanization. Nor does this one-off approach consider the relative impact per mega-watt of electricity produced or whether the project will serve as a gateway to other development by providing key pieces of infrastructure such as roads and transmission lines.

In BC, cumulative effects are considered in the environmental assessment of a hydropower development only if the project has the potential to generate at least 50 mega-watts of electricity.[272] For these projects, the proponent usually provides information about other potential developments and existing developments, and hypothesizes regarding their combined effects. In practice, this procedure is inadequate for at least three reasons: i) business competitors do not generally share their development plans or information on project effects with each other, so even if a company truly wishes to gather all relevant information, it is not likely to be available, ii) neighbouring hydropower developments are excluded from the analysis if there is any uncertainty about their completion, even if they would be enabled by the current project's infrastructure, and iii) above all, a cumulative effects analysis done as part of the approval process for an individual project addresses the wrong perspective in time and space. This problem of scale has been amply illustrated with river diversion developments in BC but is also true for many other types of development.

> In our view, cumulative effects are the only real effects worth assessing in most environmental impact assessments.... In the long run, what we really need is a shift in the focus of cumulative effects assessment from project assessment to a regional assessment context
>
> –Duinker and Greig 2006[273]

Working at the wrong scale

In practice, the cumulative effects assessments done for individual projects almost always decide that cumulative impacts will not be a problem. This outcome has more to do with the narrow scope of investigation than with the actual likelihood of cumulative impacts.[274] In fact there is extensive documentation[275] of how cumulative effects assessment is ineffective when applied to individual projects – and speculation that these assessments may even do more harm than good by giving the impression that cumulative effects are in fact being addressed.[276] The broad consensus is that the project-level scale of analysis simply cannot address environmental impacts over large enough areas and long enough time scales. Applying cumulative effects assessment to a single project cannot properly account for the regional context.

The use of the wrong scale in time and space is a problem that is structurally embedded in Canadian law and policy frameworks for cumulative effects assessment. This same problem also exists in other jurisdictions around the world. As a result, environmental impact assessments usually fail to predict "significant residual cumulative effects," even though there is ample evidence of profound cumulative impacts occurring over time.[278]

> Cumulative effects of natural resource development [in BC] remain largely unknown and unmanaged....The [Forest Practices] Board believes that progress can be made if cumulative effects assessment methods are appropriately embedded in a land management framework that is designed to meet the objectives society has for values on the land.
>
> -Forest Practices Board 2011[277]

Cumulative effects assessment for the East Toba-Montrose run-of-river project

The East Toba-Montrose project (a project with two linked river diversions in the Toba Valley) is a prime example of the problems with the current approach to cumulative effects assessment. Firstly, the assessment used present-day conditions as the baseline for measuring cumulative impacts, despite federal policy guidance which defines cumulative effects as: "changes to the environment that are caused by an action in combination with other past, present and future human actions."[279] The timeframe chosen for analysis was only 10 years into the future, even though hydro projects are planned to be operational for 40 to 100 years.[280]

Secondly, future run-of-river projects were not considered, even though they would depend on the transmission line developed for this project, and even though the project proponent had expressed interest in developing at least 20 nearby rivers. The Environmental Assessment mentions two of the same company's proposed projects in neighbouring valleys that, if developed, would use the same transmission line. These projects were at the conceptual phase and so were considered to be out of scope. Surprisingly, the Environmental Assessment did not mention the then-proposed (now approved) Upper Toba project, which consisted of three nearby river diversions to be tied in to the Toba-Montrose infrastructure. The Upper Toba project was submitted to the Environmental Assessment Office just three months after the East Toba-Montrose project was approved, and was touted for its lower environmental impact due to reliance on the infrastructure for the East Toba-Montrose project.

The East Toba-Montrose assessment also does not account for any residual effects that are individually inconsequential, but may be cumulatively significant. This is in direct opposition to what the Practitioners Guide[281] describes as, "a fundamental principle in the understanding of cumulative effects."

While the East Toba-Montrose cumulative effects assessment could be improved within the existing framework, it also highlights how cumulative effects assessment done for individual projects takes the wrong perspective by not addressing the appropriate scale in time or space.

Damien Gillis

Many river diversion projects are proposed in areas affected by logging and other land uses. Cumulative effects assessments should address the past, present and future land uses in the area to ensure that human actions don't destroy valued ecosystem components

Tipping points and limits to development

All species have minimum requirements for survival. For example, animals need adequate food, cover and water, and must be able to produce offspring and avoid predators. Likewise, for ecosystems to maintain their structure and function, their component parts must remain sufficiently intact. When species no longer have all of their minimum requirements, or when the defining elements of an ecosystem become sufficiently degraded, they reach a "tipping point" or "threshold." When this happens to a species, it may become extirpated (locally extinct), and when it happens to an entire ecosystem, it often shifts to a degraded, undesirable state that is difficult or impossible to recover from. Such shifts can have profound social and economic consequences. Identifying these tipping points and not going past them should be the goal of any cumulative effects assessment.

Flathead Lake Biological Station

How do we ensure that an ecosystem or species isn't pushed past its tipping point? Usually the limit is discovered when it's too late, and when it is difficult and costly – or impossible – to turn back. Instead, we need to determine which species and ecosystem components we most value and plan ahead to conserve them. This is best done by modeling possible futures and determining whether they might surpass ecological thresholds or societal limits. For example, it might be decided to conserve grizzly bear and other species, to maintain views and trails for hiking, to manage forests for sustainable harvest of timber and non-timber forest products, and to conduct forestry and hydropower development in ways that maintain old-growth forest, riparian buffers, and wildlife migration corridors. The effects of different land management choices would be modeled and assessed so that the best course of action could be agreed to. A good assessment automatically incorporates the cumulative effects of past, present and future human activities, such as logging, mining, recreation, urbanization, and hydropower development, and does so at an appropriate geographic scale. Good land use planning will then set limits and use post-development monitoring to make sure that ecological and social values are maintained.

Looking at cumulative effects in BC

The provincial government has begun to investigate "benchmarks" for valued ecosystem components. While benchmarks are potentially less rigorous than "limits" or "thresholds," this project does acknowledge the need to manage cumulative effects. However, the kind of structural change required to truly manage the cumulative effects of hydropower and other land uses remains elusive.

Cumulative effects of the Northwest Transmission Line:
A gateway to mines and river diversions in the "Serengeti of the North"

The recently-approved Northwest Transmission Line (NTL) project provides a perfect example of how cumulative environmental impacts are not being adequately addressed in BC . Billed by the federal and provincial governments as a piece of "green" infrastructure that would negate the use of diesel generators in northern communities,[282] the 287-kilovolt powerline is viewed by many analysts as a gateway to massively increased mining and hydropower development in a region so rich in wildlife it has been described as the "Serengeti of the North ." Indeed, the line stops approximately 100 km short of Iskut, the only sizeable diesel-powered community that could feasibly be reached by a potential future connector line. The settlement of about 350 people would require less than 1% of the powerline's 260 mega-watt (MW) capacity . However, the five most likely contenders out of the region's dozen or so proposed and approved mines[283] would require an estimated total of 234 MW of electricity.[284]

The NTL's true purpose was partially acknowledged in the powerline's environmental assessment, which required a cumulative effects analysis to consider the effects of new and existing mines, as well as the effects of roads, existing human settlements, and forestry activities, in addition to the footprint of the transmission line itself. Only two of the region's 12 or so proposed and approved new mines and only one of the region's 60+ potential hydroelectric projects were included in the analysis, even though most of these potential projects would be enabled by the existence of the powerline. The one hydropower project included was the already-approved Forrest Kerr project on the Iskut River.[285]

The Forrest Kerr project itself provides an excellent example of how cumulative impacts may go unaddressed due to piecemeal environmental assessments that allow proponents to avoid triggering more rigorous screening. Originally proposed for the purpose of powering the nearby Galore Creek mine, the project was to consist of a 100 MW diversion and low-voltage roadside transmission line, and it received a provincial Environmental Assessment certificate in 2003.[286] At the time, conservationists chose not to oppose the project after giving it careful scrutiny and consulting with First Nations. The project design has since been amended five times, nearly doubling the capacity to 195 MW, and now requiring a high-voltage transmission line with separate right-of-way, and a three km diversion tunnel, 10 meters in diameter, whose construction would generate an estimated 850,000 tons of waste rock that was not tested for acid drainage potential. A new provincial assessment was never required, and the 195 MW project was still under the 200 MW threshold for a federal "comprehensive" assessment. Since approval of this increased capacity and the NTL, the proponent (AltaGas) is actively pursuing two additional nearby projects, only one of which (McLymont Creek – 70 MW) is subject to the provincial environmental assessment process. The other new project (Volcano Creek – 18 MW) is below the threshold that would trigger a provincial environmental assessment. A precautionary assessment process would have viewed the three clustered diversions sharing a single transmission line and a single proponent as a single project well above the federal government's 200 MW threshold for "comprehensive" assessment.

In the end, the cumulative effects analysis for the NTL could be viewed as pointless. The Environmental Assessment Office accepted the proponent's conclusion that none of the 15 Valued Ecosystem Components identified in the analysis[287] would be adversely affected by the cumulative impacts of the powerline and multiple mines and hydro projects that it would enable[288] – a conclusion not shared by area residents.[289] The Red Chris mine alone is projected to produce more than 180 million tonnes of tailings and approximately 300 million tonnes of waste rock, requiring 200 years of treatment for acid-rock drainage. Several fish-bearing streams would be dammed and used as storage pits for this toxic waste, along with a trout-bearing lake. The Red Chris mine would also destroy valuable habitat for Stone's sheep and other wildlife, and is just one of a dozen other proposed mines.

What is a Regional Strategic Environmental Assessment?

An R-SEA assesses the potential environmental effects (including cumulative effects) of different policy choices or different development plans. The objective is to inform a plan and a management framework for a particular region.[290]

A good R-SEA includes:

- Collecting baseline data;
- Engaging the public in a transparent process;
- Exploring and modeling various alternatives to meet social and ecological objectives;
- Considering cumulative effects;
- Creating a plan to guide decision-makers forward; and,
- Monitoring and adaptive management once the planned land use is underway.

Aside from addressing cumulative effects, R-SEAs can streamline project-level assessment and can ensure more democratic decision-making.[291]

Scaling up the analysis

The solution regularly proposed for dealing with cumulative effects is to scale up the analysis[292] to a landscape level and to a timeframe where human activity can be better understood and managed. This is exactly what the Alberta Ministry of Environment and Water is proposing, in recognition that their typical project-by-project cumulative effects assessments are not working.[293] The approach is to do regional land use planning informed by **regional strategic environmental assessments** (R-SEAs), which model the potential impact of different land management decisions to help choose the best outcome. An understanding of the likely cumulative effects for different land use choices is a key product.

Many jurisdictions are now filling gaps in project-level assessment through strategic environmental assessments.[294] In Canada, the Canadian Council of Ministers of the Environment is promoting regional strategic environmental assessments to address cumulative effects, and the council recommends that R-SEAs be used as a tool for regional energy strategies and initiatives, among other things.[295] In order to be effective, follow-up monitoring and adaptive management are needed, to ensure that the assumptions being used are correct and that impacts in the real world remain acceptable. But most importantly – as the Alberta Ministry of Environment and Water seems to recognize – such environmental assessment will be of little use unless it is employed in strategic planning or land use frameworks. The following section makes the case for such planning.

Damien Gillis

Homathko River Valley and Bute Inlet

A case for planning

Regional land use planning began in the 1990s in BC, providing a welcome means for public input into land use decision-making. Plans were developed by consensus to direct uses such as forestry and recreation, and to protect ecological values. However, hydropower was not considered in most regions, because the dramatically increased scale and privatization of renewable energy development had not yet become provincial policy.

Since the 2002 policy change that directed BC Hydro to purchase energy from private developers,[296] no strategic energy planning has been done, nor have land use plans been updated to address the new reality. Even the celebrated 2006 Great Bear Rainforest agreement, which set out protected areas and mandated "ecosystem-based management" for over 65,000 km^2 of land on BC's central coast, did not deal with hydropower development. Around one hundred rivers and streams in this region are now targeted by active water licence applications for hydropower development.

Strategic planning could go a long way toward addressing public frustration and disenchantment with run-of-river developments and the environmental assessment process in general. Watershed Watch and many other groups[297] are calling for a strategic land use planning framework that designates areas that are appropriate (and inappropriate) for development, so that intact fish and wildlife habitat can be preserved. Strategic planning would benefit project proponents, too, by giving them more certainty about the feasibility of their projects, and saving the time, expense and frustration of dealing with issues beyond a proponent's control.[298]

The [Forest Practices] Board's experience has been that lack of strategic planning tends to drive project-level complaints, which can be frustrating and counterproductive for all. However, where a strategic land use plan was in place, satisfaction is higher that forest stewardship plans adequately manage and conserve forest resources. Similarly, satisfaction with run-of-river project plans may be higher if a strategic environmental assessment process asks the broader-scale questions around the appropriate type and level of development, allowing the assessment of individual projects to focus on local impacts.

-Forest Practices Board 2011[299]

Liquified natural gas in British Columbia

High natural gas prices overseas have sparked a frenzy of extraction in Northeastern BC. To allow the gas to be exported, there are plans to build at least five liquefied natural gas (LNG) terminals around Kitimat and Prince Rupert.

Converting gas to LNG is extremely energy intensive.[300] For example, just one LNG terminal (Kitimat LNG) would use almost all of the energy that would be produced from the proposed Site C dam. Premier Clark has announced that the two currently approved LNG terminals (Kitimat LNG and BC LNG) will be powered with "clean" energy,[301] and that development of the Site C dam as well as private power projects (including river diversion projects) must proceed in concert with natural gas extraction.[302] However, it is extremely unlikely that hydropower or other renewable energy options can provide the massive amounts of power required. In fact, all the currently operating river diversion projects in BC don't produce enough power for even one LNG plant. To power these plants, natural gas would likely be required. Given how environmentally damaging it is to extract natural gas (i.e., through shale gas "fracking")[303] and how much energy is required to liquefy it, this whole enterprise could be considered less "green" than proponents suggest.

Developers could also benefit from strategic planning that includes the coordination of different projects occurring in the same region. For example, planning for a shared transmission line could reduce the expense and impact of competing transmission lines. In general, a strategic planning approach should result in faster assessments for new projects, as the biggest and most contentious questions will likely have been addressed.

Strategic land use planning provides many benefits, and above all it deals with cumulative effects. Project proponents are simply not equipped to address cumulative effects at the appropriate scale, nor do they have the authority to do so. This is acknowledged in the *Terms of Reference for the Bute Inlet Hydroelectric Project Environmental Assessment*[304], which asks the proponent to identify cumulative effects measures out of their control and then refer these issues to the agencies with the authority to act. While this approach is an attempt to address cumulative effects within the limited scope of an environmental assessment, it is clearly ineffectual.

The BC Environmental Assessment Office (BCEAO) has said they are committed to continuous improvement of the way they oversee cumulative effects assessments and that they are open to feedback on how this can be done.[305] While commendable, many hydropower projects are below the BCEAO's 50 mega-watt threshold for review. Furthermore, the BCEAO is not in charge of strategic land use planning. Any such planning would need to be done under the guidance of BC's resource ministries and First Nations. It would also have to be informed by a strategic environmental assessment that accounts for social and environmental objectives and specifies limits to development.

A proposed strategic planning framework for BC

Some valleys and rivers simply cannot support hydropower developments without suffering serious and irreparable harm. In other instances, sensitively planned projects can be built with relatively little risk to fish and wildlife populations. While project planning and siting is important, Watershed Watch's focus is not on making individual projects better. The bigger need is for regional and/or provincial strategic energy planning that is informed by rigorous and scientific assessments of cumulative effects. Unlike the current practice, this effort needs to be transparent and include meaningful public and First Nations participation. Regional land use plans that use thresholds or benchmarks to manage cumulative effects would be the ultimate outcome of this process. This is the only way to ensure the long-term persistence of BC's ecosystems and species and to ensure that social concerns and needs are met (for example, to preserve areas of cultural and recreational value).

One of the most important outcomes of a strategic planning approach is the designation of zones that are appropriate and inappropriate for development. For example, this could be a traffic light approach, using red, yellow and green land use zones to indicate where development is appropriate, possibly appropriate, or unacceptable.[306] Any such approach would be a "coarse filter" that would help guide development to appropriate areas.

There are many examples of this kind of planning from other jurisdictions, including sensitivity mapping for wind farm locations in Scotland,[307] and strategic environmental assessment for tidal power in the Bay of Fundy, Nova Scotia.[308] Other efforts include mapping and modeling of species and ecosystems in the Tongass region of Alaska, to help decision makers identify priority areas for conservation.[309] These planning initiatives entail "trade-offs" – losing one thing while gaining another – as trade-offs are usually unavoidable in resource management decision-making. Ideally, strategic planning should produce multiple development scenarios, and seek direction from rights-holders, stakeholders and the general public when it comes to making the necessary trade-offs inherent in any proposed solution.

What about Site C?

BC Hydro is moving forward with plans for their proposed Site C hydroelectric dam. They state that Site C is required to meet future hydroelectricity needs, as well as to provide back-up for intermittent power such as wind power (or more likely, river diversion hydropower). Many people are upset about the prospect of the Peace River valley being further flooded for this project, and worry that much of the power produced would be used for nearby shale gas extraction, which in turn would be primarily used in the Alberta tar sands for bitumen extraction. Others have argued that extensive and more harmful river diversions may be required to produce the same amount of electricity – see Table 2. Without strategic energy planning, we don't know the best way to develop new energy in BC. Of course, aggressive energy conservation could negate the need for some or all new electricity development and this should take first priority.

Strategic assessment and planning should proceed in any region of the province where it would be useful and practical, but at a minimum, efforts should be focused on the hot spots for river diversion developments, such as BC's south coast region and the area affected by the Northwest Transmission Line (NTL). In the case of the NTL, it will be essential for planning to consider new proposed industrial developments such as mines that would be facilitated by new hydropower development. In any area under consideration, all past, current and likely future land uses, as well as likely climate change impacts will have to be included in the planning so that cumulative effects can be properly understood. An understanding of the potential cumulative effects of different development choices is an important outcome of any good planning process.

Watershed Watch recommends the following process, which is similar to the Regional Strategic Environmental Assessment process proposed by the Canadian Council of Ministers of Environment:[310]

Table 2: A comparison of the proposed Bute Inlet Project and the proposed Site C project*

Feature	Bute Inlet Proposal[311]	Site C Proposal[312]
Energy potential	1,027 megawatts	1,100 megawatts
Energy to be generated annually	2,906 gigawatt hours	5,100 gigawatt hours
Number of streams dammed	17 (small to medium tributary rivers and streams)	1 (large valley-bottom river)
Area of land flooded	~8 hectares	5,340 hectares
Transmission line total length	443 km	77 km
Access road length	271 km	<10 km
Total length of penstocks	85 km	n/a (penstocks incorporated into the dam)
Direct project footprint	60 km^2	84 km^2 including reservoir (53.4 km^2)
Overall project area	~400 – 500 km^2	~100 km^2
Efficiency and reliability	Dependent on seasonal flows that are out of phase with seasonal energy requirements in BC	Stable year round flows for highly efficient water use

*In presenting this comparison we are not attempting to promote either project, but to illustrate the importance of open and transparent energy planning so that each renewable energy option can be used most effectively. Note that this comparison only represents a small proportion of the many factors that must be considered in a meaningful planning exercise.

Step One: Gather information and examine the options

The only way to understand and manage cumulative effects is through a rigorous analysis of the impacts of different development scenarios. For instance, scenarios could be developed that would illustrate how different development choices would affect valued ecosystem components such as salmon or grizzly bear populations. A particularly interesting project now underway at Simon Fraser University is using a scenario-based approach to prioritize watersheds suitable for hydro development in BC, based on predicted ecological impacts and energy return on investment.[313]

The province should be prepared to revoke water licenses in areas deemed inappropriate for development.

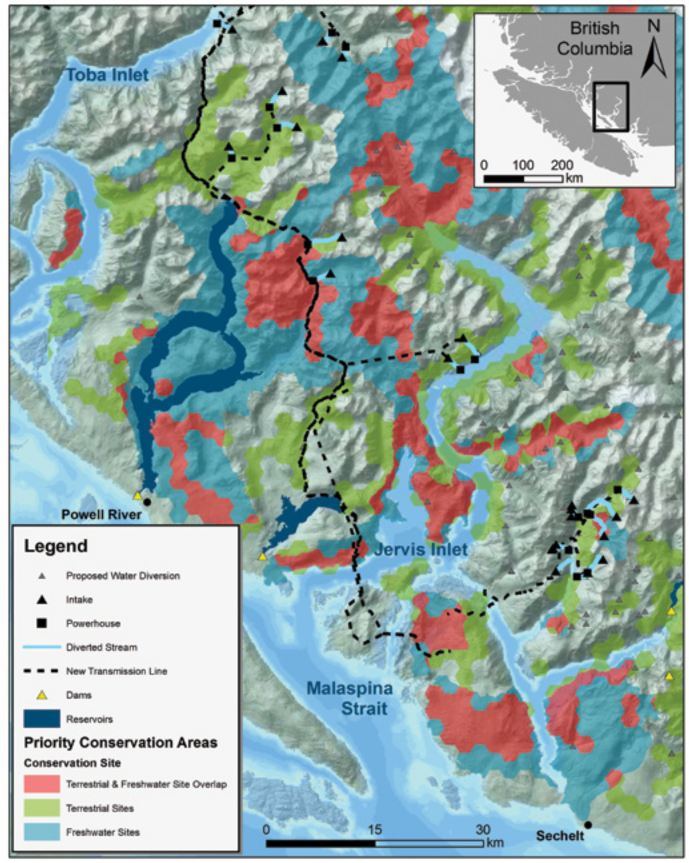
Any chosen methodology should map and model areas of high ecological and social value such as important wildlife habitats, old forest, sensitive plant communities, wildlife movement corridors, development-free areas for biodiversity conservation, and high value fish and riparian habitats. It will be particularly important to illustrate the effects of different land use choices on First Nations traditional uses and other established land uses.

None of this can be done without good data. Fortunately, plenty of pre-existing work and data are available for some ecosystem components, including publicly held data on identified wildlife,[314] existing land use plans, and conservation mapping and other work done by non-profit groups[315] and academics. However, there are also significant data gaps for many species and regions. Most notably, the pervasive lack of fish presence and stream flow data for many smaller streams with hydropower potential will necessitate a great deal of further data collection.

Land use planning is as much about social values as it is about scientific data, and trade-offs between different values are inherent in any land use choice. Thus, the public and especially First Nations need to have meaningful input into development scenarios and into final land use plans.

Step Two: Use scenarios for public land use planning

The outcomes from scenario modeling should be used as a tool for making land use choices. Some areas will be deemed appropriate for development, others may be appropriate depending on local circumstances and project plans, and some areas will be simply inappropriate for any form of industrial development. This type of planning is sometimes referred to as a "coarse filter," as individual projects will usually still need site-specific assessment and planning to determine their feasibility and appropriateness.



Conservation planning has already been completed by the Nature Conservancy of Canada,[316] as a strategy for the long-term survival of BC's native species and communities. A sample of this work is shown here, overlain with existing and proposed power developments on the South Coast. While these proposed conservation areas were created using land use assumptions that did not include hydropower development, this work could be updated to provide valuable input to a strategic hydro development planning exercise.

Good planning will generate several future scenarios to choose among and the chosen scenario will be used to guide land management decisions into the future. A well-researched understanding of the cumulative effects of each scenario will be important for making the final land management decision. Mapping and computer modeling will help inform this discussion, but it is meaningful public participation that will ensure that the final decision represents the broad public interest. Public land use planning can be a protracted and expensive undertaking, but a carefully designed framework for public input can streamline this process.

One of the main benefits of land use planning is the certainty it provides for affected stakeholders and rights-holders. Therefore, the province should be prepared to revoke water licences in areas deemed inappropriate for development. Hundreds of water licences for power generation have been filed because they effectively give the applicant first rights to develop an area. While many of these licences are unlikely to be used, their very existence creates apprehension for the stakeholders and rights-holders (e.g., First Nations) that would be affected if the projects were ever built. Thus it is important to remove the possibility of future development in areas that support crucial ecological, cultural, or social values.

Step Three: Monitoring and adaptive management

Monitoring involves the collection of data to understand project impacts, starting before the project is built and continuing after it is operational. Enough data should be collected before a project is constructed so that post-project changes can be recognized and properly understood.

Adaptive management is a process of continuous improvement that uses knowledge gained from monitoring, research and practical experience to improve planning and management activities.

Monitoring and adaptive management are required at two scales:

i. ***Project scale:*** Most river diversion projects in BC are already monitoring some indicators of ecosystem health. In recent years, provincial monitoring requirements have become more rigorous and now include the health of fish and benthic invertebrate (bottom-dwelling insect) populations as well as information about instream flow volumes and changes to the stream channel. These data are invaluable and need to be routinely and fully analyzed and shared to inform the assessment and planning of all other river diversion projects. Staffing levels at the Ministry of Forests, Lands and Natural Resource Operations are not currently adequate for this task.

ii. ***Regional scale:*** Land use planning requires assumptions to be made about how different land uses will affect social, cultural and ecological values. Once regional land use/energy development plans are in place, follow-up monitoring is essential to ensure that the planning assumptions were correct and to allow for a course correction if development impacts are greater than expected. This is an essential part of good planning and the only way to properly manage cumulative effects from river diversion hydropower as well as other land uses.

First Nations land use planning

First Nations have been leaders in providing effective land use planning to sustain ecological and cultural values in their traditional territories. In BC, First Nations have unceded rights to their traditional territories (or treaty lands, where treaties have been signed), making them legally recognized stewards who can effectively mandate better land use practices. Some watersheds staked for river diversion developments may see land use planning efforts led by First Nations, potentially in collaboration with the provincial government.

A collaborative government-to-government process with the Taku River Tlingit First Nation (near Atlin) and the Province of BC recently led to the 2011 Atlin Taku strategic land use plan.[317] The local non-First Nations community and stakeholders also contributed to the plan, which provides resource management direction and zoning to direct how activities are carried out on the land. Aside from a small local river diversion project intended to negate the community's use of diesel generators, hydropower projects are not currently proposed in Taku River Tlingit territory. However, if such activities are proposed then the land use plan is to be amended to deal with them.

Other examples of First Nation-led planning include the land use plan (LUP) that was developed by the Gitanyow First Nation for their territory – also in northwest BC. The vision includes an enforceable (and enforced) plan for all resource use and development, which would provide economic benefits for the Gitanyow, certainty and security for all, and the long-term sustainability of ecological resources.[318] The LUP was signed on to by the provincial government on March 28, 2012 as a part of the Gitanyow Recognition and Reconciliation Agreement, which stipulates a shared-decision making process for all land and resource activities on Gitanyow Lax'yip (territory), including a Joint Resources Governance Forum, as well as an Engagement Framework (to deal with all referrals and land and resource decisions that do not go through BC's Environmental Assessment Office). Provincial government Strategic Resource Management Plans (Cranberry and Nass South areas) are the enabling provincial policies which ensure that BC is living up to the Gitanyow Huwilp LUP. The Agreement is now being jointly implemented by BC and Gitanyow over a 3 year term. The LUP deals mostly with forestry related activities, but also has key management direction for all resource activities operating in sensitive areas such as water management units and moose winter range. Additional planning on renewable energy projects, upstream mines, and carbon offsets is a part of the 3 year implementation (including a Gitanyow Energy Plan layer to be added to the LUP).[319] Even prior to the LUP being formally recognized by the Province of BC, it was useful in protecting areas of high ecological importance and for managing activities in the Gitanyow traditional territory, including the routing of the recently-approved Northwest Transmission Line to avoid important spawning streams for salmon.[320]

Nega-watts: the next frontier

Any energy we can conserve will help avoid the environmental damage caused new electricity development. BC made strides towards the more efficient use electricity; however, there are still many untapped opportunities. Realizing these opportunities requires creative thinking and willingness on the part of the government, BC Hydro, and others ensure that energy conservation and efficiency are highest priority.

John Pickard

The Kokish—a salmon-bearing river on Vancouver Island—was approved for a major river diversion project that will remove the majority of the river's flow from important spawning areas. Other important salmon rivers can be spared from development if energy conservation is made a higher priority.

How to get there:

Implement an appropriate mix of incentive programs, rate structures, and regulations so that all cost-effective opportunities to reduce electricity consumption are pursued — that is, wherever the cost of efficiency and conservation is less expensive than the full environmental, social and economic cost of new supply;

Pilot innovative programs like Local Improvement Charges[321] and Pay-as-You-Save[322] models, and deploy them at scale as soon as possible to make it easier for families and businesses to use energy more efficiently; and,

Seek new supply options only after the BC Utilities Commission has confirmed that all cost-effective opportunities for improving energy efficiency are being pursued.

Currently, BC Hydro has a goal of meeting 66% of the future demand increases through conservation measures. We use two and a half times the energy per capita than Germans or Britons do, so we should be able to conserve even more than planned, without diminishing our quality of life.

Getting it right with renewable energy development in BC

BC has remarkable potential for developing most forms of renewable energy, but our current strategy for doing so can be substantially improved. River diversion hydropower is best planned within a framework that includes large storage dams as well as wind, tidal and geothermal power. Ideally, the exercise described above should include all forms of renewable energy, not just river diversion power. Experts need to be engaged to help BC develop the best path forward.

Roger Tabor USFWS

Strategic planning is the most effective way to conserve BC's wild salmon stocks

For BC, the best outcome would be a strategic plan – or several regional strategic plans – that include all renewable energy options, to help develop the most energy for the least amount of environmental, social and cultural impact. Any plan should take into account the predicted and ongoing effects of climate change, in order to remain relevant into the future. BC has renewable energy potential that is the envy of other jurisdictions. With our committed citizenry, with a government that purports to be a world leader in supplying clean, green power,[323] and with solid science to inform decisions, we should be able to produce a world class plan.

We can be global leaders in sustainable energy development if our government works with First Nations, other citizens, and experts to manage our resources in a precautionary, strategic and forward-thinking manner.

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Watershed Watch SALMON SOCIETY

Watching Out for BC's Wild Salmon