

Water Quality and Forest Management

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West coast stream in April. (Photo: I. Ricketson).

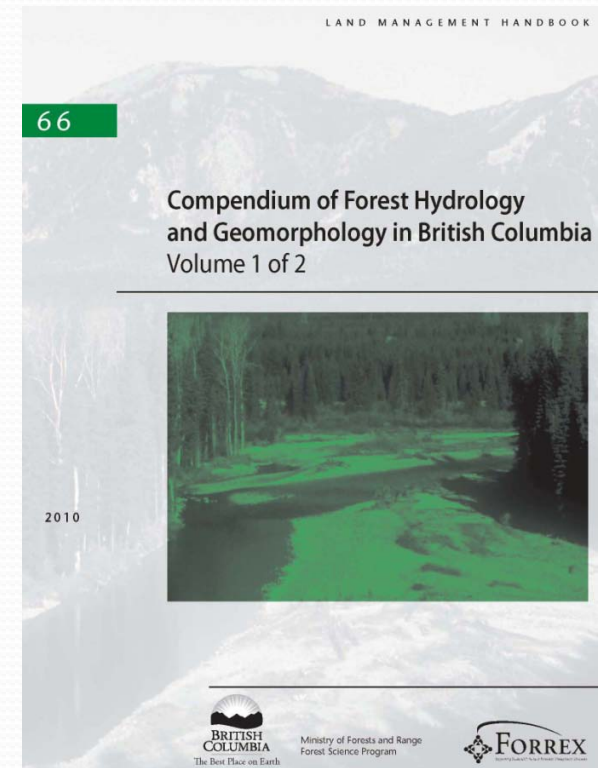
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Chapter 12: Water Quality and Forest Management.

www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh66.htm

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Source: R.G. Pike et al. 2010.

What is Water Quality?

Term used to describe the chemical, physical, and biological characteristics of water, sediment and biota with respect to a **particular (designated) use**.

Some examples:

- drinking water
- aquatic life
- wildlife
- agriculture/ range
- recreation/ aesthetics
- industrial water supplies



Upper Penticton Creek. 2008. (Photo: R.G. Pike).

WQ Guidelines and Objectives



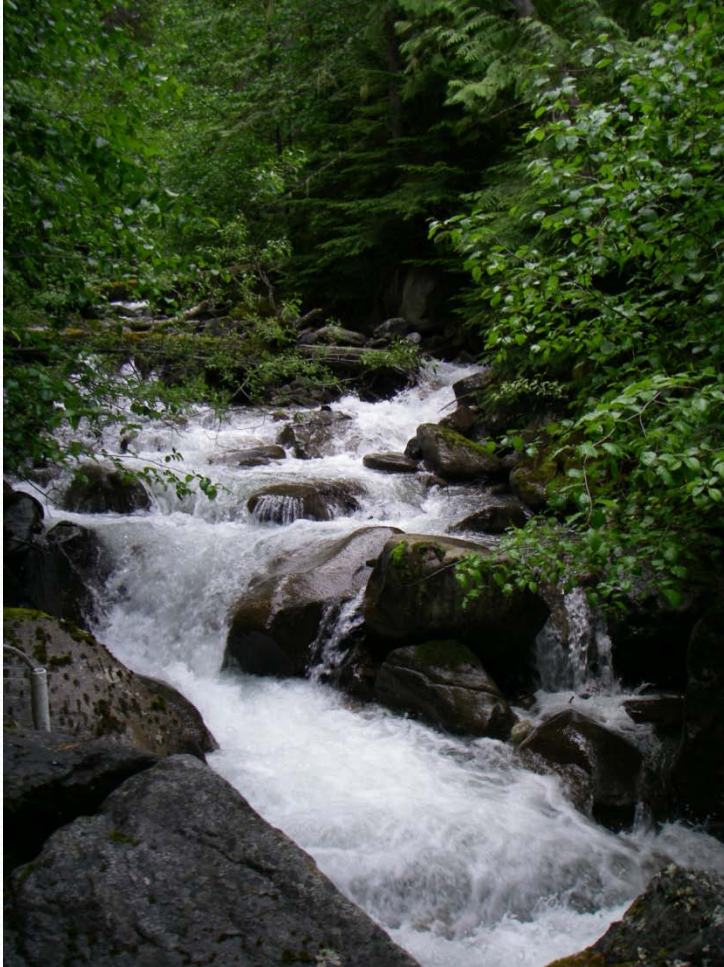
Measuring the turbidity of a water sample. (Photo P. Teti). Source: Pike et al. 2010.

Approved *water quality **guidelines*** are applied **province-wide** to prevent detrimental effects to a designated water use and to support aquatic life.

*Water quality **objectives*** are established on a **site-specific** basis and take into consideration local water quality, water use, and waste discharges.

A water quality problem is deemed non-existent if the substance concentration is lower (or higher as in DO) than the guideline or objective level.

Influences on Chemical Water Quality Across BC Watersheds



Factors influencing surface water chemistry include:

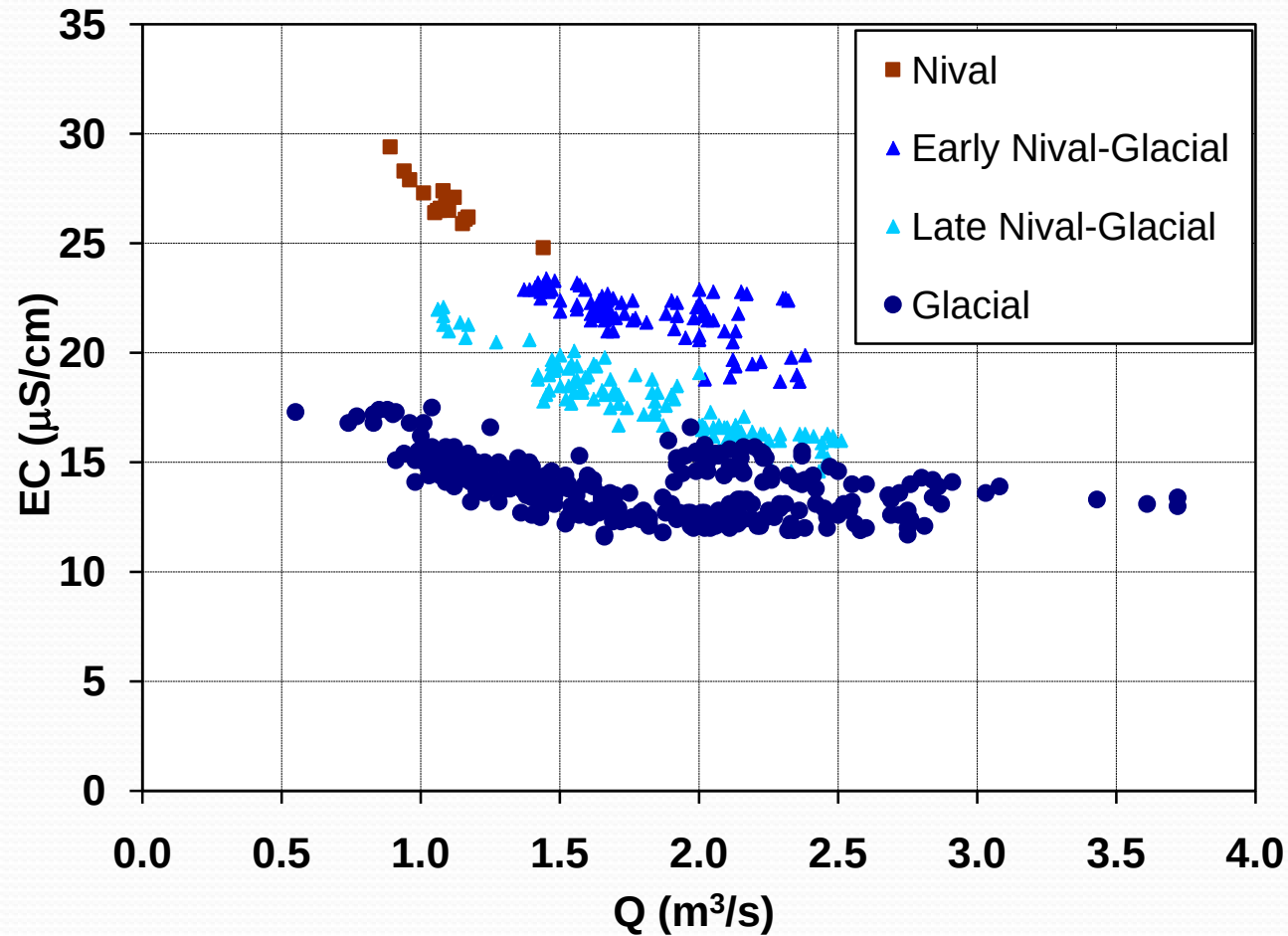
- geological weathering;
- climate: ppt amount and timing, temps
- ppt: chemistry;
- streamflow: volumes / sources;
- terrestrial processes: chemical production, uptake, transformations;
- physical, chemical, and biological processes within aquatic ecosystems.

Place Creek, June 2008. (Photo: R. Pike).

Discharge and Water Chemistry

Temporal variations in water chemistry are also **caused by streamflow dilution** or by different seasonal streamflow sources / residence times.

This is important to consider, as **natural variability is the baseline** from which we regulate activities that affect water quality.



Source: Pike et al. 2010: 403

Forest Management Activities That Affect Water Quality

Clearing of forests for mining, dams, agriculture, or urban development, recreation, etc. can all affect water quality, but these activities are not discussed in the presentation.

Forest management related disturbances:

- forest harvesting;
- road construction and use;
- yarding and skidding of timber;
- wildfire suppression
- chemicals-retardants, herbicides, fertilizers.



Road Construction in Carnation Creek, Aug 1971. Project photo.

What are the Water Quality Parameters of Interest (Studied)?

- Stream Temperature
- Sediments
- Nutrients (N, P)
- Chemicals



Brennan Creek flume (top right), and Adams Lake sorting pond filled with logs to be driven down the Adams River (bottom left). (Photos: Royal BC Museum Archives, I-62756, F-09177, F-09179). Source: Pike et al. 2010.

What Influences Water Temperature?



Measuring stream temperature. Carnation Cr. Sept. 2008.
(Photo Todd Redding).

- Solar radiation: modified by the seasons, latitude, elevation, cloud cover, time of day, **vegetation cover, stream discharge, and stream channel characteristics.**
- The riparian forest canopy provides shade, emits long-wave radiation, and reduces wind speed.
- The **sensitivity** of stream temperature to energy inputs is **related to stream depth/ width.**
- Within a catchment, stream temperature is generally **coldest in the headwaters and increases downstream.**
- **Lakes and wetlands: cooling downstream.**

Importance of Stream Temperature

- Surface water temperatures 0°C to more than 40°C.
- Groundwater temps approximate avg. annual temp (e.g., 10 degrees Victoria, 9 in Kamloops, 5-6 in PG).

Significance

- Water temperatures have significant effects on aquatic life (e.g., metabolic rates, biological activity, and decomposition).
 - E.g., Minor changes in stream temperatures at Carnation Creek in the fall and winter profoundly affected salmon populations, accelerating egg and alevin development rates, emergence timing, seasonal growth, and the timing of seaward migration (Tschaplinski et al. 2004).
- Fish have preferred temperatures for spawning and incubating and for residence (e.g., Bull Trout).
- Increasing water temperature may lead to more rapid decomposition = decreased oxygen levels.



Vancouver Island Steelhead. (Photo R. Pike).

Forest Mgmt. and Stream Temp.



- Riparian forest harvesting can affect stream temperature through the **removal of shading vegetation** and alteration of riparian microclimate.
- Riparian forest harvesting can also **cause stream widening (lateral instability)** caused by a loss of bank strength as tree roots decay, resulting in greater temperature response to heat inputs.
- Forest harvesting outside the riparian zone can also lead to channel changes and widening as a result of increased inputs of sediment and altered streamflows.
- Forest harvesting has led to increases in stream temperatures in all seasons, with the greatest increases occurring in the summertime (see Chapter 15, Table 15.12 for details).

Upper Penticton Cr., riparian shading and lack thereof... (Photos R. Pike).

Sediment in Forested Environments

- Sources of **natural and human-caused** sediment in forests include: i) surface erosion (e.g., roads, exposed soils); ii) mass movements (e.g., landslides); and, iii) stream bank erosion.
- Each sediment source contributes **different sizes** at different time intervals.
- Importantly, natural sediment production in any watershed is generally related to precipitation and snowmelt events.
- Implications to water depend on the degree of connectivity of sediment source to waterway.



Landslide on W. Vancouver Island. Jan 2011. (Photo R. Pike).

Sediment and Forest Management



Investigating the Donna Creek landslide, 1992. (Photo: D. Hogan) Source: Pike et al. 2010.

- **Historically**, forest management increased the production and movement of sediment through:
 - the logging of floodplains, fans, and riparian forests;
 - cross-stream yarding;
 - harvesting unstable or marginally stable terrain;
 - road construction causing landslides and surface erosion; and,
 - inadequate stream crossings.

Sediment and Forest Management

- **Landslides** connected to stream channels remain a primary sediment input for **episodic events**.
- **Stream crossings** at roads or skid trails remain a frequent source of **chronic sediment input**.



Insufficient cross-drainage resulted in the capture and routing of water along road ditches.
(Photo: J. Schwab) Source: Pike et al. 2010.

Fine Sediment in Streams



Suspended sediment in streams can have many important implications for water quality. (Photo P. Teti). Source: Pike et al. 2010.

- Pea-sized and smaller
- Suspended sediments (clay, silt, and very fine sand particles) less than 0.1 mm in diameter.
- Fine sediment in forested watersheds is generally measured as total suspended solids (TSS) or turbidity.
- **Total suspended solids** refers to the portion of sediments suspended in a water column.
- Turbidity refers to the amount of light scattered by a fluid and is measured in nephelometric turbidity units (NTU).
- **Turbidity is used as a proxy** to describe sediment content of water samples.
- Increasing turbidity is usually associated with increasing suspended sediment concentrations.

Fine Sediment WQ Implications



Stoltz bluff, Cowichan River. BC Ministry of Environment. Undated.

- Fine sediment can restrict light penetration = reduces primary productivity.
- Can damage to fish gills
- Can kill fish eggs by filling gravel interstices = reduced oxygen availability and decreased transport of ammonia and other metabolites away from the egg pockets.
- Excessive turbidity can negatively affect the aesthetics / recreational water use.
- Turbid waters often require altered levels / increased levels of treatment for drinking water use.

Nutrients: Nitrogen

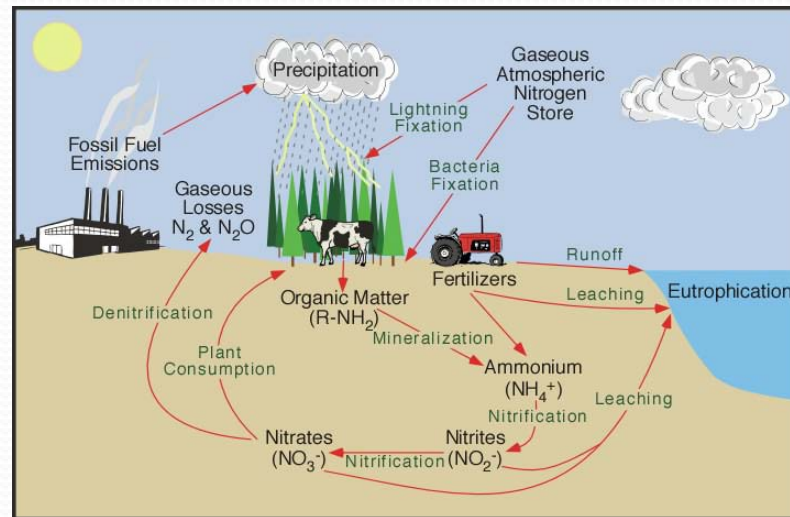


Sarita Lake in Spring. (Photo R. Pike).

- Changes to nitrogen (N) and phosphorus (P) inputs are considered important as N and P typically limit terrestrial and aquatic productivity, respectively.

Nitrogen

- Excessively high levels of nitrate (N) can be toxic to fish.
- High levels can cause “blue baby” syndrome.
- In North America, background concentrations of nitrate-N in streams are low.
- Sometimes localized, elevated levels (e.g., Red Alder).



Source: Pidwirny, M. 2006. "The Nitrogen Cycle". *Fundamentals of Physical Geography*, 2nd Ed. April 4, 11. www.physicalgeography.net/fundamentals/9s.html

Nutrients: Phosphorus

- Phosphorus (P) is often the nutrient that **limits biological** production in **aquatic ecosystems**.
- Phosphorus is naturally derived mainly from the weathering of minerals.
- Additional sources of phosphorus include agricultural and urban runoff, soil erosion, and sewage.
- Overloading a system with phosphorus can lead to excess production of unwanted algae, as well as other water quality problems, including reduced oxygen content.



Green Filamentous Algae in Old Growth, WC VI Stream. (Photo R. Pike).

Nutrient Cycling in Forests

- **Nutrient cycling** in forested environments is often **complex process**.
- Dependent on specific ecosystems characteristics, vegetation species and structure, temperature, ppt and soil processes of an area.

So... the **effects of Forest Harvesting** on nutrient cycling is also **complex**.

Influencing factors include:

- proportion of the watershed harvested;
- level of reduction in organic contributions to the soil/ water;
- nature of the site treatment following forest harvesting;
- rate of re-vegetation following harvesting; and
- nutrient content and buffering capacity of the soil;



Water drop on moss. 2009. (Photo R. Pike).

Forest Management and Nutrients

- Most published BC studies reported minimal to modest changes in water chemistry due to timber harvesting.
- Results from Washington and Oregon are consistent with BC.
- Site preparation treatments, such as mechanical scarification, slash burning, or herbicide application, can potentially increase the effects of timber harvesting on stream water chemistry.
- E.g., Feller (1989) found that nitrate-N in stream water increased from clear cutting (approx. 10 kg/ha), to clear cutting plus slash burning (approx. 20 kg/ha), to herbicide application in young plantations (approx. 40 kg/ha) in Coastal Western Hemlock (CWH) biogeoclimatic zone forests in south-western British Columbia.



Russell Creek watershed, near Tstika river. (Photo: R. Pike).

Fire Effects on Water Processes

- In British Columbia, some wildfires have lead to severe erosion and flooding.

Potential fire effects on watershed processes:

- Formation of **water repellent** (hydrophobic) soil properties.
- Altered snow accumulation, snow ablation, and interception processes.
- Altered streamflow patterns, possible enhanced events, early melt, altered flow timing.
- Altered riparian areas / stream channels.
- **Decreased channel bank stability.**
- **Fire-related erosion and mass movements.**
- Altered water quality.



Testing for hydrophobic soil properties. (Photo: R. Pike).



'Black water' at Bridge/Fraser Rivers. Aug 2010. (Photo : R. Winkler).

Fire and Water Quality Impacts



Debris flow deposit on Kuskonook Creek fan. (Photo: P. Jordan).
Source: Pike et al. 2010.

Potential Impacts of Fire

- Discontinuous water-repellent layer can lead to localized decreases in infiltration = potential for increased runoff and sediment/ash input to water bodies.
- Loss of the protective vegetation and organic soil layer can increase the likelihood of splash erosion of exposed mineral soil (i.e., fine sediment/ ash mobilization).
- Increased stream temperatures if fires burn through riparian areas = tree death.
- Altered microclimate due to blackened surfaces.
- Channel widening due to the loss of channel bank strength (internal instability). Not necessarily increased sediment or altered flows.

Overall,

- Wildfire can increase the potential for sediment /ash inputs, increased stream temperatures, flooding/ sediment events, and other water chemistry changes.

Fire and Water Chemistry

- **Burn severity / extent influences** fire's effect on stream chemistry.
- Many studies have reported increased nutrient movement through soils and into streams.
- Fire leads to the conversion of insoluble chemicals (organic matter) into readily soluble chemicals (ash), thereby facilitating nitrate, phosphate and sulphate additions to streams.
- Phosphate and sulphate fluxes in streams are often greater following fire, whereas these fluxes are usually unaffected, or reduced following forest harvesting.



Aftermath of the Okanagan Mountain Park Fire. (Photo: P. Tschaplinski).

Fire Retardants and Water Quality

Forest fire suppression sometimes involves the aerial application of fire retardants.

Retardants can be ammonium phosphate- or sulphate-based with small amounts of other chemicals used as dyes or for anti-corrosion.

The major factors that influence the effects of fire retardants include:

- location of the application in relation to the water body;
- retardant type;
- application method / quantity applied;
- weather following of application;
- ability of the aquatic ecosystem to utilize the added retardant chemicals; and
- ability of the water body to dilute the retardant chemicals.



*Soil loss and burning on well-developed epikarst. (Photos: P. Griffiths):
Source: Pike et al. 2010.*

Fire Retardants and Water Quality



Hand built fire guard. (Photo: R. Pike).

- Fire retardants applied close to a water body can lead to increased stream water ammonium, phosphate, and nitrate concentrations.
- Increases are usually short lived (< 1 hour initially) but may re-occur in response to subsequent ppt events.
- Some fire retardants contain sodium ferrocyanide as a corrosion inhibitor.
- In the presence of UV radiation, the ferrocyanide decomposes yielding cyanide ions that react in acidic solutions and produce the highly toxic hydrogen cyanide.
- Norris et al. (1983) estimated that toxic concentrations of cyanide are unlikely following application of ferrocyanide-containing retardants.
- In contrast, Little and Calfee (2002) suggested that toxic concentrations can occur, particularly when light levels are high and soils adjacent to streams are coarse textured and contain little organic matter.

Herbicides and WQ- Nutrients

- Herbicides may affect stream water chemistry, through i) nutrient loading and ii) the loading of the herbicide chemicals themselves.
- Herbicide applications can cause greater increases in nutrient chemical concentrations in streams than forest harvesting.



Mayfly, Carnation Cr. May, 2010. (Photo: R. Pike).

Herbicides and WQ- Nutrients



I. Ricketson. *Oncorhynchus mykiss*, Vancouver Island.

- Stream water nitrate concentrations increased following herbicide applications.
- Other nutrient chemical concentrations have also increased, whereas sulphate concentrations decrease following herbicide application.
- These trends are generally the same as those following forest harvesting, suggesting that the factors controlling stream water nutrient chemistry response to forest harvesting also control the response to herbicides.

Herbicides and WQ- Chemicals

- Factors influencing the fate of herbicide are the same as those for fire retardants.
- Herbicide chemicals are more likely to enter water bodies if they are soluble, do not degrade quickly, and are not easily sorbed by soils.
- Direct application, aerial drift, and overland flow (including roads) are the main flow pathways.

Effects:

- Herbicide concentrations in surface waters have sometimes exceeded permissible levels.
- High concentrations tend to be short lived and generally occur soon after application.
- Heavy rain shortly after application can result in relatively high concentrations of herbicides in stream water if flow occurs either **overland (e.g., roads)** or in ephemeral channels.



Resident Cut throat trout from WC VI stream. (Photo: T. Redding).

Fertilizers



Top: Damselfly Adult. July 2010. (Photo: R. Pike). Bottom: Measuring Coho salmon. (D. Spittlehouse).

- Some forest stands are fertilized with urea to increase stand volume and reduce rotation length.
- Some lakes, reservoirs, and streams in British Columbia are fertilized with *P* to increase primary productivity and the growth rates of fish.
- The added nutrients increase growth rates of algae, which increases food availability for zooplankton (in lakes) or benthic invertebrates (in streams and lakes) = increases food availability for fish, yielding greater growth rates and survival.

Fertilizer (N) and Water Quality

- Forest Fert: most concerns related to unintentional increases in concentrations of urea, nitrate, ammonia/ammonium, phosphorus, sulphur, and heavy metals.
- In several case studies, forest fertilization resulted in short-term increases in nitrogen (e.g., nitrate-N) concentrations in streams.
- Leave strips or buffers applied to water bodies resulted in lower peak concentrations .
- Concentrations of nitrate-N generally remained above background for several months to a year after treatment (Perrin 1994).



Forest stand near Cotton Cr. (Photo: R. Pike).

Fertilizer (P) and Water Quality

- In review of forest fertilization trials in coastal British Columbia, Perrin (1994) found that low-level phosphorus concentrations commonly increased but then dropped to background levels within 120 days of fertilizer application.
- Stream water phosphorus concentrations are influenced by the time-release factor of the fertilizer; higher concentrations are likely to occur with fast-release rather than slow-release fertilizers (Sharpley and Syers 1983).



Top: Cowichan River Brown Trout, Bottom, Chum Salmon. (Photos: R. Pike).

Summary

- Forest practices have been modified over the years to address/ minimize many of the concerns identified.
- Stream Temp / Sediment production still remain the two biggest concerns wrt Forest Management.
- Use of riparian reserves and well planned / maintained roads / cuts are the strategy used to minimize the potential for changes.
- FM can affect nutrient cycling - the release of nutrients seems to be minimal to modest in most studies if background not initially high.
- Chemicals will always be a high concern - application method / buffers have a strong bearing on a chemical reaching a water body.



View of Barkley Sound, Carnation Creek. (Photo: R. Pike).

Interested in more?

www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh66.htm