COLUMBIA MOUNTAINS INSTITUTE
of Applied Ecology

Resource Roads in British Columbia:
Environmental challenges at a landscape level

May 14-15, 2014
Nelson, British Columbia, Canada

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Columbia Mountains Institute of Applied Ecology
Box 2568, Revelstoke, British Columbia, Canada V0E 2S0
Phone: 250-837-9311 Fax: 250-837-9311
Email: office@cmiae.org
Website: www.cmiae.org
Facebook: www.facebook.com/cmiae

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Conference description

Within BC, paved and unpaved road length increased by 82% between 1988 and 2005. In 2000, there were over 420,000 road-stream crossings in BC; over the following five years, road-stream crossings increased by about 13,000 per year (BC Ministry of Environment 2007).

In 2005, acknowledging that there were no comprehensive accurate resource road inventories available, the BC Forest Practices Board indicated there were an estimated 400,000 to 550,000 km of unpaved roads in the province.

More recently, in its 2010 State of BC's Forests report, the Ministry of Forests, Mines and Lands indicated that in 2005, BC had over 700,000 km of roads.

Since then, more roads have been built by companies in the forest, mineral, petroleum, hydro, and wind energy sectors. At the same time, many roads have been abandoned and have become unusable due to a lack of resources for maintenance; others have been intentionally closed or decommissioned. Thus recreational access has been constrained.

The environmental effects of roads are diverse, and include impacts on aquatic and terrestrial wildlife, plants, and their habitats, as well as ecosystem and biophysical processes (including soils, water, and air).

This conference explored road-network effects and management responses (solutions) for addressing landscape-level environmental and social impacts.

Over 150 people attended our 2 day conference. Participants heard 36 speakers, and viewed 12 posters and displays. A networking / social session late afternoon of the first day took place whereby lively conversation took place.

Follow-up: take action

At the closure of the conference, about 70 participants completed Evaluation Forms to give us valuable feedback (summary of feedback forms can be found on p.177). There were many positive comments about the conference (e.g., well organized, diverse topics, speaker expertise, etc). However, nearly 20% of the respondents indicated they'd like an increased emphasis on solutions to resource road issues[1].

Here is one 'set of solutions'. Implement currently available recommended practices (some of which are already in use in some areas). The following is a list of some of BC's best practice examples sequenced from oldest to newest:

Watershed assessment procedure guidebook (Coastal and Interior). 2001. BC Ministry of Forests (MoF).
http://www.for.gov.bc.ca/tasb/legsregs/fpc/FPCGUIDE/WATRSHED/WAPGdbk-Web.pdf

Watershed assessment in the southern interior of BC. 2001. Toews and Chatwin (editors). BC MoF.
http://www.for.gov.bc.ca/hfd/pubs/docs/Wp/Wp57/Wp57-01.pdf

Terrain stability and forest management in the interior of BC. 2002. Jordan and Orban (editors). BC MoF.
http://www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr003/TechRep3Front.pdf

The effects of forest harvesting and best management practices on streamflow and suspended sediment concentrations during snowmelt in headwater streams in sub-boreal forests of BC, Canada. 2003. Macdonald et al. Cdn J of Forest Research.
http://www.wou.edu/las/physci/taylor/g473/refs/macdonald_etal_2003.pdf

Managing coastal forest roads to mitigate surface erosion and sedimentation. 2003. Carson and Younie. Steamline Bulletin.
http://www.forrex.org/Streamline/ISS25/streamline_vol7_no2_art4.pdf

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[1] Over 15% of the evaluation respondents identified another 'solutions' theme they'd like clarity about. They posed a challenging request--People want "clear solutions about who will lead, regulate, coordinate, fund, plan and be accountable for BC resource roads." So, who in BC could respond to that request?

Karst management handbook for BC. 2003. BC MoF.
http://www.for.gov.bc.ca/hfp/publications/00189/Karst-Mgmt -Handbook-web.pdf

Adaptation to climate change in forest management. 2003. Spittlehouse et al. J of Ecosystems and Management.
http://jem.forrex.org/index.php/jem/article/view/254/173

Standards and best practices for instream works. 2004. BC Ministry of Water, Land and Air Protection and Fisheries and Oceans Canada.
http://www.env.gov.bc.ca/wld/instreamworks/downloads/GeneralBMPs.pdf

Landslide risk case studies in forest development planning and operations. Wise et al. (editors). 2004. BC MoF.
http://www.for.gov.bc.ca/hfd/pubs/docs/lmh/Lmh56_HiRes.pdf

Effectiveness evaluation of road deactivation techniques on the west coast of Vancouver Island. 2004. Dunkley et al. BC MoF.
http://www.for.gov.bc.ca/rco/research/wrp/en-020.pdf

Access management in BC: Issues and opportunities. 2005. Vold and Chatwin. BC Forest Practices Board.
http://www.fpb.gov.bc.ca/SR23_Access_Management_in_BC_Issues_and_Opportunities.pdf

Erosion and sediment control practices for forest roads and stream crossings: A practical operations guide. 2007. Gillies. FPInnovations.

Guidelines for management of terrain stability in the forest sector. 2008. Assn of Professional Engineers and Geoscientists of BC (APEGBC) and Assn of BC Forest Professionals (ABCFP).
http://www.abcfp.ca/regulating_the_profession/documents/Management_Terrain_Stability.pdf

Application of structured decision making to an assessment of climate change vulnerabilities and adaptation options for sustainable forest management. 2009. Ogden and Innes. Ecology and Society.
http://www.ecologyandsociety.org/vol14/iss1/art11/main.html

Guidelines for professional services in the forest sector – Terrain stability assessments. 2010. ABCFP and APEGBC. https://www.apeg.bc.ca/getmedia/d32d0dc3-a709-468d-ba46-8b7edf6dd1cb/APEGBC-Guidelines-for-Terrain-Stability-Assessments.pdf.aspx

Stream, riparian and watershed restoration. 2010. Polster et al. FORREX and BC Ministry of Forests and Range. http://www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh66/Lmh66_ch18.pdf

Interim operating practices for oil and gas activities in identified boreal caribou habitat in BC. 2011. BC Ministry of Environment (MoE). http://www.env.gov.bc.ca/wld/speciesconservation/bc/documents/Operating%20Practices.pdf

Implementation plan for the ongoing management of boreal caribou (Rangifer tarandus caribou, pop. 14) in BC. 2011. BC MoE. http://a100.gov.bc.ca/pub/eirs/finishDownloadDocument.do;jsessionid=Q9JNTcRSVKTkpjGhhny6s09tBvQYQXyBb54m5QQ1yC1bcz3L2Ljf!234374013?subdocumentId=9121

Recovery strategy for the woodland caribou (Rangifer tarandus caribou), boreal population, in Canada. 2012. Environment Canada (EC). http://www.sararegistry.gc.ca/virtual_sara/files/plans/rs%5Fcaribou%5Fboreal%5Fcaribou%5F0912%5Fe1%2Epdf

Fish-stream crossing guidebook. 2012. BC Ministry of Forests, Lands and Natural Resource Operations (MFLNRO); BC MoE, and Fisheries and Oceans Canada. http://www.for.gov.bc.ca/hfp/fish/Fish-stream%20Crossing%20Web.pdf

Engineering manual. 2013. BC MFLNRO. http://www.for.gov.bc.ca/hth/engineering/documents/publications_guidebooks/manuals_standards/Eng-Manual.pdf

Recovery strategy for the woodland caribou, southern mountain population (Rangifer tarandus caribou) in Canada [Proposed]. 2014. EC. http://www.tngportal.ca/themes/tng/documents/Communication/RecoveryStrategyWoodlandCaribou.pdf

Thanks to our sponsors and volunteers!

This workshop was hosted by the Columbia Mountains Institute of Applied Ecology (CMI). The CMI is proud to have worked with these organizations that contributed financial assistance in support of this event.

The Columbia Mountains Institute gratefully acknowledges the financial support of **Columbia Basin Trust,** a regional corporation created to deliver social, economic, and environmental benefits to the residents of the Columbia Basin. http://www.cbt.org/

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Masse Environmental Consultants Ltd., based in Nelson BC, provide environmental consulting services with a multidisciplinary team of engineers, architects, planners, project owners, and community groups to develop environmentally friendly and cost effective solutions that minimize the impacts of anthropogenic activities. http://www.masseenvironmental.com

We are appreciative of the work of our event organizing committee, and others who contributed expertise as the workshop developed. The members of the organizing committee were:

- **Kevin Bollefer**, Revelstoke Community Forest Corporation, CMI Director
- **Patrick Daigle**, CMI Director, Chair of organizing committee, and Master of Ceremonies.
- **Malcolm Gray**, BC MFLNRO
- **Peter Jordan**, MFLNRO
- **Phil MacDonald**, MFLNRO
- **Darcy Monchak**, RPF (Retired), OneSparrow Images
- **Hailey Ross**, Executive Director, CMI
- **Richard Thompson**, BC Ministry of Environment
- **Del Williams**, BC Forest Practices Board

We appreciate our **presenters and the people who brought posters and displays** travelled from various communities in British Columbia, Alberta, and the US Pacific Northwest. We are grateful for your willingness to share your expertise with us, and for the support of your organizations that enabled you to partake in our conference.

We appreciate the willingness of **Garth Wiggill** for providing a welcoming address at the start of the conference. Garth is the District Manager for the Selkirk region with BC MFLNRO.

Additionally, CMI expresses our respect and gratitude to the **Sinixt, Sylix, Ktunaxa and Secwepemc peoples –** the First Nations on whose traditional territory this event took place.

Special thanks go to our volunteers **Jen Peebles, Adrienne Shaw, Laticia MacDonald, and Erin Scaia** for their help in keeping the event running smoothly.

About the Columbia Mountains Institute of Applied Ecology
www.cmiae.org

The Columbia Mountains Institute of Applied Ecology (CMI) is a non-profit society based in Revelstoke, British Columbia. CMI is known for hosting balanced, science-driven events that bring together managers, researchers, educators, and natural resource practitioners from across southeastern British Columbia. CMI's website includes conference summaries from all of our events, and other resources.

Presentation Summaries

The summaries of presentations in this document were provided by the speakers. Apart from edits to create clarity and consistency in layout and style, the text appears as submitted by the speakers.

The information presented in this document has not been peer reviewed

1. Stream crossing assessment procedures as a tool for mitigating impacts on freshwater fish

Presenter: Axel Anderson, PhD, P.Eng., RPF, Water Program Lead, Foothills Research Institute, Hinton AB (secondment); Forest Hydrology Specialist, Environment and Sustainable Resource Development, Edmonton AB; Adjunct Professor University of Alberta, Edmonton AB
axel.anderson@ualberta.ca

Co-authors:
Bryan M. Maitland, MSc, Graduate Research Assistant, University of Alberta, Department of Renewable Resources, Edmonton AB

Mark S. Poesch, PhD, Assistant Professor, Conservation Ecology, University of Alberta, Department of Renewable Resources, Edmonton, AB

A growing body of research has shown negative impacts on fish populations from the cumulative effects of natural resource industry activities (Ripley et al. 2005; Scrimgeour et al. 2008), particularly where resource roads cross streams.

In Alberta, the forest and energy sectors have been expanding rapidly in recent years, and in turn have established vast road networks across the Foothills and Boreal Forest natural regions. These road networks have in turn lead to the installation of hundreds of thousands of stream-crossing structures which have been shown to reduce available fish habitat (Gibson et al. 2005), deteriorate instream habitat (Eaglin and Hubert 1993), and disrupt ecological connectivity by acting as barriers to fish and aquatic organism movement (Warren and Pardew 1998; MacPherson et al. 2012).

Recently, Alberta regulators, in collaboration with Fisheries and Oceans Canada, have developed a stream-crossing assessment procedure for inspecting these structures and determining the impact on fish movement (ESRD 2012).

To investigate the effectiveness of the Alberta stream crossing assessment method in identifying barriers to freshwater fishes, we examined stream crossing structures in relation to fish communities and aquatic habitat in West-Central Alberta. We collected fish community and in-stream habitat data in the Simonette watershed at 33 sites above and below culverts, bridges and crossing-free reaches. Streams crossed by culverts that were classed as being either a complete or partial barrier showed significant differences in fish community metrics upstream versus downstream as compared with bridged reference streams.

Specifically, both species richness and abundance were strikingly reduced upstream of culverted crossings classified as barriers. Interestingly however, our field data suggests that the underlying mechanisms driving these changes are in fact a combination of synergistic, cumulative effects rather than a simple problem of barrier passability. That is to say that culverts may be a first order control on fish communities, but for unexpected reasons. Sediment loading and geomorphological changes in streams caused by the installation, maintenance, and ongoing use of the crossing structure are likely playing a large role in community shifts by altering instream habitat. For example, we observed significant differences in instream habitat variables and concomitant altered fish assemblages upstream of culverts as compared to downstream reaches, whereas instream habitat and fish assemblages upstream and downstream of bridged and crossing-free reference streams were very similar. We believe that the flow-chart assessment procedure for inspecting stream crossing does a fairly good job of identifying meaningful barriers to fish movement in the Foothills and Boreal regions of Alberta. The method is simple and easy to carry out by a single surveyor in approximately 15-20 minutes.

A secondary objective of stream-crossing assessments is to help prioritize barriers for restoration or removal. With limited resources (time, money, personnel), barriers must be prioritized to ensure remediation and conservation dollars are used efficiently. Determining the passability of barriers (i.e. no concern, partial barrier, complete barrier) is a fist step in this process.

Following this, riverscape perspectives of habitat connectivity need to be incorporated into the prioritization process.

The Dendritic Connectivity Index (DCI; Cote et al. 2009) is a recently developed habitat-availability measure for assessing riverine connectivity within Dendritic Ecological Networks (DEN; *sensu* Grant et al. 2011). We explored the utility and application of this method the to (1) quantify the extent of fragmentation by road culverts on longitudinal connectivity in DENs located in a heavily developed watershed, and (2) to use the DCI to prioritize barriers for restoration planning.

We show that connectivity in DENs of west-central Alberta, as measured by the DCI at small scales (10^1), is impacted greatly by a small number of instream barriers, and can vary widely depending on the spatial arrangement of barriers within a DEN. Further, we demonstrate the applicability of the DCI to determine priorities for barrier restoration planning and fish passage improvements. The DCI thus appear to be a promising tool for prioritization schemes in Alberta, however more work is needed to incorporate other pressures (i.e., cumulative effects) and fish habitat-suitability models that will further focus and improve the efficacy of this method. These lines of inquiry provide fruitful topics for future research.

We suggest that culvert removal and Best Management Practices need to account for landscape-scale pressures and cumulative effects to help mitigate potential harm to freshwater ecosystems.

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Grant, E. 2011. Structural complexity, movement bias, and metapopulation extinction risk in dendritic ecological networks. Journal of the North American Benthological Society 30(1): 252-258.

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MacPherson, L., M. Sullivan, A. Foote, and C. Stevens. 2012. Effects of culverts on stream fish assemblages in the Alberta foothills. North American Journal of Fisheries Management 32(3): 480-490.

Park, D., M. Sullivan, E. Bayne, and G. Scrimgeour. 2008. Landscape-level stream fragmentation caused by hanging culverts along roads in Alberta's boreal forest. Canadian Journal of Forest Research 38(3): 566-575.

Ripley, T., G. Scrimgeour, and M. Boyce. 2005. Bull trout (Salvelinus confluentus) occurrence and abundance influenced by cumulative industrial developments in a Canadian boreal forest watershed. Canadian Journal of Fisheries and Aquatic Sciences 62(11): 2431-2442.

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2. *Modeling human accessibility and remoteness to assist grizzly bear population research and cumulative effects assessment*

Presenter: Clayton Apps, PhD, RPBio, Research Ecologist, Aspen Wildlife Research, Calgary AB
clayapps@telus.neta

Co-authors:
Bruce N. McLellan, PhD, Wildlife Biologist, BC Ministry of Forests, Lands and Natural Resource Operations (BC MFLNRO), D'Arcy BC
bruce.clellan@gov.bc.ca

Christopher Servheen, PhD, Wildlife Biologist, University of Montana, Missoula, MT.
grizz@umontana.edu

Grizzly bear conservation largely pertains to the potential for displacement from otherwise suitable habitats and the risk of direct or indirect mortality. Grizzly bears do, however, exhibit behavioural adaptability, and displacement is affected by habituation, time of day, and the age, sex, and reproductive status of bears. The more important conservation consideration is mortality risk, primarily related to bear interactions with people and the lethality of those encounters. Notwithstanding local grizzly bear habitat conditions and population density, mortality risk can be described simply as a function of the number of people in bear habitat (frequency of encounter), and both the behaviour of those people (including whether, what and how they are hunting) and whether they have firearms (lethality of encounter). It follows that human accessibility to the landscape is perhaps the most direct and relevant predictor of potential impact to grizzly bears, beyond that of legal hunting. These effects are primarily tied to roads.

Human influence is often assessed and modeled with respect to impacts on grizzly bear movements, habitat use, and vital rates. In this process, densities and/or buffers of linear and point sources of human disturbance are often derived. Yet, roads and trails may not in themselves be detrimental to grizzly bears, and may, in some areas, benefit bears through both ease of movement and improved forage value within road easements. What is relevant to the potential for bear displacement and mortality is the amount of traffic and the behaviour and intentions of people comprising the traffic.

Within localized study areas, road density may be a satisfactory proxy for the distribution of people and motorized disturbance. But the degree to which the existence and density of roads is the primary factor underlying the distribution of people depends on: (1) an even distribution of road types and associated speeds, including main arteries, and (2) whether the study area is small enough to assume a uniform and free distribution of people with respect to roads. However, these assumptions are unlikely to hold in for most grizzly bear study areas that are typically quite large, often exceeding several thousand km^2. A simple measure of road density is even more problematic as one moves to broader scales relevant to assessing grizzly bear population distribution and its underlying influences. In evaluating factors related to grizzly bear population abundance and distribution in the upper Columbia basin, Apps et al. (2004) calculated human access by way of network analysis as a function of travel time from human population centres and the size of those localized populations. This approach was repeated for the southern Canadian Rockies (Apps et al. 2007), with the measurement referred to as human accessibility, or "remoteness". In these examples, this intuitive index has proven to be a powerful predictor in understanding and predicting grizzly bear distribution.

Remoteness is also largely synonymous with "wilderness", an important value often considered in resource and land-use planning. Yet, aside from being free of mechanized access, wilderness attributes are otherwise nebulous. Although grizzly bears and other large carnivores have been assumed to represent this value many factors such as the distribution of important foods confound such a direct association. The highest densities of these species do not always match what people consider to be the most wild places, and protection with priority focus on remote (e.g., roadless) landscapes is inadequate in the conservation of large carnivores. In clarifying the relationship and interacting factors, and in predicting impacts, a spatial model of human accessibility or remoteness can be a relevant tool. Moreover, such a model can be helpful in directly accounting for and tracking a societal value of considerable importance in and of itself.

In the aforementioned derivations of the remoteness measure, there have been two primary limitations to accuracy. First, these examples considered relatively localized modeling areas. However, it is best if the distribution of seasonally or permanently resident human populations were fully and accurately quantified over a large region. That is, since relatively far-distant but substantial human population centres can influence local remoteness (e.g., city of Calgary can be expected to influence landscape use in portions of southeast BC), successively larger modeling areas that include major population centres are more likely to account for true accessibility demand, even if the area of interest is far more localized. Second, the applications to date have only considered human accessibility through network analysis of linear features facilitating movement, especially motorized travel. Yet, terrain and land-cover conditions will also greatly influence the off-road movement and dispersion of people, mediating or exacerbating the localized influence of traffic accessing the larger landscape. Addressing the above limitations, we have been focused on the development and application of an improved iteration of a model of human accessibility, or remoteness.

Our current model accounts for the distribution of resident human populations, networks of linear features (roads, etc) that facilitate and influence travel time from those centres, constraints to non-motorized travel posed by biophysical conditions, and the influence of both time costs and urbanization on the propensity to travel. We illustrate the model through application across a 180,000 km^2 region of southeastern BC and southwestern Alberta for the snow-free season. The model accounts for differential impact of roads depending on their type, state, connectivity, the human population they service, and the context of landscape conditions. Spatial output is scale-independent, and is relevant to comparative assessment across broad regions down to local landscapes.

For regional analyses and projections, our derived index of human population accessibility/remoteness may be the most relevant predictor of human influence on landscape effectiveness and population fragmentation for wide-ranging species. Advantages of this model are that it (1) is scale-independent (i.e., can be applied in broad regional to very localized assessments), (2) is relevant to the hypothetical mechanism of human influence, addressed to date through surrogates such as road density, (3) is intuitive, and (4) can directly address the value of "wilderness" or "remoteness", which is itself an important value that is typically not directly addressed in cumulative effects assessment. There have been several applications of the model to date across BC whereby projected or hypothetical scenarios have been considered that account for future population growth and/or changes in the capacity and connectivity of roads and highways to facilitate human travel and access.

Our model provides a more realistic depiction of regional human influence, accessibility and remoteness than anything of which we are presently aware. As such, our model has utility in environmental assessment and planning, but limitations should be recognized. Most importantly, the modeling is only as good as the inventory data and assumptions that go into it. Clearly, there are differences between the inventory data and reality on the ground. However, iterative refinement can occur as the accuracy of the underlying inventories is improved. Planned improvements will also address helicopter and fixed-wing aircraft transportation to specific or dispersed landing sites, as well as seasonal differences particularly as influenced by snow. We also note that the model does not presently account for the influence of destination preference. The destination and associated reason for travel is obviously relevant to where and how far people go. However, this factor is complex and will require very good spatial and temporal data on amenities and values. As well, the present model does not account for ephemeral resource extraction (such as forestry). This type of traffic is not dependent on human population centres though it is often associated with localized work camps. Over the long term, one may assume that such industrial traffic is spatially consistent to the degree determined by land-use designations and resource development controls. Finally, we note that our model is not intended as a direct predictor of localized traffic volume. Model output is less relevant to shorter-term behavioural responses of a given species, and more relevant to longer-term ecological processes such as those related to species mortality, distribution and persistence.

In conclusion, there are countless ways in which cumulative effects are theoretically manifested for different values. Our understanding of these relationships and thresholds is not well developed, but accessibility is clearly relevant to a suite of values, including conservation requirements for several high-profile species. Hence, the accessibility metric we model is a relevant measure to assess and monitor cumulative effects independent of any defined value.

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3. *The effects of roads on survival, condition, and demography of grizzly bears in Alberta*

Presenter: John Boulanger, MSc, RPBio, Integrated Ecological Research, Nelson BC
boulange@ecological.bc.ca   www.integratedecologicalresearch.com

Co-Author: Gordon B. Stenhouse, MSc, Wildlife Carnivore Biologist, Foothills Research Institute, Hinton AB
gstenhouse@foothillsri.ca

One of the principal factors that have reduced grizzly bear populations has been the creation of human access into grizzly bear habitat by roads built for resource extraction. Past studies have documented mortality and distributional changes of bears relative to roads but none have attempted to estimate the direct demographic impact of roads in terms of both survival rates, reproductive rates, and the interaction of reproductive state of female with survival rate. We applied a combination of survival and reproductive models to estimate demographic parameters for threatened grizzly bear populations in Alberta. Instead of attempting to estimate mean trend we explored factors which caused biological and spatial variation in population trend.

We found that sex and age class survival was related to road density with subadult bears being most vulnerable to road-based mortality. A multi-state reproduction model found that females accompanied by cubs of the year and/or yearling cubs had lower survival rates compared to females with two year olds or no cubs. A demographic model found strong spatial gradients in population trend based upon road density. Threshold road densities needed to ensure population stability were estimated to further refine targets for population recovery of grizzly bears in Alberta. Models that considered lowered survival of females with dependant offspring resulted in lower road density thresholds to ensure stable bear populations. We also extend the multi-state model approach to explore the relationship between bear condition, survival rates, road density, and regeneration habitat. Our results demonstrate likely spatial variation in population trend and provide an example how demographic analysis can be used to refine conservation measures for threatened species.

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4. A Resource Road Radio Communications Protocol for BC

Co-presenter: Allan Bradley, RPF, P.Eng, Associate Research Leader, Resource Roads Group and FPInnovations, Vancouver, BC
allan.bradley@fpinnovations.ca

Co-presenter: Brian Chow, MEng, P.Eng, Chief Engineer, BC MFLNRO, Victoria BC
Brian.chow@gov.bc.ca

The Province of BC has 400,000 or more kilometres of resource roads most of which are open to the public and industry to use. Mobile Very-High Frequency (VHF) radios are utilized by many resource road users to communicate their location and learn about the location of nearby vehicles. Although voluntary on all forest service roads (FSRs), this system of radio-assisted road use has been effective at improving road user safety. Numerous stresses have eroded the safety of resource road radio communications in the last decade including:

- Increased traffic volumes.
- Increased use of resource roads by multiple industries and public groups.
- Increasingly mobile work force (within and outside of the Province).
- Mobile radio frequency congestion with increasing demand.
- Lack of consistency in calling protocols.
- Lack of consistency in source road sign conventions.

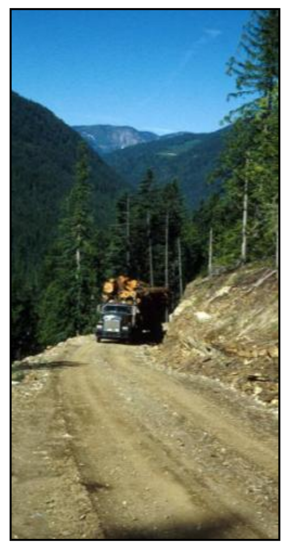


Figure 1 Figure 2

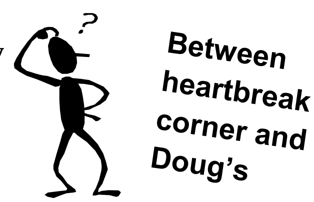
Figures 1and 2. Both of these collision incidents involved loaded trucks rear-ending other loaded trucks during adverse weather conditions – both drivers were not on the right radio channel (as they were short-term hauls), and didn't have appropriate channels programmed into their radios**.**

Figure 3. Example of irregular and ineffective signage. Inconsistencies abound: protocols for providing direction, site-specific location names, contact frequency and message content. These inconsistencies can vary by industry, company, company division, or geographic area.

Figure 3

DIRECTION:

- **Loaded – Empty**
- **In – Out**
- **Up – Down**

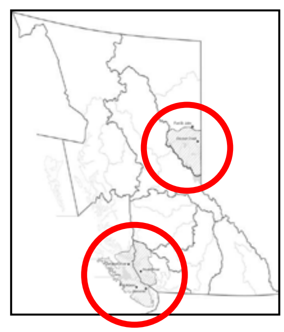


- **Calling interval frequency**
- **Call content and order**

The current state of VHF radio is that there are limited mobile radio frequencies available with increasing demand. This has led to congestion within this part of the radio spectrum. Many different radio frequencies are used on BC resource roads. Commonly referred to as Appendix 6 frequencies, there are 121 discrete frequencies that are publicly available. Industry Canada licenses the use of these frequencies while the BC Ministry of Forests, Lands and Natural Resource Operations (MFLNRO) and road use permit holders specify who can use frequencies for FSRs and road use permit roads, respectively. There are currently 304 licensed users; however, many more also use these frequencies. Frequencies used on resource roads are not exclusive to resource road users and there is occasionally interference to emergency responders from other licensed radio users.

In 2006, led by the Ministry of Forests and Range (MOFR), the BC Radio Communications Working Group was drawn together to create a comprehensive communications strategy for all of the radio-assisted resource roads in BC with the intent of improving user safety. This Working Group included representatives from MOFR; FPInnovations (formerly the Forest Engineering Institute of Canada, or FERIC); Industry Canada; Forestry TruckSafe; and the Council of Forest Industries.

A 2007 BC Coroner's inquest into the death of a logging truck driver travelling on a northern radio-assisted forest service road cited poor communication as one of the key factors that led to the fatal accident. The inquiry's jury recommended to the MOFR that forest service road signage be standardized; and, to the BC Forest Safety Council, that efforts be made to standardize radio use protocols.



The road radio communications strategy was piloted in two areas of BC: the Strait of Georgia Business Area of BC Timber Sales (including the Sunshine Coast), and the southern part of the Peace Forest District. In the pilot areas, engagement and consultation occurred amongst resource road users at the local level, including road safety committees consisting of a variety of industrial and commercial users (forest, oil and gas, mining, recreation, etc.).

The intent of the radio pilots was to determine how best to simplify resource road radio communications. The pilots had three objectives:

1. Establish consistent road radio calling procedures.
2. Standardize radio communications signage.
3. Establish a set of standard resource road radio channels.

FPInnovations verified the effectiveness of the piloted RR (Resource Road) Channels through interview feedback and extensive field-testing. Over 300 road users were surveyed through web-based questionnaires about their impressions of the new signage, calling procedures and road channels. FPInnovations conducted an additional 150 roadside interviews with those travelling resource roads in the pilot areas in order to assess whether the piloted radio communications protocol improved road user safety or not, and whether the protocol would be recommended for implementation province-wide in its piloted form or with modifications. FPinnovations and Industry Canada conducted a site visit to Chetwynd to investigate pilot-related radio communication problems and found several root issues that resulted in changes to the form of the road channels.

Finally, a project report was prepared to summarize the key findings from the pilots. Based on the experiences in the pilots and in consultation with various experts, FPInnovations prepared best practice guidelines for radio equipment installation and maintenance, and for radio use. Implementation guidance is currently being drafted. These reports are publically available on the Ministry of Forest, Lands and Natural Resource Operations (MFLNRO) website at the following link:
http://www.for.gov.bc.ca/hth/engineering/Road_Radio_Project.htm

The current status of this initiative is that the pilots and evaluations are complete and have been reported on the project website and road safety committees have been established around BC. Standardized radio calling procedures were introduced in 2009 on all FSRs and consisted of:

- Call travel direction as **Up** or **Down** (‘**UP**’ in direction of increasing Kms; ‘**DOWN**’ in direction of decreasing Kms).
- Calling order is **Road Name, Km, Direction.**
- Frequency of location calling, by default, consists of **Down-direction calling every 2 Km** and **Up-direction calling every 2 Km** but this can be varied as deemed necessary by the local road safety committee.
- Call location when starting, stopping, leaving or entering an FSR, and at all **MUST CALL** signs.
- Do not call location if traveling in a convoy and within 1 km of the lead vehicle.

Standardized, simple signage was introduced in 2010. Specifications for sign materials and format can be found in the 2008 Engineering Manual on the

MFLNRO website at the following link:
http://www.for.gov.bc.ca/hth/engineering/sign_standards.htm

The standardized format of the signs will make them easy to recognize from a distance even before the details can be read. Signs at FSR entrances will provide details such as the road name, the road channel, and calling procedures specific to the road. Kilometre signs consist of road name, Km, and direction (shown by an arrow) and drivers should call the information exactly as the signs reads, from top to bottom.

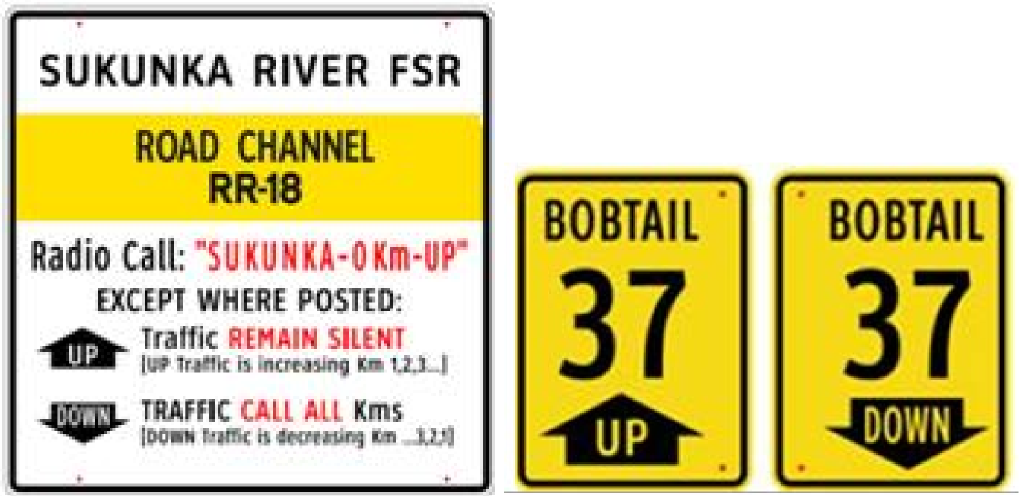


Figure 4
Figure 4 Examples of one road entrance sign and two Km marker signs**.**

Industry Canada has specified a bank of 40 narrowband, 30-Watt frequencies to be dedicated exclusively for resource road use:

- **35 RR channels** (exclusively for communicating location and direction when traveling on road or for safety messages).
- **5 LD channels** (for communications at loading/ staging areas).

Four pre-existing LAD channels are also available for general administration communications. By standardizing communications on these radio channels FSR users will no longer have to reprogram their radios with individual channels, and they will always have the correct channel no matter where in the

Province they go. Feedback from pilot road users indicated strong support for a standard bank of resource road channels. Resource road communications should experience less interference as well because only road users will be using the frequency. In order to avoid road user mistakes in reading radio frequencies, road channels now will be displayed only as a simple alpha-numeric name rather than the actual frequency (e.g., RR-01 instead of 150.0800).

Numerous BC forest districts have gone through the transition to the new protocol for FSR radio communications (others are in the transition process now):

- **Peace:** The southern portion of the Peace Forest District completed the transition in June 2013 and the northern portion plans to switch over soon**.**
- **South Coast:** Transitioning pilot areas on South Coast, as well as Squamish, by August 2014. Transitioning remaining South Coast FSRs by December 2015. Licensees have been encouraged to implement the new protocol on their permitted roads concurrently.
- **Central Cariboo:** Williams Lake and 100 Mile House Forest Districts transitioning in Spring 2014.
- **North-Central Interior:** Prince George and Quesnel Forest Districts transitioning in Spring 2015.

When transitioning an area to the new radio communications protocol the RR radio channels must be distributed across the landscape. This process involves rationalizing the road naming conventions in the area, mapping radio area polygons across the landscape, and then assigning RR channels to the polygons and, where necessary, to busy mainline roads.

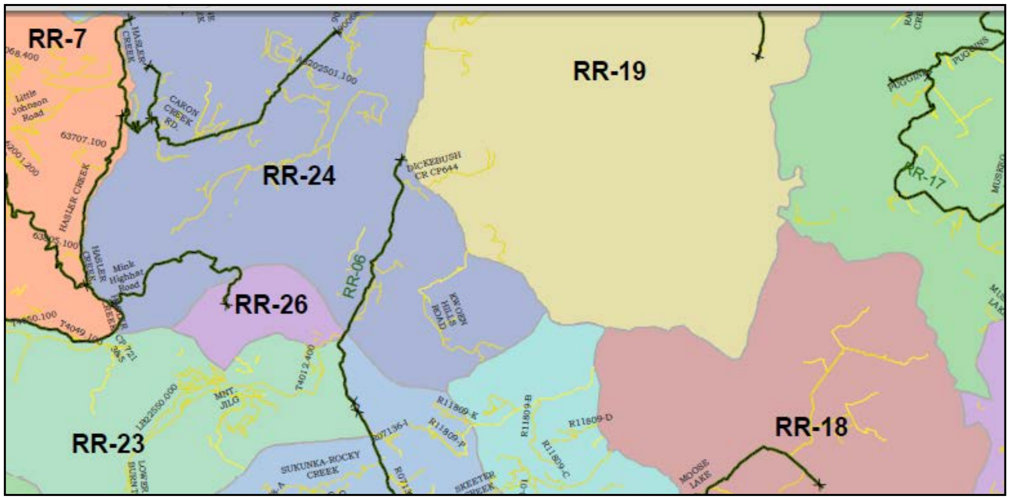


Figure 5

Figure 5. Examples of Resource Road radio channel assignments to polygon areas and mainline roads in the Peace Forest District.

A vital aspect to implementing the radio communications protocol has been to secure buy-in from key stakeholders. This has been achieved by extensive consultation and communication in the pilot areas. Stakeholder support has been sought for transitioning to a standard bank of radio channels, and for standardizing calling procedures and signage.

The benefits of implementing a resource road radio communications protocol across BC are expected to include:

- A dedicated set of channels for resource road communications.
- Always having the correct radio channels available with no need to constantly reprogram.
- Fewer things for workers, first responders, and the general public to worry about.

Consistency and standards will lead to operational efficiencies and simplified training, **and most importantly - increased safety!**

Over the medium to long term, the following outcomes are expected:

- Throughout BC, a gradual expansion of the protocol, led by MFLNRO and its FSRs;
- Resource road users will shed Appendix 6 channels and any other frequencies presently used on roads;

- MFLNRO, with input from local road safety committees, will manage use of the 40 RR channels (the Province of BC will hold the RR system licence); and
- Industry Canada will promote expansion of a radio communications protocol in other Provinces and Territories.

For further information about this initiative, explore the resources provided at the following website:
http://www.for.gov.bc.ca/hth/engineering/Road_Radio_Project.htm
or contact the authors.

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5. *Using expert elicitation to extract landscape-level data from high-resolution digital images*

Bill Chapman, PhD, Soils Scientist, BC MFLNRO, Williams Lake BC
Bill.Chapman@gov.bc.ca

As part of the Forest Resource Evaluation Program (FREP), the BC Ministry of Forests Lands and Natural Resource Operations (MFLNRO) Soil Resource Team conducts annual landscape-level audits and/ or effectiveness evaluations. This work focuses on the management of soils, primarily from the perspective of resource road construction, harvesting related soil disturbance, coarse woody debris management, and the management of site-specific drainage Chapman et al. 2013). An initial FREP assessment procedure used a combination of ground-based survey and interpretation of high-resolution digital imagery. The ground-based assessment is costly and requires constant training to maintain a pool of individuals who have the skills to conduct the work.

The high-resolution images used in the initial process are contain large amounts of information, but it is difficult to quantify that information in an objective way. After exploring various approaches to process digital data (such as PCI Geomatica software), an expert-elicitation system was settled upon as the most practicable way to extract quantifiable data from imagery at this time. This presentation details the procedures used for this large-scale analysis. The basic tools are high-resolution digital imagery, a structured expert-elicitation protocol, and on-line collaboration of experts to develop interpretations that are followed by limited field checking.

The process (of combining digital imagery, expert interpretation and ground-based surveys) has flagged proliferating Temporary Access Structures (e.g., resource roads) in portions of the interior of BC. That led to publication of an Extension note to alert forest managers to the existing regulations pertaining to Temporary Access Structures (Chapman et al. 2014).

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6. Scope and context for resource road management in BC

Patrick Daigle, MSc, RPF (Retired), Science Emeritus, BC Ministry of Environment (MoE), Victoria BC
P.Daigle@telus.net

Introduction

Roads that are initially built to access natural resources (e.g., timber) are called "resource roads". Later, these roads may be used by other industrial sectors to access other resources (e.g., mineral or energy development, commercial recreation) or by the public who may be seeking opportunities for recreation.

Road needs and construction requirements of other sectors may differ (e.g., mineral development and transport); thus, the initial resource road may require up-grading. Frequently, in the same area, a different road may be developed to specifically address the needs of a user group (e.g., transport of ore). Resource roads may be deemed primary, secondary, connectors, or temporary; each of these types of roads may be built to a different construction standard.

Resource road management and road access management are complex fields. Figure 1 outlines a road continuum – from road genesis to abandonment.

Un-roaded area
Plan and design road
Build road for initial use
Use road: Initial and subsequent different uses
Retain, maintain and repair the road
Close road (seasonal or restricted access)
OR
Abandon road
OR
Deconstruct road (or portions), then abandon road

Figure 1. Conceptual sequence of resource road management phases. Bold italicized letters indicate the main phases relating to resource road access management.

Benefits of resource roads

Resource roads are built to address human needs or wants.

- To access mineral, timber, energy and recreational resources.
- For commercial development which can create employment for an array of people to support their families.
- To provide access to communities and homes located in out-back areas.
- To assist wildland fire managers, foresters involved in silvicultural activities, and forest scientists conducting research.
- Resource roads enable citizens to access many forms of outdoor recreation.
- To provide access to cultural, First Nations, and recreational activities.

Social and economic downsides of resource roads

There can be negative environmental impacts relating to resource roads. Resource roads can impact soils, water, wildlife and their habitats, and ecosystems. Detailed road impacts are outlined in Daigle (2012) and extensively summarized in Daigle (2010).

Numerous negative social and economic impacts can result from resource roads.

- Human injuries and deaths can be caused by vehicle-wildlife collisions. Collisions and landslides can also trigger insurance claims.
- Resource roads can provide opportunities for negative human actions (e.g., garbage dumping, a chronic nuisance problems along some roads).
- Due to the access provided by resource roads, other illegal activities may also occur (e.g., fish and game poaching; some off-road All Terrain Vehicle use; and unauthorized releases of non-native fish into lakes).
- Resource roads can provide vectors for the initial transfer (and subsequent expansion) of non-native organisms. Non-native organisms can have negative effects on water quality, agriculture, ranching, and forestry. Examples include knapweed, Scotch broom, and other invasive plants.

- Road surfaces don't produce ecological services for humans; these services include growing timber, sequestering carbon, and filtering water.
- Landslides from abandoned resource roads can be slow to recover; altered soils can impede revegetation and reduce valued ecosystem services such as water filtration.
- Sediments from resource roads can enter streams. In some instances, when water is needed for domestic consumption, it may be necessary to install costly water treatment systems. Stream sediments can also degrade fish habitat and thus reduce angling opportunities.
- Appropriate management of resource roads can create economic burdens, some of which are passed along from generation to generation. (More about this below.)

Scale and context for resource roads in BC

Just how big is the resource roads issue? In 2005, an estimated 400 to 550 thousand kilometres of resource roads coursed across the province. Another 2005 estimate indicated over 700 thousand kilometres (BC MFML 2010). Because resource road inventories have been inconsistent, lacking, or out-of-date, estimates are pretty loose (BC FPB 2005). Due to continuing resource development, many more roads have been constructed over the past decade. For perspective, at the equator, the circumference of the earth is about 40,000 kilometres.

Road management is costly. There are many components to the appropriate management of resource roads and access. This include the costs of:

- inventories, analyses, ground-truth investigations;
- people management and coordination;
- access management planning;
- decisions and actions about road locations and construction;
- monitoring and research (to determine what works and what doesn't);
- maintaining roads (surfaces, drainage, stream crossings);
- repairing roads (landslides, culvert blow-outs, slumps);
- closing roads (e.g., retaining the road but closing it seasonally due to wildlife concerns or other requirements); and
- decommissioning roads (removing the travel function).

Resource roads are an important concern of the BC Forest Practices Board (Board). Focusing on resource roads, between 2005 and 2014, the Board conducted many audits and investigations. There were instances of compliance with sound planning and practices. However, the Board identified numerous safety issues, unsound practices, significant non-compliances, and areas requiring improvement. Also of concern to the Board, during the two-year period of 2010-2011, there have been five times more road or bridge issues detected than the previous five years combined (BC FPB 2013, 2014).

Four former BC forest and land managers (Archibald et al. 2014), with a combined experience of 120 years, summarized three main trends in BC renewable resource management.

- Legal requirements for forest management.
- Investments in the management of wildlife, fish, parks, and forests.
- Numbers of professional foresters and biologists in BC.

There are legal requirements for management of BC natural resources. Archibald et al. examined provincial statutes and requirements that oblige natural resource agencies (and their staff) to carry out work. Starting in 1912, the number of requirements rose steadily over several decades; since the 1970s, the pace of statutory change increased sharply. Beyond statutory obligations, Archibald et al. acknowledge that other factors (e.g., First Nations claims) also increase the complexity of natural resource management (Archibald et al. 2014).

In contrast, the renewable resource ministry budget capacity has lagged, making it difficult to address and manage the increased legal requirements and complexity. During their analysis, the authors adjusted provincial budgets for inflation. Over the past 25 years, renewable resource agencies have fluctuated greatly, but are now at approximately the same level as they were in 1976. Over the same period, total BC government budgets have more than quadrupled (Archibald et al. 2014).

The professional capacity to address these matters has lagged. Over the past 11 years, the number of Biologists working for the BC Ministry of Environment has decreased. Likewise, the number of Professional Foresters employed by government and industry has decreased substantially (Archibald et al. 2014). Recently, the BC Professional Employees Association has summarized similar findings (2014).

In contrast with increased legal responsibilities and complexities, neither professional capacity nor budgets have kept up. Over time, what can come of that?

Here is one outcome that the Trends report summarized; it relates to resource roads (Archibald et al. 2012, Appendix 3). The issue is whether fish can make it beyond road-stream crossings (particularly culverts). In BC there are many instances where deficient road-stream crossing structures truncate up-stream use of fish habitat, diminish aquatic connectivity, and/or reduce valued ecosystem services.

Across the province, in fish-bearing stream habitat, over 77,000 stream crossings require assessment and repair. Funding to assess and remediate road-stream crossings has been severely reduced in recent years—fewer than 25 crossings are repaired each year (BC FPB 2009 and Mount et al. 2011 cited in Archibald et al. 2012, Appendix 3).

Divide 77,000 crossings by 25 repairs per year. At that rate of repair, it will take over 3,000 years to remediate existing stream crossings (Archibald et al. 2012, Appendix 3).

Discussion: Let's manage our resource roads

Why has there been no public outcry about resource roads in BC? This is largely due to the invisible nature of the resource road impacts. For example, lay citizens can see and understand instances of wildlife road-kill and roadside dumping and there will be instances of lay people recognizing road-triggered landslides. They cannot see or recognize the rest of the negative environmental, social, and economic effects, such as:

- road-triggered stream sediments; altered stream velocity and water temperature; culverts that block fish passage; wildlife avoidance of roads; spread of non-native organisms; and increased vehicle-caused contamination discharges.
- the lack of professional capacity for planning, maintaining or repairing roads, and
- political negotiations about funding and staffing natural resource ministries.

If citizens do not see road-related problems, they will not pressure politicians to address resource road problems.

It is costly to appropriately manage resource roads. So, who (or which entity) should pay, take on the liability, or carry out the work? Most resource roads are on public lands, so some say "government". Is that expectation realistic?

What is needed in BC is an affordable resource road system that can be sustained. If resource roads are not appropriately managed, this generation will pass along the economic burdens and environmental and social damages to subsequent generations. Off-loading road costs to future generations runs counter to a basic concept of sustainability.

What could be done to improve resource road management?

Resource road inventory forms the basis of road management (FPB 2011)[2]. If you don't know what you have, then you can't manage it. It is important to develop resource road inventories, analyze the data, and publish road-related plans and maps.

Resource road inventories need to be current, accurate, comprehensive, and consistently gathered and made available. In order to track and analyze damage to the environment, appropriate inventories would include road-related data about the roads (of course), but also landslides, wetland and stream crossing types; road proximity to riparian zones; and invasive organisms.

Ideally, road-related data would be analyzed with consistent and comprehensive techniques such that key information can be calculated, assessed, and summarized so that valued ecosystem components can be protected. Examples of key information include: road density; road-stream crossing density; erosion potential; landslide hazard; water diversion potential, and the cumulative effects of human-caused and natural disturbances.

In order to assist managers and decision makers, road-related plans would consistently provides all elements to identify, map, quantify, prioritize, implement, and monitor road locations and impacts.

Resource road access is of concern to many people, be they citizens or land managers. Within the socio-economic realm, human dynamics become very

[2] Fortunately, improvements to road inventories are underway. See Ogborne and Hlasny in this document.

important. As mentioned, road-related impacts are largely invisible. However, when it comes to road access in BC, citizens and industry sectors tend to be audible and visible about their needs and wants.

For improved resource road management in BC, what is needed is:

- a single accountable coordinating organization;
- long-term political will and funding to manage roads and road access;
- legislation and regulations, including a legal basis for road access management plans and on-the-ground actions;
- policies and a decision-making framework; and
- Best Planning Practices for road access management. At this time, one can look at previous access management plans and figure out the approaches and methods that seem to work.

How can road management and land stewardship be addressed? In the technical realm, at both landscape- and site levels, there are numerous approaches and tools for stewarding the environment. (See examples under FOLLOW-UP: TAKE ACTION starting on page 6 of this document). These can be used while planning, assessing, building, maintaining, and repairing resource roads. Soon, when thorough accurate and up-to-date resource road inventory data is available, standardized road analyses are needed to assist decision-makers and to develop thorough road plans.

It is time to sustainably manage BC resource road networks.

During the resource roads conference, at the end of my presentation, I asked people to recall Robert Frost's 1920 poem titled The Road Not Taken.

Frost's last stanza read:

> I shall be telling this with a sigh
> Somewhere ages and ages hence:
> Two roads diverged in a wood, and I –
> I took the one less traveled by,
> And that has made all the difference.

For the resource roads conference, I took the liberty to re-write Frost's last stanza.

> I am telling you this with a sigh:
> Somewhere ages and ages past,
> Two road networks diverged in a wood, and we –
> We took the one less costly to plan, build and manage,
> And that has made all the difference.

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7. Roads and cumulative effects: Incisive foresight and strong mitigation are needed for sustainability

Peter N Duinker, PhD, Professor, School for Resource and Environmental Studies, Dalhousie University, Halifax NS
peter.duinker@dal.ca
http://www.dal.ca/faculty/management/sres/faculty-staff/our-faculty/peter-duinker.html

The presentation was divided into three sections:

a) a reminder of the conundrum of hinterland roads - at once both a practical necessity and an ecological scourge;
b) two frameworks for systematic thinking, one for the biophysical impacts of roads and one about cumulative effects; and
c) implications for further road development and assessment.

The conundrum is this: roads are a practical necessity – how can we do anything industrial in the wooded landscape unless we can drive to sites of operations - and also an ecological scourge – we build them, use them, abandon them, rebuild them, use them again, etc., all of which takes a big toll on ecosystems and valued ecosystem components.

The framework for systematic thinking about the biophysical impacts of roads (Robinson et al. 2010) consisted of:

Below, Figure 1 diagrams the impact drivers: road construction effects; road presence effects; and road use effects. The figure also indicates the pathways to intermediate effects variables to final effects variables (the latter focussing on terrestrial and aquatic biota).

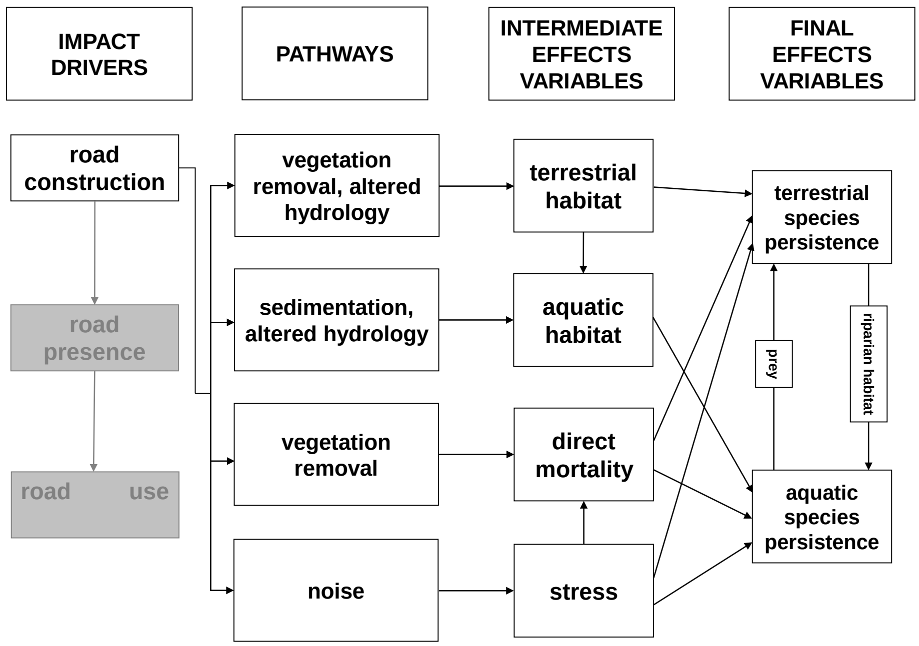

Figure 1. Impact-hypothesis diagram summarizing ecological impacts related to road construction, presence and use (taken from Robinson et al. 2010).

Figure 2 (below) outlines an assessment process consisting of five steps: synthesis of the knowledge base; determination of ecological impacts of road construction/ presence/ use; determination of road importance; determination of a mitigation strategy; and implementation of actions and monitoring indicators.

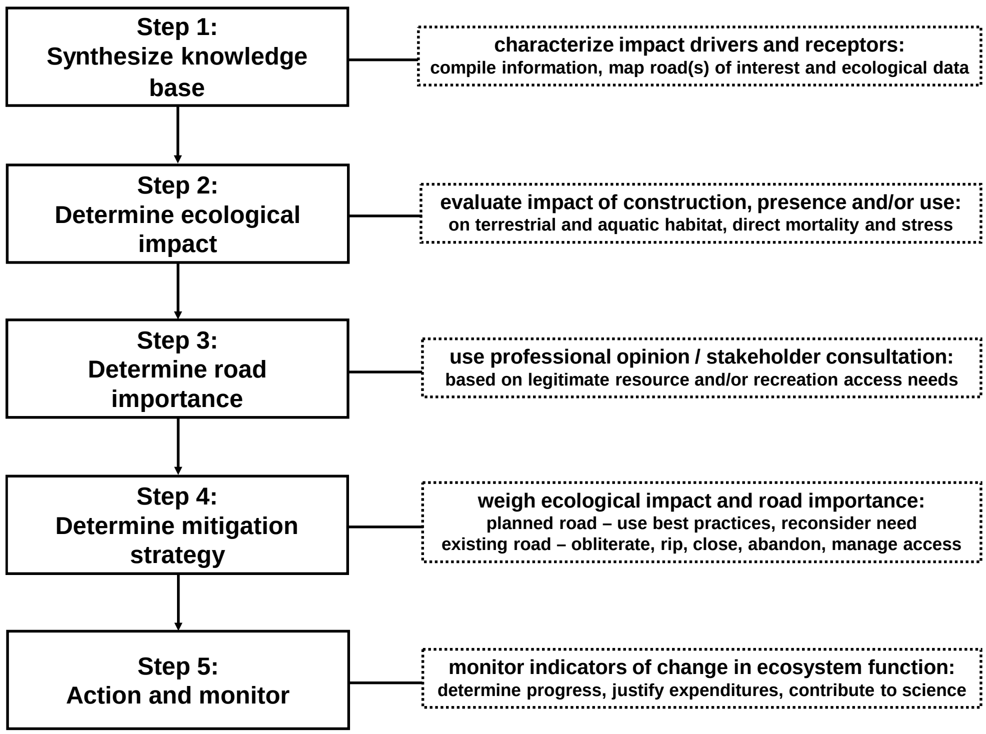

Figure 2. A five-step approach for assessing ecological effects and importance of forest roads, and informing road development and management that minimizes impact (taken from Robinson et al. 2010).

The decision matrix below (Figure 3) can be used to contrast road importance against ecological impacts. Within each cell are suggested strategic directions for action in the face of construction, existence, and use effects.

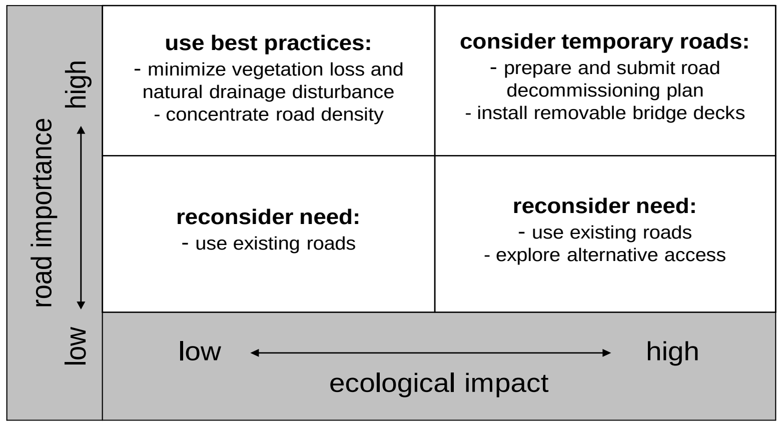

Figure 3. A decision matrix for weighing potential ecological impact and road importance to determine appropriate strategies for mitigating impacts associated with the construction of forest roads (taken from Robinson et al. 2010).

To conclude about roads, some experts have said that hinterland roads are the single most ecologically damaging type of back-country infrastructure. If that is true, how can we minimize the length of new road developments and locate what we absolutely need for least ecological intrusion?

The discussion on cumulative effects (CE) covered the following topics: what are CEs; why take CEs seriously; how to think about CEs; and demands on CE assessment (see Duinker and Greig 2006; Duinker et al. 2013).

Regarding CEs, I related the following definition: when one human action stresses a Valued Ecosystem Component (VEC) along multiple pathways, or when multiple human actions stress a VEC along the same pathway, CEs on the VEC occur.

I presented a typology for CEs that included additive, compensatory, synergistic, and masking effects. Then I stated that all ecological effects in nature are multiply determined, so a prudent approach is to consider all effects in an environmental assessment to be cumulative unless demonstrated conclusively to be otherwise. I suggested that in thinking about CEs, rather than ask what are the effects of road X on VECy, it is better to ask what are the effects on VECy from road X and other stressors. I related the example of the multiple stressors acting upon the population of mainland moose in Nova Scotia (NSDNR 2007).

A final thought in the presentation was this: if we really care about sustainability of VECs, we will proceed with incisive landscape-scale foresight and strong mitigation, thus treading lightly and smartly!

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8. *The BC Natural Resource Road Act project: Proposed changes to road administration as we know it*

Presenter: Wayne Hagel, RFT, BC MFLNRO, Victoria BC
wayne.hagel@gov.bc.ca

Co-Author: Tom Bradley, RFT, Woodlot Forestry Services Ltd, Winlaw BC
tomb@netidea.com

When implemented, the *Natural Resource road Act* (NRRA) will create a single uniform approach to the management and administration of resource roads in BC by harmonizing the existing enactments grant that applies today. The presentation given by Wayne Hagel gave insight into the proposed models including; permit requirements, contribution to road maintenance costs, development of the practice requirements, opportunities to keep more roads open, and planned consolidation of information technology systems. For updates and additional information about the NRRA Project visit http://www.for.gov.bc.ca/mof/nrra/

NRRA principles

Harmonize the 12 Acts that currently apply to resource roads to create a single administration regime with uniform:

- Fees and securities
- Practice requirements
- Compliance and enforcement

Proposed permitting regime

- One permit/maintainer per road, eliminating multiple road-use permits
- Continue to have "in block" roads authorized within a licence area, cutting permit, oil/gas well site, linear corridor, etc.
- Create an Aggregate Permit:
    - Authority to occupy the area and remove material
    - For purposes of a resource road, clarify definition of an aggregate pit under the *Mines Act*

Industrial use

- Permit holder maintains road for its intended use as well as those of contributing users (multi-sector)

- Other industrial users must:
  - Notify the maintainer of intended use
  - Contribute a fair amount to the maintainer's cost of road maintenance
- For maintenance contribution disputes, either party can apply to the Civil Resolution Tribunal (under development)
- Government support continues for Road User/Safety Committees (representing employers and stakeholders
- Continue the policy of "resource road (use) is not a workplace" (Occupational Health and Safety Regulation amendment October 2012)
- Establish consistent road-use rules
- Provide a foundation for education and enforcement

Public use

- Open Roads Principle
  - Uniform rules for road use
  - Maintainer's liability to the public (*Occupiers Liability Act (*or NRRA)
    - Not creating a danger with intent to do harm
    - Not acting with reckless disregard for the safety of a person
    - Public willingly assumed risk
- When industrial use terminated, it is a challenge to find ways retaining open roads:
  - Not desirable to add to the inventory of resource roads without a specific road maintainer
  - Allow for a non-industrial user to obtain a road permit for a low-risk road?
    - What's a low risk road? What is a structure?
    - Maintenance capacity of a non-industrial user?
    - What happens when the non-industrial user is no longer interested?

Practice requirements

- Modelled on requirements under;
  - *Forest and Range Practices Act*
  - *Oil and Gas Activities Act*
- Primarily results-based
- Prescriptive components;

    - Peak flow design for road-stream crossings
    - Removal of road-stream structures when deactivating
- Conduct a review to determine if improvements can be derived from:
    - Compliance and Enforcement Program statistics
    - Forest and Range Evaluation Program reports
    - Forest Practices Board reports

Proposed compliance model

- Primarily results-based obligations
- Similar to *Forest & Range Practices Act* and *Oil & Gas Activities Act* until rolled into the *Natural Resource Compliance Act*
- Use of Qualified Persons can form part of due-diligence defense
- The NRRA will provide for:
    - Penalties against an individual responsible, including a Qualified Person
    - Vicarious liability (employers are responsible for actions of their employees)

Records and drawings

NRRA could adopt the *Oil & Gas Activities Act* model:

- Submission of an Audit Report regarding the maintenance of prescribed records may be ordered
- Under the NRRA, prescribed records could include:
    - Plans and as-built drawings
    - Crossing Assurance Statement
    - Conformance Certificate

NRRA proposed timelines

- Have the legislative bill ready for introduction in the Spring 2015
- Act can be brought into force (by Regulations) in the Fall 2015/Spring 2016

NRS road systems consolidation

- Evaluation of the 12 information technology systems used for resource roads amongst Natural Resource Sector ministries
- Review of business needs is underway
- Development/modification of system to support business needs
- A common integrated system that separates road and tenure data
- A seamless linkage of sector systems and applications

- Provide a client-centered user experience for resource roads and tenure
- Collection and sharing of date to meet the business needs of both clients and government
- Systems are expected to be in place by 2017

For more information, refer to the Questions and Answers posted on the NRRA Project web-page. http://www.for.gov.bc.ca/mof/nrra/faqs.htm

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9. *Ecological indicators for access and access management: A wildlife perspective*

Brandie Harding, MSc, Royal Roads University, Victoria BC
bharding@greenwoodenvironmental.ca

Human access into areas of wildlife habitat and the management of that access has become one of the most significant issues in sustaining wildlife populations worldwide. Access management is identified in primary wildlife research and provincial land management plans as the solution for minimizing and managing potential human access effects on wildlife. Yet research is limited on the status of access, implementation of access management, and measures of progress for achieving the goals of access management.

The focus of this research project was to identify measurable attributes or indicators of access to characterize access management and for environmental inventory, monitoring, assessment, and evaluation of access management programs.

Based on a review of the literature, resource management plans and provincial management strategies, this research identified and described fifteen potential ecological indicators for measuring and monitoring human access and access management. These include:

- human development rate,
- linear density,
- distance to development,
- access network structure,
- intact areas or no-access designation zones,
- landscape structure, ecosystem networks,
- species diversity or abundance,
- access closure and restrictions,
- rate of illegal or non-compliant activity, and
- rate of motorized activity, focal species, habitat effectiveness, core areas, and rate of human-caused wildlife mortality.

Five key findings were summarized from this review.

(1) Meaning and implementation of the term ‘access management’ remains vague and ambiguous.

(2) Measures of human access are often tied to large mammal management and studies.
(3) Access management is a big question, encompassing cumulative impacts, and when viewed from a systems approach should consider ecological indicators across multiple levels of biological organization.
(4) Attention is brought to two sub-types of indicators to monitor access management, land use indicators and wildlife use indicators.
(5) Ecological indicators of access and access management share one similar building block, GIS access infrastructure data.

Reference

Harding, B. 2013. Ecological indicators of access and access management: A wildlife perspective. MSc thesis, Royal Roads University. http://dspace.royalroads.ca/docs/handle/10170/588

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10. The missing link: Roads as an afterthought in cumulative effects assessment

Presenter: Bill Harper, Stantec Consulting Ltd., Sidney BC
bill.harper@stantec.com

Co-Authors:
Derek Ebner, Associate and Regional Wildlife Lead, Stantec Consulting Ltd., Calgary AB
derek.ebner@stantec.com

Lindsay Giles, Stantec Consulting Ltd., Calgary AB
lindseygiles@stantec.com

Steve Parker, GIS Analyst, Stantec Consulting Ltd., Sidney BC
steven.parker@stantec.com

The current rate of resource development, including transmission (i.e., pipelines), across Western Canada is providing many challenges to regional planners, regulators and stakeholders. Balancing needs for a variety of users puts pressure on existing road networks to provide access for resource extraction, construction/operations, hunting, recreation, etc. Challenges arise in the environmental assessment process when practitioners attempt to quantify the pressure (i.e., environmental, social) on existing and proposed road networks and predict future effects due to further resource development (i.e., cumulative effects).

To assess the cumulative effects of anthropogenic activities, road-specific data requirements (i.e., current and future traffic volumes, route planning for future access) need to be met in order to assist the assessment of direct and indirect effects due to roads. These data are rarely available, however. Beyond inadequate inventory of the location and ownership status of resource roads, information on traffic volumes is typically only available for provincially numbered highways and county roads. As well, what would be assumed to be accessible data, such as project-specific plans for access, is typically missing from environmental assessments, as the permit process for roads is not always linked to the overall project. Additionally, regional planning objectives for access management do not always have firm guidelines for proponents, which can lead to complications for cumulative effects assessments. An overview of the challenges and recommendations for practitioners to facilitate the incorporation of roads into the overall cumulative effects assessments process was discussed.

11. Resource road removal as an option for conservation offsets: Opportunities and challenges

Presenter: Bill Harper, Stantec Consulting Ltd., Sidney BC
bill.harper@stantec.com

Co-Authors:
Colleen A. Bryden, Stantec Consulting Ltd., Sidney BC
colleen.bryden@stantec.com

Victoria M. Stevens, Stantec Consulting Ltd., Sidney BC
Victoria.stevens@stantec.com

Conservation offsets are increasingly being used to compensate for residual environmental effects (e.g., habitat loss and fragmentation) associated with major industrial projects. Conservation offsets are implemented within regulatory and policy regimes such as Environment Canada's Operational Framework for Use of Conservation Allowances, and the Province of BC's Environmental Mitigation Policy. For some species, closing or deactivating and removing legacy resource roads can be an effective means of offsetting the adverse residual effects of a project. For example, core security habitat for grizzly bears is typically defined as being greater than 500 m from open roads, therefore closing roads to motorized vehicles is an obvious way to improve security and reduce grizzly bear mortality risk.

Common techniques for blocking vehicle access include the placement of gates, boulders, berms, ditches, and logging slash (rollback). Recently however, typical road closure techniques have been identified as largely ineffective at preventing access by all-terrain vehicles.

Resource road deactivation and total road removal is potentially a more effective technique to improve habitat conditions and reduce wildlife mortality risk. Road removal is defined as the complete removal of drainage structures, ripping of the roadbed, full to partial recontouring of hillslopes, and revegetation of the right-of-way with native vegetation. The goal of road removal is to prevent all vehicular access, and to restore ecological function and landscape processes. Roads that are removed will not be passable to vehicular traffic, and will not require any future maintenance to prevent landslides, soil erosion, or siltation of adjacent waterbodies. However, the early stages of habitat restoration on deactivated roads can have unintended consequences if revegetation creates a forage source that may trigger a change in predator-prey dynamics (e.g., the attraction of moose into caribou habitat, followed by an increase in wolf predation risk to the caribou). One technique for reducing predation rates on deactivated roads is to reduce line-of-site with the introduction of visual and physical barriers (e.g., logging slash, berms, and dense tree plantings).

The Northern Gateway Pipelines Project intersects the ranges of both woodland caribou and grizzly bear. Northern Gateway Pipelines recognizes that linear feature developments such as the pipeline Rights of Way and associated access roads can have negative effects on these species. Northern Gateway Pipelines has committed to no net increase in linear feature density in sensitive caribou and grizzly bear habitats. To achieve no net increase in linear feature density, conservation offset (habitat compensation) programs will be undertaken to restore caribou and grizzly bear habitat in areas that had been disturbed by other human activities such as logging, mining, and oil and gas exploration.

Challenges to using linear feature removal for conservation offsets include:

- identifying the magnitude of the offset (e.g., how many kilometres to remove);
- identifying and addressing potential ‘side effects’ (e.g., moose and wolf attraction);
- managing stakeholder involvement and public perception; and
- managing the implementation, complexity, and effectiveness of monitoring the performance of conservation offsets.

12. *Using the Recreation Opportunity Spectrum to evaluate the temporal impacts of timber harvesting on outdoor recreation settings*

Presenter: Howie Harshaw, PhD, Faculty of Physical Education and Recreation, University of Alberta, Edmonton AB
harshaw@ualberta.ca

Co-Author: S.R.J. Sheppard, PhD, Faculty of Landscape and Architecture Program, University of British Columbia, Vancouver BC

The relationships between outdoor recreation settings and resource roads are complex. Resource roads provide access for outdoor recreation activities, but can also alter the character of the places that people seek for recreation activities, particularly in backcountry settings. Strategic planning tools are needed to provide structured approaches for assessing road networks and their relationship to outdoor recreation settings.

This presentation describes a novel method for assessing the impacts of resource roads on the diversity of outdoor recreation settings using a temporally dynamic application of the recreation opportunity spectrum (ROS). The ROS is a management tool that delineates the diversity of outdoor recreation settings based on landscape features and infrastructure elements, such as roads and harvested areas. Harshaw and Sheppard (2013) provide details about the approach and case study; this summary provides a brief description.

The GIS- and model-based approach presented permits the quantification of potential resource development impacts on recreation settings. This temporally dynamic, spatially explicit approach allows the measurement of the diversity of recreation settings and an evaluation of the effects that resource development activities, such as road building, can have on recreation settings. This method enables evaluations of different resource management approaches, such as forest harvesting scenarios, through a systematic assessment of road building and deactivation, and their effects on outdoor recreation for defined planning horizons.

The use of visual dynamic maps allows managers and stakeholders to understand the relationships between road building/deactivation and outdoor recreation settings, and can facilitate the integration of outdoor recreation opportunities into forest certification processes such as sustainable forest management. This presentation uses an example of two timber harvesting scenarios in Northeastern BC to visually demonstrate the spatial and temporal relationships between road building/deactivation and outdoor recreation settings. The example used here highlights the vulnerability of backcountry recreation settings to resource development activities, including road building, that do not incorporate recreation opportunities into management planning decisions.

Management implications

This paper presents a novel method for assessing the diversity of outdoor recreation settings in a commercial forest using a temporally dynamic application of the ROS. The advantages for management are the following:

- The method enables the evaluation of different forest management scenarios and their effects on outdoor recreation for various defined planning horizons.
- It enables managers to integrate outdoor recreation settings into planning at a very early stage.
- It facilitates the integration of outdoor recreation into certification processes such as Sustainable Forest Management (SFM).
- The method is particularly useful in large areas of managed forests that lack quality data about outdoor recreation use and characteristics, but are committed to the maintenance of backcountry condition, because the approach is able to quantify and forecast outdoor recreation settings and associated opportunities. The addition of the temporal element achieves this and addresses one of the main criticisms of the ROS.

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For more information, go to Dynamic Recreation Opportunity Spectrum Modelling page on the Human Dimensions Research web-site http://www.hd-research.ca/ros

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13. Legacy Roads – some observations using an example from Castlegar, BC

Peter Jordan, PhD, Research Geomorphologist, BC MFLNRO, Nelson BC
Peter.Jordan@gov.bc.ca

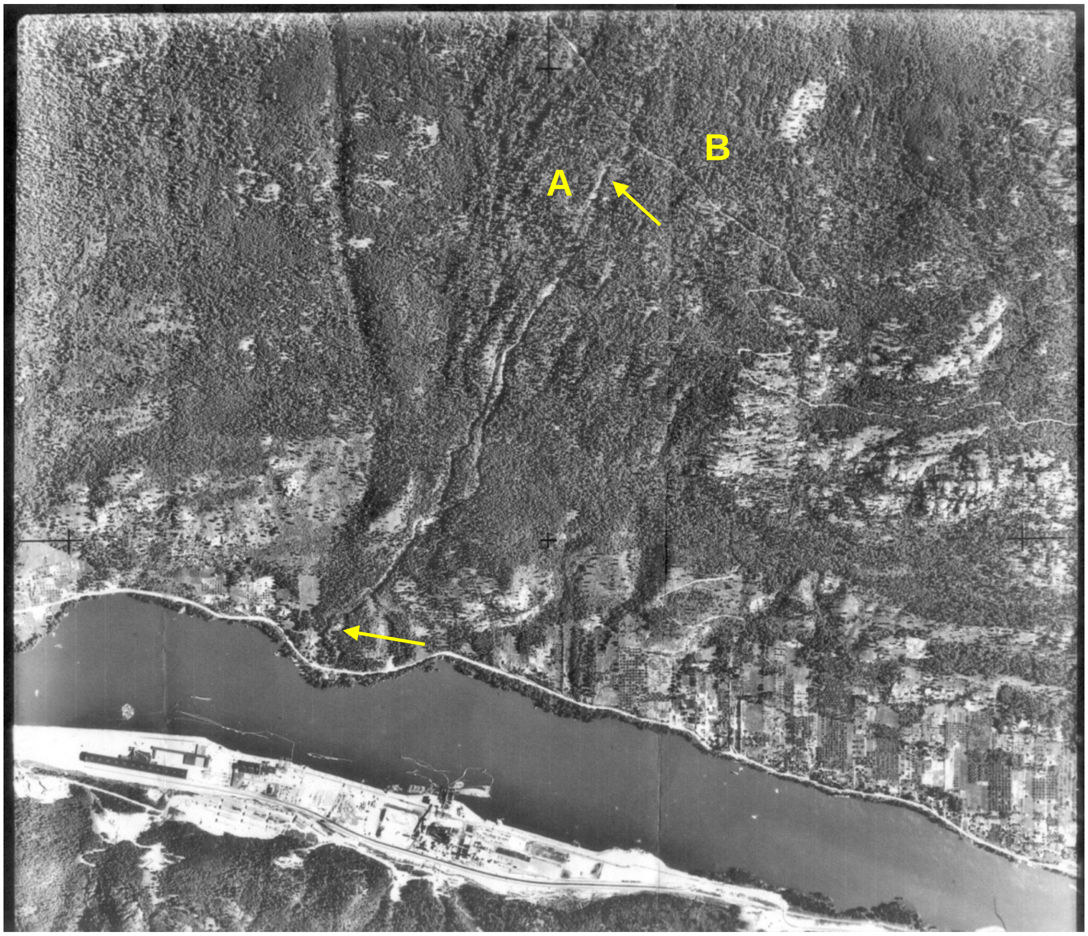

Figure 1. Image: 1961 air photo.
(A) Landslide and debris flow in the 1950s reached an alluvial fan (Balfour Creek) on the Columbia River. The landslide started below a forest road (**B**), which at the time provided the main access for logging on the plateau north of the river.

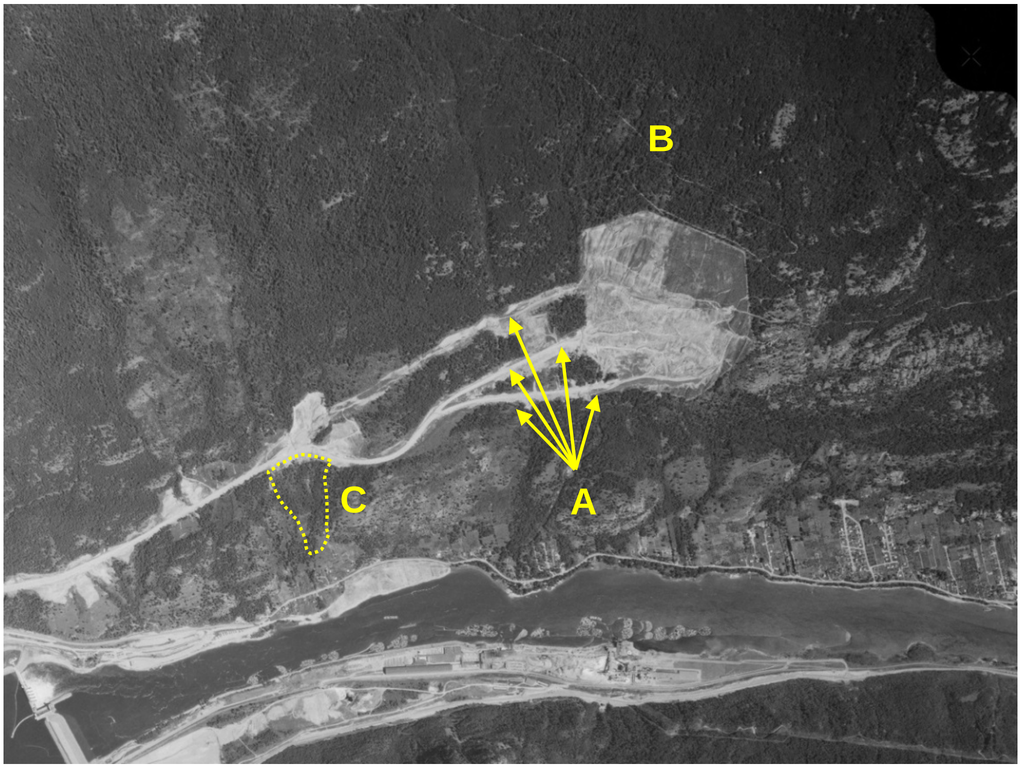

Figure 2. Image: 1969 air photo.
In the 1960s, a dam (the High Arrow, or Hugh Keenlyside, dam) was constructed on the Columbia River. A highway-calibre road was constructed to access a borrow pit, the source of fill used to build the dam. The road and its various branches cross both forks of Balfour Creek (**A**) with large fills. The road is on Provincial Forest land, and after completion of the dam, ownership of the road was transferred to the BC Forest Service.
Note the forest road (**B**). Note the new subdivision being built downslope on the alluvial fan. Also, construction of the 1960s road reactivated an old, slow-moving landslide (**C**).

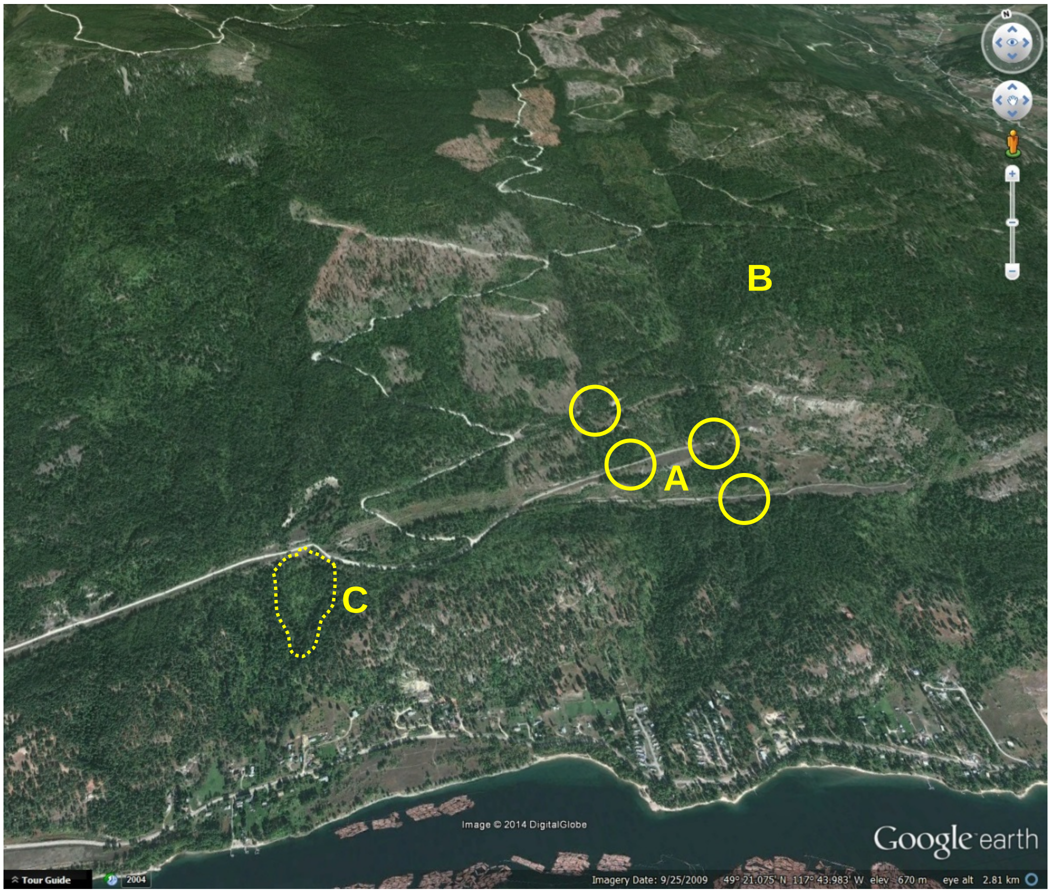

Figure 3. Image: Google Earth from 2009 orthophoto (oblique view). Fifty years after construction, the culverts on the road fills (**A**) have deteriorated, and the fill material must be removed by the Forest Service at great public expense, to prevent the risk of debris flows or outburst floods. Note the dense residential development on the alluvial fan below. The old (1960s) forest road is now almost invisible on air photos (**B**). A network of newer roads has replaced it. Following logging of the slope above, the landslide (**C**) was stabilized by BC Hydro in the 1960s (and was then 'forgotten'). However, the landslide at (C) resumed movement in 2011, cutting off the active road and threatening the residential area below. Area (C) has now been stabilized at considerable public expense.

Figure 4. Image: recent photo.
Sixty years later, the original forest road is still there, and so is the drainage diversion that caused the landslide in the 1950s.

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14. Can citizen science help address the conservation challenges presented by resource roads?

Presenter: Tracy Lee, MSc, Senior Project Manager, Miistakis Institute, Mount Royal University
tracy@rockies.ca

Co-Author: Danah Duke, MSc, Executive Director, Miistakis Institute, Mount Royal University

Addressing the complexity of environmental problems, such as monitoring the impacts of resource roads on the environment, requires the development of new approaches and frameworks where citizens, academics and decision-makers work jointly to understand and address issues of significance. Ultimately, making science-based information more accessible requires an exploration of new approaches to integrate public participation in scientific research, often referred to as citizen science. Based on this premise, we present two case studies, Road Watch in the Pass and Collision Count, from southwestern Alberta that used a citizen science approach to inform and address the issue of safe passage for wildlife across a busy transportation corridor.

Our results demonstrate the potential/benefits of using a citizen science framework to address a conservation challenge, e.g. the public's ability to collect useful data, development of an open source interactive mapping tool and smart phone app and successfully engaging citizenry in a local conversation challenge. We also identify important lessons for improving the success of a citizen science approach, including clearly developing project goals and objectives, understanding the needs of a community, defining success and evaluation metrics and engaging and motivating volunteers through regular communication and clearly articulated goals.

Building on our results from Road Watch we offer considerations for the application of citizen science programs to assist with monitoring of resource roads in remote areas as a means to mitigating road-related environmental impacts.

Background

Engaging citizens in environmental research has many societal benefits including promoting awareness of local environmental issues, building community capacity to enhance public involvement in stewardship, fostering an environment for a stronger public role in decision-making, and generating data at a lower cost than conventional science. Many of today's environmental problems require the development of new approaches and frameworks where citizens, academics and decision makers work jointly to understand and address environmental challenges. Recent critiques of the ability of science to provide information in a timely, efficient manner, and of a quality to address increasingly complex environmental issues, emphasize the importance of exploring alternative approaches to knowledge generation and sharing (Cohn 2008; Danielsen et al. 2009; Irwin 1995). Ultimately, making science-based information and processes more accessible and fluid (the democratization of science) requires the development of mechanisms to engage citizens in research to inform environmental (Bäckstrand 2003; Carolan 2006).

Certain fields have a continued history of engaging and being informed by citizen experts, such as astrology and natural history. In recent years there has been a renewed interest in citizen engagement and today there is a proliferation of research projects, with a component involving citizens, aimed at addressing a diversity of environmental challenges such as climate change, road ecology, invasive species and water quality, human use and wildlife monitoring (Morisette et al. 2008; Lee et al. 2010; Crowl et al. 2008; Gallo and Waitt 2011; Cooper et al. 2007; Sharp and Conrad 2006; Weckel 2010). The explosion of research involving the public is due to factors such as new emerging technology making communication, data collection and dissemination of information more fluid and assessable, appreciation of the benefits of engaging the public in science and their potential role as concerned informed citizens for addressing an environmental challenge and the realization that the public can be a large source of experienced, free labour and in certain cases a financial contributor (Jordan et al. 2011; Silvertown 2009).

There are also many perceived challenges to engaging the public in science, such as the integration of data collected by citizens into scientific process, ensuring data quality, difficulties of working with volunteers and maintaining their engagement and quantifying success (Bonardi et al. 2011; Conrad and Daoust 2008; Galloway et al. 2006; Kremen et al. 2011; Schmeller et al. 2009;

Whitelaw et al. 2006). Many of these issues should be addressed in the planning and research design phase of program development.

Case studies

Here we highlight two case studies developed by the Miistakis Institute of Mount Royal University, Road Watch in the Pass and Collision Count, both developed to address human wildlife conflict and the impact of a major transportation corridor on wildlife. The case studies are presented to highlight the success and role of engaging citizens in a conservation issue. The impacts of roads include both direct mortality from wildlife collisions with vehicles and impacts on connectivity for species that need to access habitat and mates on both sides of the highway. Both projects take place along Highway 3 in southwestern Alberta, a transportation corridor that supports over 6,000 vehicles a day. The region supports the full complement of large mammals and wildlife vehicle collisions are common. Avoidance behaviour from carnivore species has been identified as a concern (Proctor et al. 2012).

Road Watch in the Pass was developed in 2005 to enable citizens from the region to enter their wildlife observations into an interactive mapping tool so that wildlife vehicle collision hotspots could be identified. Over a five year period, over 5,000 observations were reported to Road Watch, and the data was used along with other datasets to identify high collision zones (Lee et al. 2010). The program was initiated and supported financially by the Miistakis Institute for the first five years. Currently, the program continues to be run by local volunteers, and has shifted focus to be more educational and stewardship based. The information collected by Road Watch participants contributed to the identification of mitigation sites along Highway 3 along with recommendations of strategies to ensure safe passage of wildlife across Highway 3 (Paul et al. 2014; Clevenger et al. 2010; Lee et al. 2010).

Miistakis and its partners, the Western Transportation Institute and Yellowstone to Yukon Conservation Initiative, are now working with Alberta Transportation (AT) and Alberta Environment and Sustainable Resource Development (AESRD). Together, they will implement mitigation recommendations at two of the priority mitigation sites identified along Highway 3. Miistakis and partners have committed to pre and post construction monitoring at the mitigation sites. The importance of monitoring can not be understated as it is important to understand the effectiveness of mitigation. To accomplish this task, a new citizen science projected called Collision Count was recently developed. Collision Count consists of a series of marked transects parallel to the highway right-of-way which are walked by volunteers once a week. Volunteers use their smart phones and the Collision Count mobile phone app to indicate which transects they are walking and to record road kill observations along specified routes.

For all road kill observations participants report on the species, number of animals, visibility of the carcass from the highway, and if necessary, a photo is uploaded to assist with carcass identification. Over time, the volunteers will generate a dataset of road kill observations that can be used to calculate the rate of wildlife vehicle collisions occurring at the mitigation site, the cost of the collisions to society and a correction factor for mortality data collected by highway maintenance contractors. Currently, wildlife mortality is under-reported as in addition to carcasses collected and documented directly from the roadside many animals that have been struck by motorized vehicles wander off and succumb to injuries out of sight from the roadway. The calculation of a correction factor using data collected from Collision Count will provide a valuable contribution to road ecology.

Both projects make use of open source technology to enable efficient data collection and in the case of Road Watch the ability to display results back to participants (Figures 1 and 2).

Figure 1: Mapping tool interface, with a data point as an example

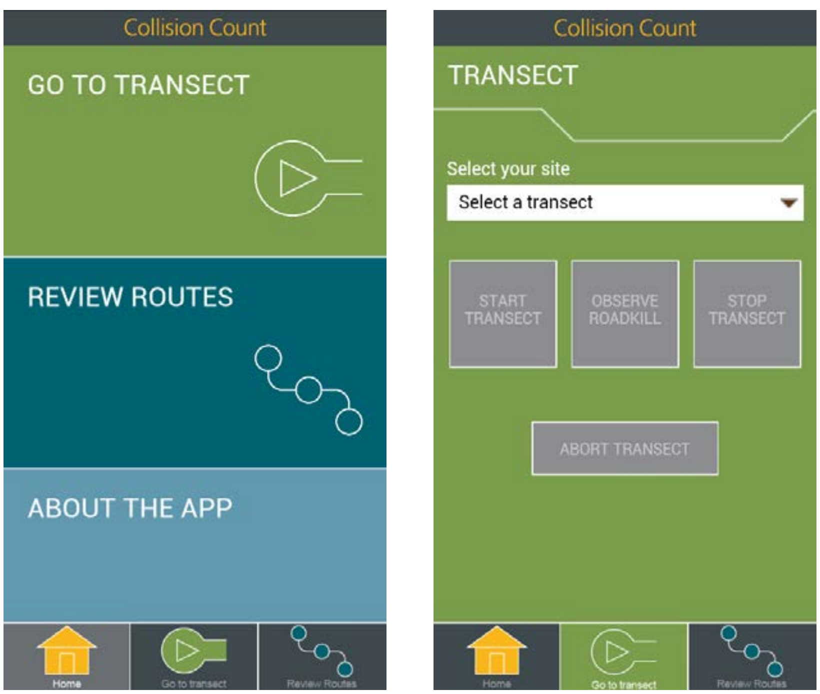

Figure 2: Smart phone app screen shot of home page and transect page

Application to resource roads

The impacts associated with resource roads are numerous, and likely the issues associated with these types of roads would benefit from increased community understanding of the challenges resource roads pose on ecosystems. There are citizen science programs that involve monitoring road kill (Lee et al. 2010), invasive species (Crowl et al. 2008; Delaney 2008; Gallo and Waitt 2011), trail conditions, hanging culverts and water characteristics (flow rate, temperature and some basic quality measures) (Cooper et al. 2007; Sharp and Conrad 2006) all of which are impacts relevant to resource roads.

There are however numerous considerations prior to the development and implementation of a citizen science program, such as:

- development of clear program goals and program outcomes;
- define program success and determine evaluation methodology;
- determine if there is an appropriate and meaningful role for volunteers; and
- understand the motivation of volunteers and design a program that will motivate and engage volunteers in a meaningful way.

Citizen science offers a framework that engages volunteers in the scientific process; which offers the potential to enhance our ability to monitor impacts while also building a community of concerned citizens.

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15. Managing environmental and human risks with resource road asset inventories

Lindsey McGill, P.Eng, RPF, Chartwell Consultants Ltd., Vancouver BC
lmcgill@chartwell-consultants.com

Aging resource road networks were originally built for quick access with little thought given towards long-term implications. Now that we are revisiting these areas – whether it be to chase second growth timber or to perform maintenance on infrastructure – we are asking ourselves who is liable? Is the road under permit, is it a Forest Service Road, a non-status road, or is it privately owned? What types of vehicles use the road and what areas are most at risk?

With increasing pressure from multiple road users, it is inevitable that there will be conflicting interests. Due to the aging infrastructure and the conflicting needs of multiple users, a detailed inventory is invaluable in managing risk.

Risks are generally defined by the road tenure holder and tend to include risks to the environment, wildlife, road prism, and assets (bridge, pipeline, hydro towers…etc). Water is generally the damaging agent and if properly controlled, limits risk. It is important to remember that risks can come from above and below when conducting an assessment. It's also important to remember is that 'Undersized Assets = Liabilities'.

Having a detailed access inventory can prevent costly power interruptions for a gas, electric or water utility.

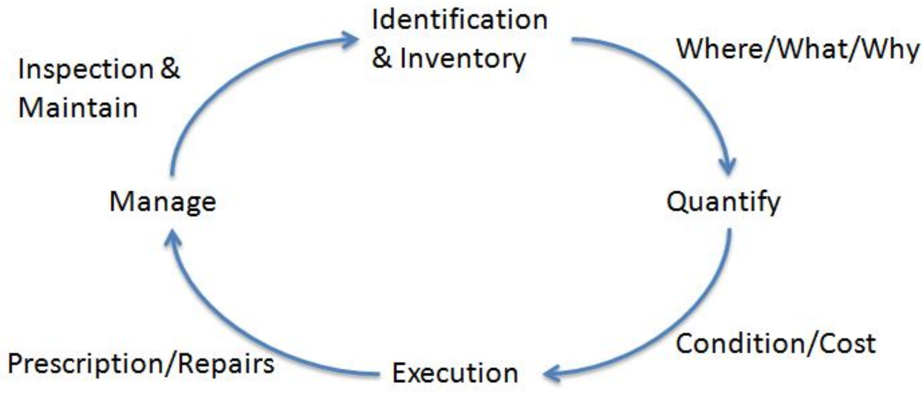
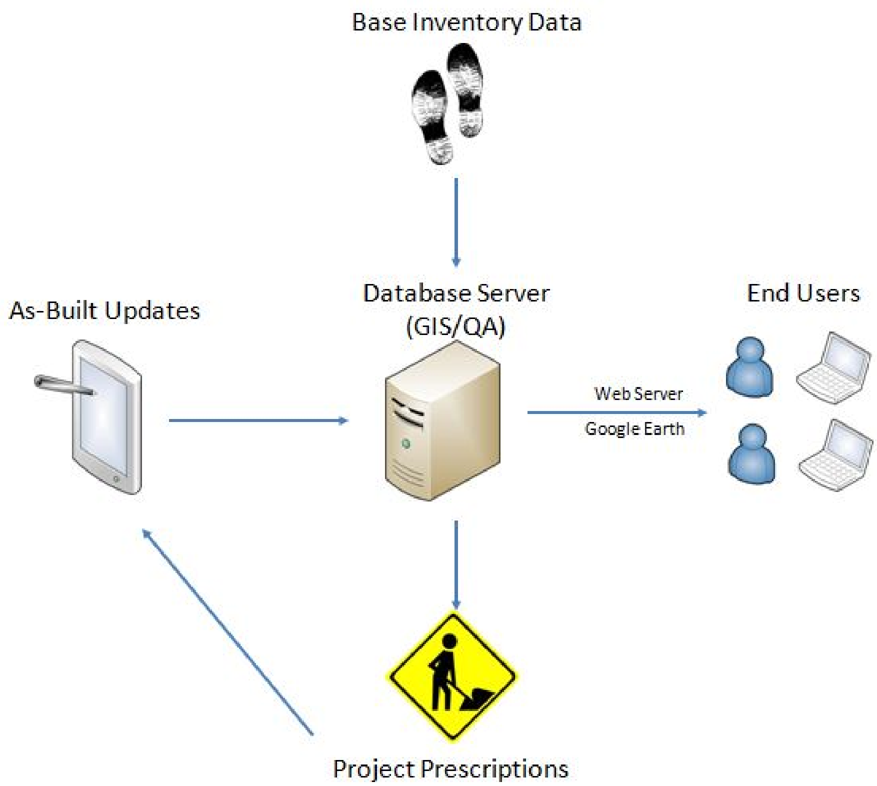


Figure 1. Managing risk in a process framework.

Start with asking ‘What information do you have?’ and ‘What information do you want…and where?”. You will need to prioritize what you want to track versus maintain. There is rarely enough funding to conduct all required works immediately, instead you must focus on remediating those risks that result in the largest consequence (whether environmental, safety or other). There are a number of online databases available to the public such as open roads, digital road atlas, forest tenure administrations…etc. It is important to identify what information you want and where you want to start as this will define the data collection methods and user interface features of your database. LiDAR is a good data collection method but it cannot detect buried structures. Nothing replaces having ‘boots on the ground’.

Data is generally collected with sub-meter GPS linked to a database server. Conditional information is regularly updated and risk is allocated based on a simple Hazard and Consequence matrix. Data outputs can be catered to the users needs and vary depending on end use (field maps, Google Earth, geo-referenced PDFs, etc).



In summary, effective risk management comes from:

- Knowing what assets you have (and where they are)
- Clearly defining risk as it relates to you or your business
- Considering the level of risk are you willing to accept?
- Prioritizing work within risk and budget constraints
- Repairing/ decommissioning/ controling access accordingly
- Updating inventories as changes are made

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16. Linking upslope management actions to in-channel sediment and wood attributes across the US Northwest Forest Plan area

Presenter: Stephanie Miller, MSc, Aquatic Riparian Effectiveness Monitoring Program Leader, US Bureau of Land Management and US Forest Service, Corvallis OR
smiller@blm.gov

Co-Author: Rebecca Flitcroft, PhD, US Forest Service, Pacific Northwest Research Station, Corvallis OR
rflitcroft@fs.fed.us

Introduction

Monitoring that informs management is an important topic of action and debate in the Pacific Northwest, and elsewhere. Monitoring that can summarize conditions at multiple spatial extents is critical for informed management action over broad spatial extents. However, developing and implementing techniques and tools that make monitoring efficient and informative is challenging and expensive. In the early 1990's, agencies in the Pacific Northwest, tasked with the management of land owned by the US federal government, came together under the Northwest Forest Plan (NWFP).

The mission of the plan was to enhance habitat across the range of the Northern Spotted Owl (*Strix occidentallis caurina*). Founding principles of the NWFP included the Aquatic and Riparian Conservation Strategy (ARCS) that was designed to halt declines in watershed condition, protect quality habitat and healthy fish populations, and ultimately establish a network of properly functioning watersheds to support aquatic and riparian dependent species (Reeves et al. 2006). Monitoring that informed management was a critical element of the NWFP leading to the development of the Aquatic and Riparian Effectiveness Monitoring Program (AREMP). Monitoring data used by AREMP includes comprehensive remotely sensed data, and field data that are collected using a rotating panel sampling framework of watersheds with at least 25% federal ownership (Figure 1). These two data sources have provided the means to evaluate the effectiveness of the NWFP, and characterize watershed condition. This has proven particularly useful at comparative analysis among watersheds with different levels of degradation due to human land use.

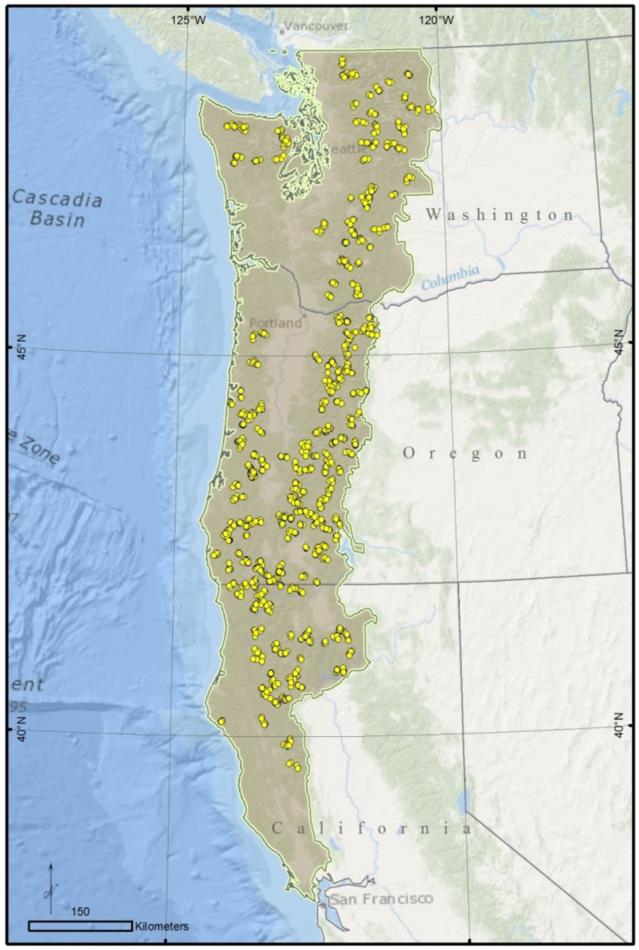

Figure 1. The extent of the Northwest Forest Plan (NWFP) includes areas in the states of Oregon, Washington, and California. Aquatic and Riparian Effectiveness Monitoring Program (AREMP) survey sites are distributed throughout the area of the NWFP in watersheds with greater than 25% federal ownership.

Roads analysis

One element of the monitoring done by AREMP has been a synthesis of the effect of roads on aquatic habitat condition. Roads are known to directly affect stream condition by increasing fine-sedimentation rates (Trombulak and Frissell 2000), and by creating barriers to migration at poorly designed culverts (Furniss et al. 1991). A broad suite of characteristics have been considered by AREMP to evaluate watershed condition and links to upslope landscape-level road management across the NWFP area.

Analysis of the effect of roads on in-stream habitat condition required the acquisition of both remotely sensed dataset, and information gathered on site by field crews. The focus of this work is at the watershed-scale. Because the work by AREMP is intended to evaluate federal land management, only watersheds with at least 25% federal ownership were included in the original sample frame (Figure 1). In-channel stream data were collected as part of probability sampling design (i.e., Messer et al 1991; Stevens 1994.) in which sites are surveyed every eight years. The spatial scale of the sampling design is the watershed, with multiple sites sampled within a watershed that are then used to characterize watershed condition. The range of natural variability in watershed condition was assessed for watersheds with minimal human use across the sampling area (NWFP).

This assessment of the range of conditions present in the least disturbed watersheds (minimally managed or reference) provided the context to assess condition throughout the NWFP area. As part of this assessment, reference watersheds were compared with highly impaired watersheds at two spatial scales: whole watershed and 2km watershed levels (Figure 2). The relationship between in-channel fines less than 6mm, large wood (30cm x 7.6m & 45cm x 7.6m), and watershed condition in minimally managed (reference) versus impaired watersheds was evaluated. Impaired watersheds were further classified into watersheds with high road density and high frequency of road-stream crossings, at the two spatial scales, and in-channel attributes compared against reference controlling for both gradient and bankfull width.

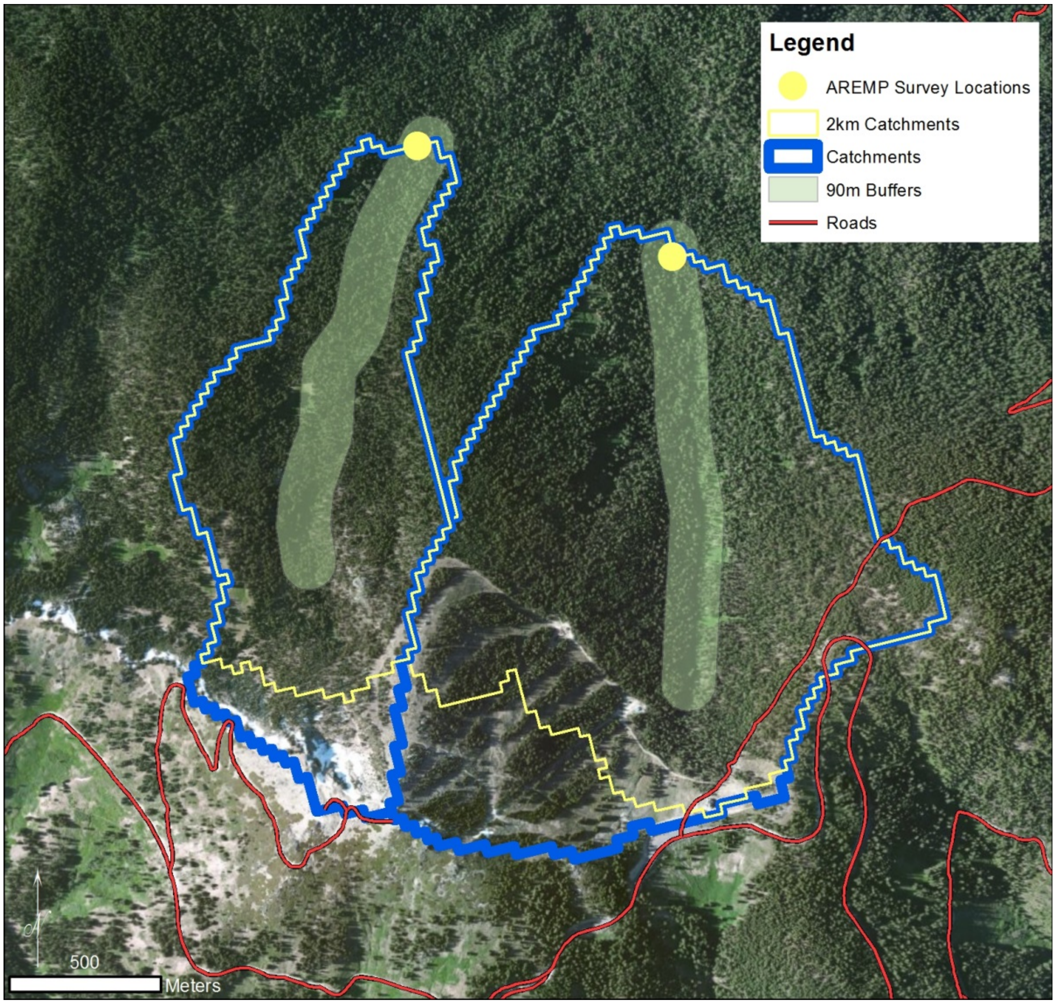

Figure 2. This figure shows two watersheds monitored by Aquatic and Riparian Effectiveness Monitoring Program (AREMP). We used a Digital Elevation Model around the stream layer to define the area that “pours” into the survey point, henceforth referred to as a watershed. The watershed and 2km level polygons were used to summarize road density and road stream crossings (among other parameters also used to define reference).

Regardless of scale, watersheds with high road density or road-stream crossings have more fine sediment and fewer pieces of large wood than reference watershed. Watershed condition scores are higher (better) at reference sites than impaired sites (Figure 3). Overall, watershed condition has improved since the Northwest Forest Plan ARCS was enacted. Additional analysis indicates that legacy management conditions (pre-NWFP) continue to effect current stream condition. Legacy management that was used specifically relates to historic log drives. Historic log drives resulted in higher amounts of fines less than 6mm compared to areas without log drives. Even after controlling for roads, we found a significant relationship exists suggesting that historic landscape level disturbance can still affect current stream conditions.

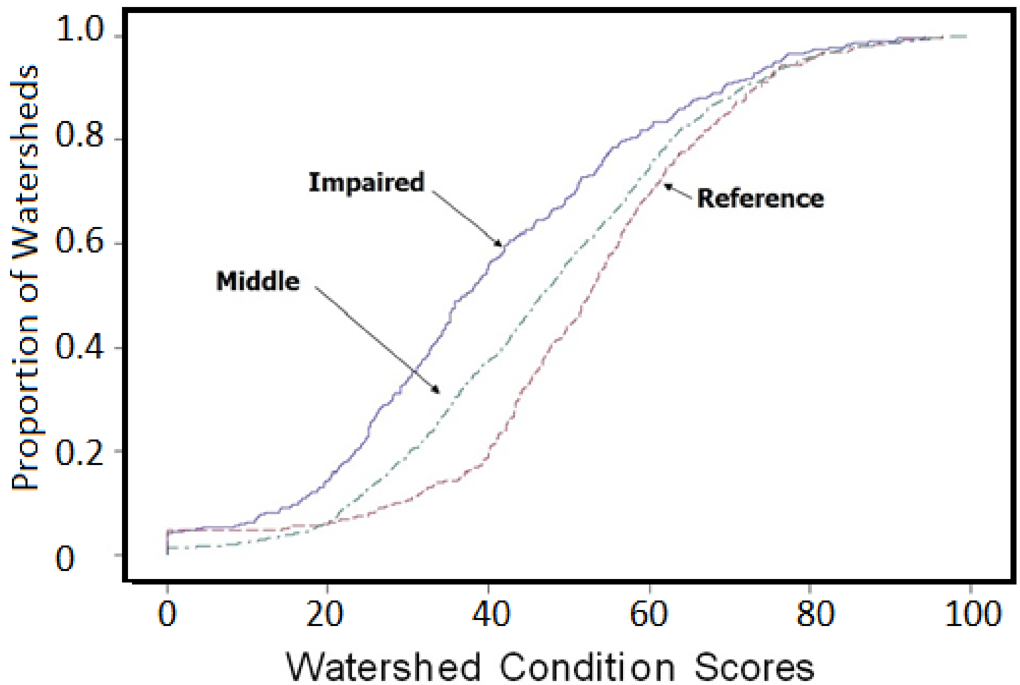

Figure 3. This cumulative distribution function shows the proportion of watersheds across the Northwest Forest Plan area (y-axis) at different watershed condition scores (x-axis). Here, only about 20% of the reference watersheds have watershed scores below 40, whereas 60% of impaired sites have watershed scores below 40. Middle represents all watersheds that ranged between impaired and reference in terms of human disturbance; 30% of these watersheds scored below 40. Higher scores represent better watershed condition.

In summary:

- Current GIS and remote sensing data were used to summarize road management at the watershed and smaller 2km watershed scale.
- Expectations of watershed condition were developed using a robust network of minimally and extensively managed sites.
- An evaluation tool was developed to estimate watershed condition. This tool was trained on minimally managed watershed data (referred to as reference watersheds).
- Reference watersheds had significantly higher (better) median watershed condition than impaired watersheds.
- Overall, watershed condition has improved since the ARCS was implemented in 1993.
- Watersheds with high road densities have more fine sediment.
- Watersheds with more road-stream crossings have fewer pieces of large wood.
- Results were similar regardless of scale.
- Preliminary analyses suggest that legacy land management practices, such as log drives, can significantly influence current stream attributes (here, fine sediment).

Conclusion

At the inception of the NWFP Aquatic and Riparian Conservation Strategy, roughly 139,000 km of roads and 21,600 road-stream crossings were recorded on federal land. Since then, few additional roads have been built and many have been deemed unusable due to a lack of resources for maintenance. Approximately 9,000 km of roads have been intentionally closed or decommissioned, thereby constraining recreational access.

The BC government is in a phased process of implementing a *Natural Resource Road Act* (NRRA) aimed to create sound environmental stewardship while improving industrial competitiveness, supporting rural economic sustainability, and reducing costs borne by taxpayers. These principals are quite similar to those set forth to guide the development of the Northwest Forest Plan. The AREMP's demonstrated comrehensive experience with effectiveness monitoring and data analyses has allowed for successful evaluation of watershed condition and may be a useful model to be used with BC NRRA.

AREMP continues to leverage evolving GIS derived data to further explore landscape level patterns and their relationship to in-channel data. The results of this study serve to illustrate how typical measures of GIS-defined management data combined with field data can predict in-channel conditions at varying spatial extents. We would welcome future collaboration with the BC professionals as they design and implement a watershed monitoring program.

Acknowledgements:

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17. Legacy roads and the long term concerns about terrain stability: Mitigating the risks

Wayne Miller, P.Geo. Eng. L., Engineering Geologist, Principal, Sitkum Consulting Ltd., Nelson BC
sitkum@telus.net

Legacy roads and the long-term concern about their effect on terrain stability in forestry is a complex issue with no single catch-all solution. In this presentation we briefly discuss the history and present-day status of these roads, and how we can approach mitigating the risks as we move forward.

Prior to ~1995, legacy roads were not addressed on a landscape level. Between 1995 and the early 2000's, there were extensive watershed restoration programs funded by government through Forest Renewal BC (FRBC). Started in 1994, FRBC was a funding mechanism that paid for terrain studies and the associated road remediation or deactivation works through stumpage fees; FRBC funding stopped in 2002.

Over the past decade, there have been varied approaches and responsibilities for managing these older road systems. Present-day solutions are *ad hoc.* Professionals *may* identify legacy road issues during planning stages and develop approaches for mitigating hazards and risks, while project owners (e.g., forest licensees or BC Timber Sales) are to follow through with implementing the on-the-ground mitigation actions (*in theory*).

While it is good to have landscape-level plans, without the means to enforce the stipulations contained in those plans, proper practices may not be followed. In the case of the forest industry, *in theory*, these identified issues are being addressed because of the need to minimize risk to other forest resources consistent with Forest Planning and Practices Regulation (FPPR) 82(1)(c)&(d) (BC Government 2014).

The problem with legacy roads at the landscape level is that different stakeholders have different roles, levels of responsibility, and their own approaches for relating to the legacy road issue. Examples include: forestry sector (BC Timber Sales, major forest licensees), energy sector (petroleum, run-of-river, wind); mineral sector; and recreational users (commercial enterprises and public citizens). Due to different agendas, these groups have a variety of attitudes about and methods for planning, building, repairing, maintaining, and monitoring roads (whether they are legacy or recently built roads).

Current problems with managing legacy roads:

a) Off-loading legacy road responsibilities, ”ownership”, and costs. The various players try to externalize costs and thus strive to frame legacy roads as “not-our-problem”. With regards to managing legacy roads, funding is a major issue. In general, government and the private sector resist paying for remediation of legacy roads problems. Ultimately, damages caused by legacy road failures (e.g., landslides) falls on the shoulders of government and the costs of remediation are paid for by taxpayers.
b) Roads deteriorate. Over time, short-term road construction techniques deteriorate and can create long-term problems (e.g., resulting in erosion, landslides, and/ or blocked fish passage).
c) Road inventories. We lack up-to-date comprehensive road inventories. For example, currently, some legacy roads/ trails may not even be on forest cover maps, so roads that are actually on the land are considered a part of the surrounding forest cover timber type.
d) Organizational differences. There are significant differences among staff working for government and industry sectors. Government agencies and staff have political, governance, and cost containment responsibilities (such as selecting low-bid contractors). On the other hand, private companies report to corporate shareholders, and generate profits by maximizing value and/ or minimizing costs (e.g., by using expedient tactics when planning, building, maintaining or repairing roads).
e) Law enforcement. Major government organizations differ in regards to enforcement of road-related laws and regulations. Examples include: Ministry of Energy and Mines; Ministry of Forests, Lands and Natural Resource Operations; BC utilities (natural gas, electricity); BC Parks; and the Ministry of Transportation and Infrastructure.

It has become clear that the extensive road and trail networks in the backcountry known as “Legacy Roads” create an ongoing problem that requires better management, especially with regards to terrain stability. Difficulties exist for multi-user roads and development areas, where there is no sense of accepting shared responsibility. As well, there is a disconnect between road planning and (1) compliance with road-related laws and regulations and (2) application of road-related Best Management Practices.

In closure, here are some comments about solutions to legacy road issues; it would be a challenge to put any of these suggestions into place.

a) If stakeholders (forest industry, mining, recreational, etc.) want less government regulation and oversight of the land-base, the stakeholders will have to take responsibility for legacy roads. Stakeholders must have the means (funds) for repairing, maintaining, repairing and/ or decommissioning roads.
b) In exchange for long-term tenures, government could provide a break on stumpage or licence fees. Money gathered in this way must be put into a fund that will be dedicated specifically for legacy road management (and not go into government general revenue). Other possible avenues for funding could include: a Transportation Financing Authority; a rebirth of Forest Renewal BC; dedicated taxes; and annual road charges for licence holders (a user-pay system). However, a user-pay system might be difficult to arrange with recreational users.
c) There must be standard protocols and resources (funding and trained staff) for inspecting sites, investigating possible infractions, and enforcing laws and regulations pertaining to resource roads.
d) Beyond laws and regulations, there must be standard approaches for assuring that Best Management Practices are applied when remediating legacy roads or when planning, building, maintaining, repairing and decommissioning new roads.

Reference

BC Government. June 2014. Forest Planning and Practices Regulation, *Forest and Range Practices Act.* http://www.bclaws.ca/Recon/document/ID/freeside/14_2004

Acknowledgements

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18. Access planning for public and commercial recreation — It's a good idea, sometimes

Darcy Monchak, RPF (retired), OneSparrow Images, Golden BC
darcy@onesparrowimages.com

Resource road access can be both a cost and benefit to society. There can often be overlapping user requirements of roads that can result in social conflicts and economic/environmental impacts. Resource managers are often placed in the difficult position of having to reconcile these overlapping requirements, which often involve societal land-use decisions, in addition to their usual operational requirements. There are various options that may assist government and resource managers to deal with these issues.

For many public and commercial recreationalists, resource roads are key to enabling access to vast areas of BC public lands. Such access can take those people into environmentally sensitive areas or bring people into conflict with each other. Impacts can be physical and site specific, but often more importantly, can affect broader landscape values.

Many resource roads provide a fundamental base for the tourism industry, as well as historical valued access corridors into public recreation areas. Such use of these roads provides overwhelming benefit to society. Awareness and designation of these key areas should be part of resource management planning.

Some history

Road-access planning involving recreationalists has been goings on in BC since the 1970s. Back in the day, Coordinated Access Management Planning (CAMP) processes were largely consultative and individual road-based. In many cases, the CAMP approach brought recreationalists into the process to provide user information and assist with final recommendations regarding which roads would be kept open and which would be closed. Such planning processes provided direction to resource managers regarding road deactivation, legal road closures, and in some cases funding efforts to keep roads open (MoF 1989; Carmanah Research 1995).

Later on in BC, all forest licensees were required to include an access management plan with their harvesting plans, and were to enable recreational and other road users to comment on road-access issues. This requirement was later eliminated and today there are no access planning requirements built into most forest tenures in BC.

More recently

Many resource managers recognize the need for road-access planning, especially where the level of recreational use is high. Existing BC regional Land and Resource Management Plans (commonly known as LRMPs) do not provide specific direction regarding road access; however, in some instances, LRMPs do provide guidance regarding where lower-level access planning may be necessary.

There are a number of areas in BC where government and resource managers have developed strategic recreational access management plans. Some of these plans are similar in process and results to the aforementioned Coordinated Resource Management Plans. However, some of these plans break some new ground in developing recreational land use zonations that seek to resolve conflicts between recreationalists as well as give direction for the status of resource roads.

One such plan was developed for the 900,000-hectare Golden Timber Supply Area (TSA). In general, land areas around Golden are experiencing steady growth in the outdoor recreation sector in terms of public and commercial, and motorized and non-motorized activities. There are opportunities to manage this growth so that it best contributes to the provincial economy while supporting social and environmental values, and so that the growing number of user conflicts are minimized. The Golden Backcountry Recreation Access Plan (GBRAP) was initiated in 1999 as a proactive decision-making process that would resolve existing and pending recreational issues and establish recreational patterns of use and opportunities throughout the 9,000 square kilometres of the Golden TSA.

Key public and commercial recreational sector representatives have worked with government on this volunteer-driven community consensus-based initiative. The process considers public recreational area and access (often road) requirements, the need to promote and provide certainty for the tourism sector, and the need to conserve important wildlife habitat for the future. By indicating where certain recreational activities can occur, the plan provides a measure of certainty for both tourism development (businesses that rely on commercial recreation directly or indirectly) and public recreation. The plan addresses recreational access only and not industrial access and use (such as timber harvest). The plan gives zonations for both ground and aerial motorized use for winter and summer, as well a zonations for levels of recreational infrastructure (e.g., where backcountry lodges may be built).

The plan outcome is largely reflective of a thorough process of negotiations among stakeholders, where trade-offs were made between different recreational interests. These stakeholders have come to consensus on approximately 93 percent of the plan area, and those consensus recommendations have been wholly incorporated into the plan direction. Consensus was often predicated on the ability to review plan content when new information becomes available.

Similar strategic recreational access plans have recently been developed for other portions of BC, including the Bulkley Valley Cranbrook, Sea-to-Sky, and other areas. Some of these plans are based upon consensus-type negotiations, and others are more consultative. The overall character of each of these plans seems to be determined by the local community (moreso with consensus-type plans), as well as the level of resources available for plan development.

Recommendations for public strategic recreational access planning

Basic road open /road closed planning involving recreation stakeholders is recommended for important recreation areas, and where key social, economic or environmental values are at risk.

Public strategic recreation access planning, which seeks to resolve conflicts between recreational users and provide guidance to road managers, is recommended only for select areas. Such areas should have many of the following criteria:

- recreation is a relatively large part of the local economy.
- there is escalating conflict among recreation user groups.
- road issues compel controversial choices.
- growth in recreation is expected.
- the public wants a say.
- the process is sanctioned by the land base decision maker.
- resources are available to conduct the process.

Consensus-type public strategic recreation access planning processes are more viable if the following aspects are present:

- grassroots community support
- a history of stakeholders working together
- user-groups agree about road closures
- participants are intimate with the geography and issues
- a balance of recreational sectors,
- political end-runs of the process are unlikely.
- the decision-maker is likely to endorse a consensus agreement.

Downsides and upsides

There are downsides to conducting public strategic recreational access planning. The workload is difficult to forecast. If the land owner (decision making body - in BC this is primarily the provincial government) has a low stewardship emphasis or is more centralized, the risks of failure may be higher. For instance, it may be difficult to initiate or carry out an access planning process, or it may tough to get government approval of the plan.

Another downside is the risk of not getting strong recreational sector agreement, an issue more relevant in consensus-seeking processes. Such instances may result in considerable inefficiencies, and even cancellation of plan development. As well, even with plan approval, implementation of plan direction requires strong leadership and monitoring.

There are, of course upsides to conducting public strategic recreational access planning. Better stewardship of the road resource and public and commercial recreation are tangible benefits. Fostering a community long-term vision for recreation is possible. Such a vision protects many key recreational opportunities, and protects important social and environmental values. Such a vision provides "staying power", because local recreational public and commercial users support the plan. Plans that result in consensus will have better leverage to seek government approval.

Operational benefits of successful recreational planning include guidance to industry and government regarding road-access priorities, and streamlining of recreational tenure approval for proposals that comply with the plan. Such plans also provides centralized government with local knowledge.

In summary

Recreational access management is one of the most significant issues affecting land and resource stewardship in the Kootenay Region, and in much of BC. As competing recreational access demands and activities on Crown land increase in intensity, the need to balance competing uses and interests becomes more imperative. There is a need to manage opportunities so that they best contribute to the provincial economy, support social and environmental values, and minimize user conflicts.

Without recreational strategic planning, conflict among resource users will increase is certain areas - with access, recreation and conservation management issues often remaining controversial and unresolved. These conflicts impede the ability to make timely recreational tenuring decisions on Crown land, and they reduce economic certainty.

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19. Road-stream crossings and fish habitat in BC: Analysis of eight years of assessments

Craig Mount, MSc, Aquatic Habitat Geomorphologist,
BC MoE, Victoria BC
Craig.Mount@gov.bc.ca

The purpose of this presentation was to give an update on the work that has been progressing over the past two years.

Background

Relating to the culvert/ fish passage problem in BC, There were three presentations at the 2012 resource roads conference in Cranbrook:

1. The background of the problem in BC and also presented the current strategic approach to the issue, including the role of the Fish Passage Technical Working Group (Miller 2012),
2. The assessment methodology used in BC (Thompson) 2012), and
3. The habitat modelling and GIS analysis that have been done in an effort to both define the scope of the issue in BC and prioritize sites for assessment and remediation (Mount 2012).

In the ensuing two years, the bulk of the work co-ordinated by the Fish Passage Technical Working Group has fallen into one of four main phases :

Phase 1 - Assessment
Phase 2 - Habitat Confirmation
Phase 3 - Design
Phase 4 - Remediation

First, the Assessment Phase involves BC Timber Sales administering contracts with field crews to assess priority watersheds and carry out a systematic assessment of each stream or river crossing that occur on known and modeled fish habitat. The assessment method involves measuring surrogate indicators to come up with a score for the following five factors.

1. Culvert Embeddedness
2. Culvert Outlet Drop
3. Stream Width Ratio (culvert diameter versus stream channel width)
4. Culvert Slope
5. Culvert Length

These scores are then added and the final score provides a measure of how easy it would be for fish to pass through the crossing structure. This data and the associated maps, photos and reports are then submitted to the Provincial Stream Crossing Information System or PSCIS database.

Phase 2 is the Habitat Confirmation Phase. The purpose of Phase 2 is to confirm the quantity and quality of habitat to be gained at selected high-priority sites. These sites are selected based on the data and the associated maps, photos and reports collected in Phase 1, combined with Geographic Information System (GIS) habitat modeling. Confirmation of the habitat that would be gained at a site involves reviewing existing reports and habitat mapping for the area as well as undertaking a site visit to walk the stream and document the type (spawning, rearing, etc.) quantity and quality of habitat that will be re-connected. Once again, the collected data and habitat assessment report are entered into PSCIS.

The purpose of the Design Phase (Phase 3) is to commission a site plan and design at priority crossings identified in Phase 2. This involves a review of habitat confirmation reports, consultations with First Nations and others, and the preparation of a site plan and conceptual design where drawings and maps are uploaded into PSCIS.

The purpose of Phase 4 is to Remediate stream crossings and reconnect fish habitat by either replacing the structure that is a barrier to fish, or through road deactivation. This involves pre-construction, construction, and post-construction steps.

Results

Between 2008 and 2013, the program has successfully completed over 15,000 fish-passage assessments throughout BC. Roughly 2/3 (9,900) of these assessments have been on Closed Bottom Structures (CBS), 4,400 on Open Bottom Structures (OBS) and 800 have been on Fords.

We are most interested in Closed Bottom Structures such as culverts because these typically represent a problem for migrating fish. Crossings that are serviced by a bridge or other Open Bottom Structure typically retain the channel morphology and don't constrict or focus the flow of water. Unfortunately, this is usually not the case with Closed Bottom Structures.

Of the almost 10,000 Closed Bottom Structures that have been assessed, 81% were scored as complete barriers, 11% were potential barriers and only 8% were found to be passable. In an effort to understand why so many Closed Bottom Structures were failing, the mechanisms behind the scores were analysed to see where most crossings are found to be lacking. Those results are presented in Figure 1.

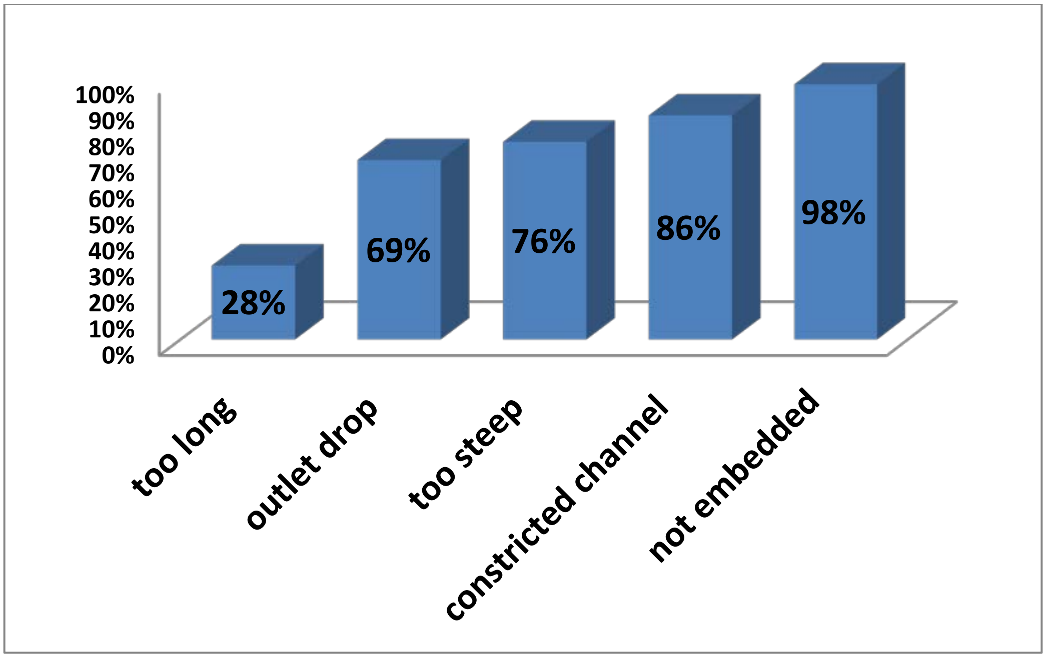

Figure 1. Mechanisms of failure for Closed Bottom Structures with a failing score

As we can see, almost every failing structure suffers from not being embedded for its entire length. This is by far the most common index which Closed Bottom Structures fail on. Close behind is the very common (86%) problem of constricting the channel, whereby the culvert is narrower than the stream channel it is meant to convey, when it should really be at least 1.2 times as wide. Three quarters of the culverts are installed at a gradient of greater than 3% which is too steep for many fish life stages and species. Likewise, almost 70% of the culverts scored points for having an outlet drop greater than 15cm which is an insurmountable obstacle for many fish life stages and species. Finally, roughly one quarter of the culverts were found to be greater than 15m long. We now have a good understanding of the mechanical reasons for why Closed Bottom Structures are failing to allow for fish migration and most have to do with poor culvert design and installation practices.

With an understanding of why culverts are failing to allow for fish migration, the next logical question is that of impact. How much habitat is being excluded from use by the fish in these aquatic ecosystems? In order to be able to assess this thoroughly, we can only look at areas with comprehensive assessment coverage. Watersheds that have only been partially assessed do not allow a definitive tallying of stranded upstream habitat, as the passability of some of the crossings is unknown.

For the purposes of this analysis, we examined five watershed groups where we have complete coverage or very close to it. In order to calculate what percentage of the habitat was cut off, we used the habitat model which was presented at the last conference. This model allows us to see how much 'theoretical habitat' exists upstream of each modelled crossing. When this is combined with the assessment data and the passability status for each of the crossings, along with the spatial relationships between all of the crossings, we can then determine the 'downstream-most' barriers. We can then tally how much habitat is upstream from them and compare that to the total amount of 'theoretical habitat' for the watershed. The results, which are presented in Table 1, ranged from less than 5% to over 30% of the freshwater habitat being cut off. These results were influenced most by the topography of the watersheds and the locations of the roads within them. Despite similar failure rates in their population of culverts, steep watersheds with little habitat upstream of the roads that sit at the valley bottom have less stranded habitat than those with gentle terrain and less constrained road building.

Table 1. Percentage of modelled habitat currently cut off by failing culverts in five sample watershed groups from around BC

Watershed Group	BULKLEY	MCGREGOR	HORSEFLY	REVELSTOKE	ELK RIVER
Number of Assessments	**1,259**	**985**	**841**	**320**	**880**
Number of Barriers	**698**	**679**	**504**	**239**	**451**
Number of Barriers on Fish Habitat	**570**	**351**	**375**	**97**	**337**
Total Isolated Habitat (km)	**1,728,058**	**345,740**	**685,377**	**75,958**	**410,129**
Total Habitat (km)	**10,792,146**	**1,289,098**	**2,046,948**	**2,632,587**	**7,141,556**
Percent % of Isolated IsolaHabitat	**16.0**	**26.8**	**33.5**	**2.9**	**5.7**

Conclusions

A significant problem exists with stream crossings on resource roads in BC. A high percentage of the crossings use a closed bottom structures (culverts) to convey water through the road prism. Unfortunately, many of these culverts represent a barrier to fish migration because of poor design or installation. With numerous native BC anadramous and other migratory species, the network of streams and rivers is highly utilized by these fish throughout the province. However, due to these non-compliant crossings, there are tens of thousands of kilometres of stranded freshwater habitat which is inaccessible for these fish. In some watersheds, this represents over 1/3 of the modelled fish habitat.

The Fish Passage Technical Working Group, with the support of the Land Based Investment Program and other partners is actively working on this issue with a four stage strategic plan.

For more information about the program, please visit the website: http://www.for.gov.bc.ca/hcp/fia/landbase/standards/fishpassage.htm

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Miller, I. 2012. Fish passage in BC – Status, issues and solutions. In conference summary: Resource Roads in BC: Environmental Challenges at the Site Level: 58-66. Columbia Mountains Institute of Applied Ecology. http://cmiae.org/wp-content/uploads/Resource-roads-2012-conference-summary.pdf scroll down

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Thompson, R. 2012. Assessing fish passage at culverts – The method, its metrics, and preliminary findings from over 8,000 assessments. In conference summary: Resource Roads in BC: Environmental Challenges at the Site Level: 67-77. Columbia Mountains Institute of Applied Ecology. http://cmiae.org/wp-content/uploads/Resource-roads-2012-conference-summary.pdf scroll down

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20. Forest Practices Board investigation of road bridges: Are they safe and do they meet legal requirements and conform with professional standards?

Co-presenter: Chris Oman, RPF, Manager, Audits and Investigations, BC Forest Practices Board (FPB), Victoria BC
Chris.Oman@gov.bc.ca

Co-presenter: Garth Lord, P.Eng, Manager, Audits and Investigations, BC FPB, Victoria BC
Garth.Lord@gov.bc.ca

The Forest Practices Board (Board) is BC's independent watchdog for sound forest practices. Over the past several years, the Board has identified significant safety and environmental issues with newer bridges through its audit program. In early 2013, the Board, in collaboration with the Joint Practices Board (JPB) of the Association of BC Forest Professionals (ABCFP) and the Association of Professional Engineers and Geoscientists of BC (APEGBC), decided to conduct a special investigation of bridge planning, design and construction.

The investigation examined whether the parties who plan, design and construct bridges are meeting legislated requirements and conforming to standards of professional practice. In other words, the Board set out to determine if new bridges are safe for industrial use and if forest resources such as water, soil and fish are being protected.

Between July and October 2013, the Board examined 216 bridges built on resource roads since January 2010 in five districts around the province. The investigation focused on safety, protection of the environment and planning. Results were variable across the five districts and amongst builders. Of significant concern to the Board were the poor safety results. Nineteen bridges were obviously unsafe and investigators had serious safety concerns with a further 13 bridges. Overall, only 85 percent of these new bridges were deemed safe.

While most builders are adequately protecting the environment, there were problems found with planning. Plans must be complete and accurate and a qualified professional must take responsibility for a bridge. Only 60 percent of bridges had complete plans and there was no professional assurance that 73 bridges were planned and built adequately.

The Board considers the results to be unacceptable. The report is a wake-up call to those who are not complying with the law or the professional practice guidelines. Due to the potentially significant consequences, there are no corners to cut when it comes to bridge design, planning and construction. The public and government expect and deserve high safety, environmental and professional standards, but those standards are not currently being met.

References

BC Forest Practices Board. 2014. Bridge planning, design and construction. Special Investigation Rpt SIR/38. http://www.fpb.gov.bc.ca/SIR38_Bridge_Planning_Design_and_Construction.pdf < this is the specific paper that Oman and Lord are referring to >

The following three “bridge” papers summarize earlier findings that stirred the FPB to conduct the 2014 Investigation cited above:

BC Forest Practices Board. 2013. Road and bridge practices: Board audit findings 2005-2011. 2013. Special Rpt FPB/SR/43. http://www.fpb.gov.bc.ca/SR43_Road_and_Bridge_Practices_Board_Audit_Findings_2005-2011.pdf

__________. 2011. Road and bridge maintenance obligations within three Forest Districts, Coast Forest Region. 2011. Special Investigation Rpt FPB/SIR/31. http://www.fpb.gov.bc.ca/SIR31_Road_and_Bridge_Maintenance_Obligations.pdf

Mosher, C. and G. Lord. 2012. Forest Practices Board: Road and bridge practices – What have we seen? In conference summary: Resource Roads in BC: Environmental Challenges at the Site Level: 130-139. Columbia Mountains Institute of Applied Ecology. http://cmiae.org/wp-content/uploads/Resource-roads-2012-conference-summary.pdf

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21. The BC Resource Roads Integration Program: Adding ‘missing resource roads’ to the provincial corporate database

Presenter: Carol Ogborne, Team Lead, Base Mapping and Cadastre at GeoBC, BC MFLNRO, Victoria BC
carol.ogborne@gov.bc.ca

Co-author: Brad Hlasny, Manager Base and Mapping and Cadastre at GeoBC, BC MFLNRO, Victoria BC
Brad.Hlasny@gov.bc.ca

Background

Resource roads are a highly valued part of the provincial transportation network. BC's expansive network of resource roads is shared by a number of different users. These roads are used to access and transport timber, minerals, and petroleum resources. Resource roads lead to ski hills, fishing lodges, hunting camps and are used by other commercial operators. Resource roads also serve as crucial links for rural communities, recreation areas and for emergency response such as wildfire fighting.

It is estimated that existing government road databases are missing up to 100,000 kilometres of the known 450,000 km of resource roads and that more than half of the road mapping in the province is more than 7 years out of date. There is currently no single agency that is collecting and consolidating spatial components of resource roads.

As the steward of the seamless demographic and resource road data, it is GeoBC’s role to support corporate initiatives that require a well-defined spatial representation of the road network. The purpose of GeoBC is to provide foundational geographic information and services for use by British Columbians, industry and government to support responsible decision making. In practice, we develop ‘shrink-wrapped” geographic products and provide geospatial services to address ongoing and unique client needs.

The Resource Roads Integration Program

GeoBC has the responsibility of bringing all of the roads in the province into a single comprehensive database for all users needing transportation information through the BC Resource Roads Integration Program (Program).

Using existing Natural Resource Sector (NRS) datasets, digital imagery, interpretation and quality control processes, the Program intends to identify and update the spatial representation of as-built resource roads on both Crown and private land.

Program objectives

1.) **Develop an efficient and accurate resource road update process using all available data.** The Program will utilize new methods to increase the efficiency of capturing both active and inactive resource roads (on Crown and private land) using existing regional resource road datasets, recent satellite or conventional imagery. The Program will also help create partnerships with private land owners, e.g., licensees.
2.) **Leverage work already available.** The province maintains and produces a Master Partially Attributed Roads dataset that is available to government and the public through the BC Geographic Warehouse Distribution Service (BCGW). The roads layer is updated monthly as new roads are added and road attributes are modified. The addition of trails and rails to the database is contemplated for the future; however the immediate goal is to solidify the process for updating the road network in the province.
3.) **Become the authoritative source for the spatial representation of all roads in BC, for both demographic and resource roads.** Demographic roads are roads in the Province that follow the Canada Post naming conventions for road types (Street, Road, Avenue, etc) and have valid civic addressing as applied by a Regional District or a Local Governments. All other roads that are not demographic in nature would be considered to be resource, recreation, or in some cases trails. The results of this program will enable GeoBC to develop an economically viable and efficient resource road update process that integrates roads from multiple sources, including industry. The road dataset supports analysis for the proposed *Natural Resource Road Act* and decision-making initiatives such as those being developed under provincial Cumulative Effects and Integrated Decision Making projects.

4.) **Build relationships with stakeholders in the NRS.** In the future, GeoBC proposes to initiate relationships with resource road data providers and custodians (public or private sector) to ensure updates are more effective, efficient and timely. Over past years, the process for updating BC resource roads has not been applied consistently and the Program will create an update process to rectify this situation.

The North East BC Pilot Project Area (NE Pilot Project)

In November 2012, within GeoBC, the Base Mapping and Cadastre Section initiated a pilot project in North East BC to identify and add in the missing resource roads within the project area. The objective of this NE Pilot Project was to determine how best to capture new resource roads given the high level of activity in both the forestry and oil and gas sectors in the area.

At the beginning of the NE Pilot Project, we conducted a literature review to examine the various technical approaches and advances in the field of remote sensing related to line detection and delineation of roads from high-resolution image sources. Scientific interest in this subject has been strong and has developed as advancements have been made in high-resolution imaging systems over the last few decades. As in BC, many other jurisdictions are interested in road mapping and the science is progressing with test study areas all around the world. The literature review included several journal publications and conference proceedings which focused on the last 10 years of research.

The NE Pilot Project had to be divided up into various phases (or tasks) in order to capture all of the requirements for the project.

Phase I was to gather all known road information from various sources. Once all of the known roads were gathered they were compared with the existing master dataset to identify known roads that were missing from the master. These were then added to the master database.

Phase II of the project involved acquiring satellite imagery of the project area and then overlaying the revised master database to identify more roads that were missing from the database using line detection techniques.

Some details about Phase II of the NE Pilot Project

To fill gaps in the province's resource road coverage, we first assembled recent digital images for the NE Pilot Project area. We elected to use SPOT imagery (at 2.5 metre resolution), because it is sufficiently detailed to identify roads while being cost-effective for large areas. In addition to the SPOT imagery, to test our process, various ancillary data layers were assembled, such as existing roads, seismic lines, hydrology and wetlands, to name a few.

In general, road mapping involves two primary tasks: road detection and road extraction.

Road detection. For road detection, each source image was enhanced with a linear contrast to more clearly define road features. This helped increase the accuracy of the road detection process. The images also had an unsupervised classification applied to them (how different surfaces appear in the imagery). This helped identify between 16 and 25 unique classes within each image.

Road extraction. The results of the unsupervised classification (and additional imagery) techniques were used to identify the features in the image and resulted in a model that could be used to identify what was a road and what was not a road. This could then be used to extract the missing road information from the image.

Results from the Northeast BC Pilot Project Area

For the entire NE Pilot Project area, it turned out that that many resource roads were missing from any existing provincial database. During the NE Pilot Project, using and assessing the imagery, we detected 12,737 km of previously undocumented resource roads.

The process of integrating the new-found roads involves identifying road features, such that:

- intersections have been created where all roads intersect,
- road end points (both to and from) are correctly assigned nodes, and labelled with a unique identifier,
- where names exist on the roads, they are correctly inserted,
- where roads that no longer exist are deleted, and

- where civic addressing existed on a demographic road, the addressing needed to be correctly interpreted where the resource road intersects the demographic road

In addition, the resource roads model can be used to capture the current state of each existing road. Has it become overgrown? Has a road been deactivated? Is a road now paved where previously it had a loose surface? These questions are of particular importance when doing any type of cumulative effects analysis. When the road detection and extraction model was developed, we were able to apply an index of certainty that the particular feature was a road. Those roads with a low model index often appeared to be overgrown in the imagery. Our intent is to investigate this concept further as time permits.

Some wish that this process of road integration was moving more quickly, but to ensure that the database can be used for multiple and divergent purposes, it's best to adhere to details and database integrity.

The integration process is carried out in two steps. The first step is to integrate all of the known roads into the database and the second step is to integrate in all of the roads collected from imagery. In Priority Area 1, we integrated 2,726 km of known roads gathered from various sources. Later, we will integrate the 1,921 km of roads collected from the assessment of the images.

NE Pilot Project challenges

There were technical challenges associated with identifying the roads in the SPOT imagery. These included such things as rail versus road corridors, seismic lines running though fields, roads obscured by shadows, tree canopy, wetlands or roads running through other features such as petroleum well-pad sites (which are sometimes not easily identified). The NE Pilot Project provided an ideal test location because these conditions are all present throughout.

There is a degree of error associated with the automated extraction of linear features from imagery. One goal was to reduce the number of errors while minimizing the requirement for manual interpretation. To quantify the success of the method selected, accuracy assessments were conducted to quantify the results of the classification technique. We want to determine the level of effort associated with expanding the NE Pilot Project approach to other regions of the province.

The future state of the Resource Roads Integration Program

This Program is a very ambitious undertaking with some very challenging timelines. It's a lot of work, being done with limited resources, to meet the needs of many.

Currently, from various sources, we have collected known roads for the areas of Vancouver Island, Cariboo, Quesnel, Morice, Prince George, Nechako and Kitimat. We are in the process of collecting the known roads for McBride/ Valemount, Kootenay, Haida Gwaii, North West BC, and the Central Coast. All of these known roads are put into a common database format.

Road collection from imagery is currently being compiled for the Liard, Prince George, Kitimat, and Vancouver Island areas. These areas have an anticipated delivery date of June 2014 after which they will go through the Program's Quality Assurance phase of these areas.

In a perfect world where money was not an object, all of these roads would be integrated in a timely manner. Our goal is to have all areas of the North East, Vancouver Island, Prince George, Nechako, Morice, and Kitimat completed by July 2015, and the rest of the province completed by July 2016. Ambitious timelines, but with the improvements made over the last five months, the process is now much quicker than it used to be.

Once all of the roads have been integrated, then the process will start all over again. That is, we will again collect new road information in the North East. By this time though, we should be getting regular updates from licensees and other resource road builders. (In part, this is due to work completed by the various working groups of the *Natural Resource Road Act*.) So, by year 5 of the Program, the complexity should be reduced and integrating resource roads into the master database will be quicker and easier to accomplish.

What is GeoBC?

GeoBC is a branch within the BC Ministry of Forests, Lands and Natural Resource Operations (BC GeoBC website). Staff at GeoBC create and manage geospatial information and products and provide consulting services across all provincial natural resource sectors.

Within GeoBC, there are four areas of focus tied to NRS business functions:

1.) We create and maintain a standard set of base spatial data such as roads, hydrology, and terrain, with the goal of progressively making this information open and accessible for use by all.
2.) We provide quality assurance for two of the Provincial Crown land registries, which are the information repositories of provincial rights and obligations on the land - specifically Tantalus (a two-way data communications networks for utilities) and the Integrated Land and Resource Registry.
3.) We offer Crown land research expertise to other government agencies, both rights-granting and otherwise.
4.) We offer services for the development of custom solutions to NRS business issues such as developing mapping products and visualization for avalanche awareness, providing assistance to First Nations treaty teams, spatial design and project management support for clean energy projects.

In short, if an NRS business area has any concerns about or interest in the concept of "place", then GeoBC is involved in some way. This involvement may be indirect (through the open provision of the authoritative base information) or direct (through mapping, analysis and land research conducted by our branch specialists).

GeoBC has four distinct business functions (BC MFLNRO, no date):

1.) Base Mapping and Cadastre
The function of the base map has an extensive history in BC, dating back to the original days of exploration and homestead land surveys. Over the years, as needs have changed, so too has the focus of the Provincial Base Mapping team. While originally dedicated to defining the shape and location of the province itself, the scope of base mapping has broadened to include a wide range of foundational geographical information used for natural resource management, land use planning, recreation, environmental monitoring, emergency response and other applications.

2.) Business Innovation and Emergency Response
This team generates value for GeoBC and other geospatial service groups through focussed application of innovative technologies, business improvement activity, training coordination, and development of new business areas. Team members lead the coordination of geospatial activities in support of emergency response activities for Emergency Management BC. This team strives to ensure that a solution built for

one client can contribute value and project efficiencies to all. GeoBC supports rights-granting agencies to make durable land-based decisions.

3.) Resource Registry and Research
This team often assists with issues relating to the determination of land and resource ownership or established rights and obligations. Internal and external self-service access is provided through the Integrated Land and Resource Registry. The Integrated Land and Resource Registry consolidates electronically captured rights and interests and provides information outputs in a consistent and credible format.

4.) Decision Support
This group provides mapping, analysis and visualization services to the broader NRS. The section provides a consulting service for a wide range of government agencies and is responsible for recommending and developing spatial solutions to address business issues and challenges.

For more information, visit the:

- GeoBC website http://geobc.gov.bc.ca
- Resource Road Program Update webpage http://geobc.gov.bc.ca/base-mapping/resource-roads/index.html

Reference

BC MFLNRO. No date. GeoBC 2013– 2015 business plan. http://geobc.gov.bc.ca/shared/docs/GeoBC-Business-Plan-2013-2015.pdf

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22. Thirty-five years of road decommissioning in the US: Lessons learned

Presenter: Adam Switalski, MSc, Wildlife Ecologist,
InRoads Consulting, LLC, Missoula MT
inroadsnw@gmail.com

Co-Authors:
Tom Black, Nathan Nelson and Richard Cissel, Hydrologists,
Boise Aquatic Science Lab, US Forest Service, Rocky Mountain Research Station, Boise ID
tblack@fs.fed.us, nnelson@fs.fed.us, rcissel@fs.fed.us,
http://www.fs.fed.us/GRAIP/index.shtmU

Charles Luce, Research Hydrologist, Boise Aquatic Sciences Lab,
US Forest Service, Rocky Mountain Research Station, Boise, ID
cluce@fs.fed.us, http://www.fs.fed.us/research/people/profile.php?alias=cluce

Introduction

The US has been decommissioning (or deactivating) old forest roads for more than 30 years. Since the first road was decommissioned in Redwood National Park in the 1970s there has been a wealth of knowledge gained on methods and effectiveness of this restoration treatment. We give an overview of road decommissioning methods and research that has been conducted in the US, including research on sediment reduction and a new road inventory and monitoring tool called the Geomorphic Roads Analysis and inventory Package (GRAIP). GRAIP helps managers more effectively prioritize road mitigation and restoration. Finally, we'll present recent research on the ecological response of decommissioning roads.

This paper does not cover all aspects of road decommissioning including costs because they are highly variable and mostly based upon how many stream crossings there are present. Prioritization strategies for treating roads are not addressed, except for GRAIP, and we do not cover simply closing or ripping roads.

Road decommissioning

Roads are essential for forest management, and extensive road networks have been developed across large landscapes (e.g., Daigle 2010). But over the course of the last 30 years or so, the US has been closing and decommissioning roads at a landscape scale. And places like Redwood National Park (Figure 1), they have removed entire road systems – hundreds of kilometers – potentially restoring landscape-level ecosystem processes (Madej et al. 2013).

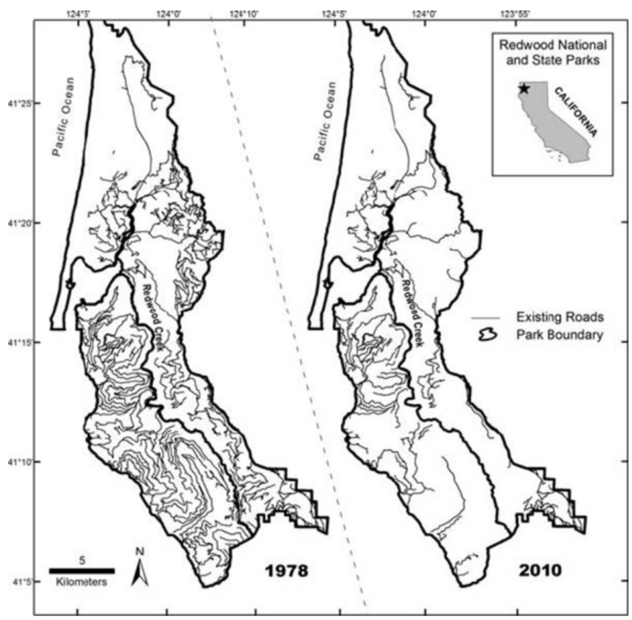

Figure 1. Presence of roads in Redwood National Park (California) in (a) 1978 and (b) 2010. About 425 km of roads were decommissioned during this time period (reprinted from Madej et al. 2013).

Road decommissioning is defined as “the physical treatment of a roadbed with a variety of methods to restore the integrity of associated hillslopes and flood plains and their related processes and properties” (Switalski et al. 2004). See Figure 2. Roads are being reclaimed at a large scale with about 3,000 km a year reclaimed on US Forest Service lands alone. In Canada, road decommissioning is commonly called road deactivation.

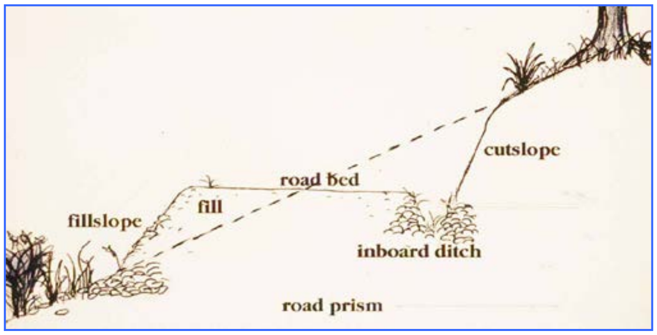

Figure 2. Components of a road and a recontoured road (reprinted from Switalski et al. 2004).

Redwood National Park (California)

Redwood National Park was the first place in the US where roads were decommissioned at a large scale. In 1978, the Park acquired 200 km^2 of mostly industrial timberlands in the headwaters of the park. The roads soon became a focus of a large restoration effort. They initially focused on just stream crossings, and spent a lot of time trying to engineer ways to reduce channel erosion after the treatment. They used hand tools in the very beginning; however, it soon became apparent that they needed to use the same heavy equipment that was used in the construction of the road. The redwoods are big trees, and big roads were built to transport them. Accordingly, large excavators and dozers were used to decommission them. Research followed, showing apparent declines in erosion on roadbeds and stream crossings following treatment (Figure 3). With this knowledge, National Forests and Parks around the US started decommissioning roads at an increasing pace.

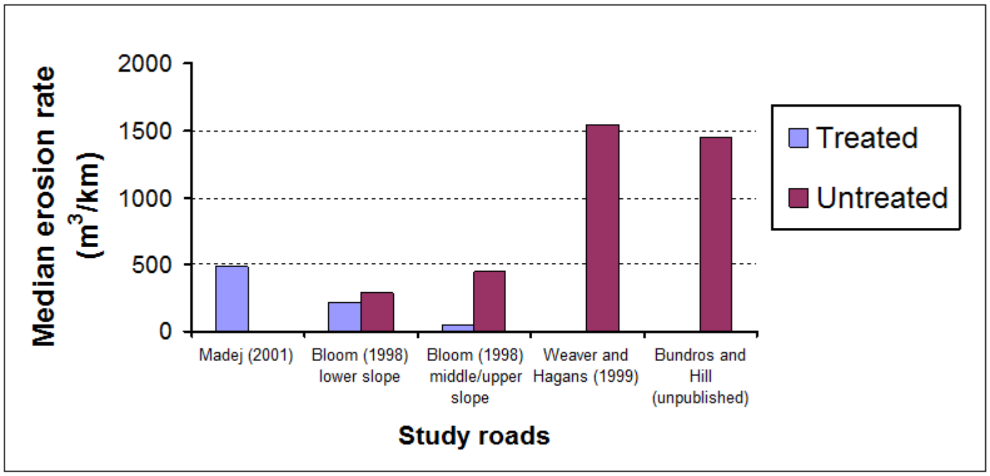

Figure 3. Sediment loss on treated and untreated roads in northern California. Values from Bloom do not include sediment loss from stream crossings on these roads, whereas the other studies include stream crossing erosion as part of the sediment loss (reprinted from Switalski et al. 2004).

Road decommissioning methods

Road decommissioning basically involves reversing the process of road building. First, any trees growing on the road are removed and staged along the road. Starting at the end of the road segment, an excavator first decompacts the inboard side of the road. The excavator then removes the fill side-cast during construction, and places the material on the cutslope - thus recontouring the roadbed to its original slope. After recontouring, staged trees are placed on the slope, and duff is pulled down from the hillside (Figures 4 and 5).

Figure 4. Example of a decommissioned road on the Gallatin National Forest, MT.

When stream crossings are encountered, culverts and fill are carefully removed. If fill was hauled in to build the crossing, it may need to be hauled off of site. In large stream crossings, a dozer may be useful for moving fill. The first step in stream crossing restoration is often to temporarily divert the creek. The fill around the culvert is excavated and the culvert removed. The excavator continues to remove fill until signs of the original channel such as darker soil or rockier substrate are detected. Then the adjacent slopes are recontoured to the original slope.

It is essential to remove all of the fill and contour the slopes correctly. Not excavating enough fill is the most common mistake that leads to post-treatment erosion (Pacific Watershed Associates 2004). After excavation, channel stabilization structures are often placed in the channel to reduce channel erosion. The slopes are vegetated through a combination of the excavator placing clump plantings (which are very successful at stream crossings) and laying woody material and duff. Hand crews may follow laying straw and revegetating with seeding, sprigging, and/or additional hand plantings.

Figure 5. Decommissioned road ten years later on the Clearwater National Forest, ID.

Research on sediment transport

As road decommissioning efforts spread around the western US, so did research - especially on the impact on reducing road-associated sediment. Studies on recontouring roadbeds found significant reductions in sediment loss and road-triggered landslides (Harr and Nichols 1993; Cloyd and Musser 1997; McClelland et al. 1997; Bloom 1998; Hickenbottom 2000; Madej 2001; Pacific Watershed Associates 2004; Nelson et al. 2012; Black et al. 2013). Short-term sediment loss was reported, but mitigated by incorporating woody debris and organics (such as duff), as well as quick revegetation.

For stream crossings, road decommissioning was found to reduce chronic sediment as well, and eliminate the risk of debris torrents (Klein 1987; Bloom 1998; Madej 2001; Pacific Watershed Associates 2004; Foltz et al. 2008; Nelson et al. 2012). Again there can be short-term sediment loss especially if all the fill is not removed which can result in channel incision, surface erosion, and slumping. This erosion can be mitigated, however, by removing appropriate amount of fill, using sediment traps or check dams, and ensuring quick revegetation.

Geomorphic Roads Analysis and Inventory Package (GRAIP)

Inventorying roads is an essential first step in managing any road system. A new approach to measuring road erosion and hydrologic hazards has been developed by the US Forest Service called GRAIP (Cissel et al. 2012; Black et al. 2012; Prasad 2007). The GRAIP approach combines a road inventory with a powerful GIS analysis tool set to predict sediment production and delivery, hydrologic connectivity, landslide and gully risk, and stream-crossing failure risk. GRAIP can help professionals determine the overall infrastructure condition with identified erosion points. The method is rapidly being adopted by forests around the western US (e.g., Cissel et al. 2011; Fly et al. 2010; Nelson et al. 2010).

Local calibration is very important for the model. So a representative sample of road-derived sediment is collected using a settling tank. The methods for collecting road sediment calibration data as well as road runoff and suspended sediment information are documented in Black et al. (2013). In an example from western Montana (Figure 6), a lightly-traveled road generated much more sediment than a gated road (notice the logarithmic scale). In this example, summer thunderstorms drove most of the sediment transport results.

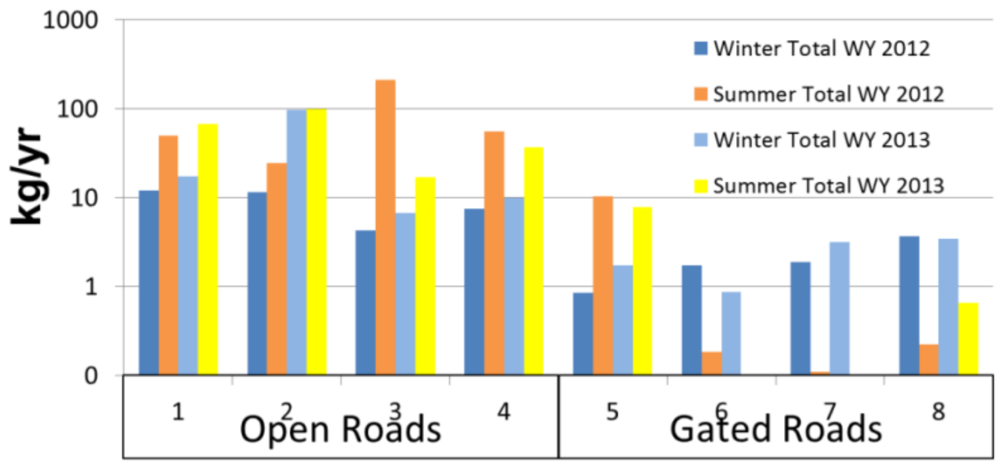

Figure 6. Road-derived sediment on open and gated roads over four seasons in western Montana.

There are two general scales at which to apply the GRAIP method.

The first way (the principal method) is to inventory all of the roads in a watershed, with the goals of determining where problems are located, so that they can be fixed, and quantifying the sediment risks and mass wasting risks that are associated with the road network in that watershed (e.g. Nelson et al. 2010, Fly et al. 2010). In addition to identifying the individual road segments and drainage features that are large sources of chronic fine sediment delivery (Figure 7), GRAIP also accumulates the delivered road sediment in channel segments in a downstream direction (Figure 8). To determine which channel segments or sub-watersheds are likely receiving the highest fine sediment impacts, a sediment per unit area value called specific sediment delivery is provided. When specific sediment impacts are added to the mass wasting and other risk metrics in GRAIP, it provides a simple GIS method for assessing the risks to water quality and aquatic resources.

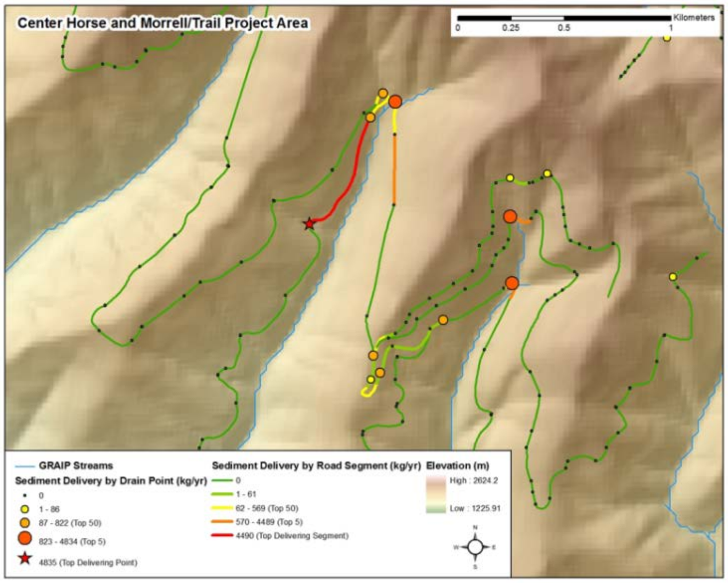

Figure 7: Example of GRAIP output in western Montana. Sediment delivery by drain point (circles), and road segment (lines) with red having high delivery rate and green little or none. GRAIP predicted that most of the road system was not connected to the channel network, however, several long road segments did route sediment to stream crossings. The highest delivery location was predicted to deliver 4,835 kg/yr.

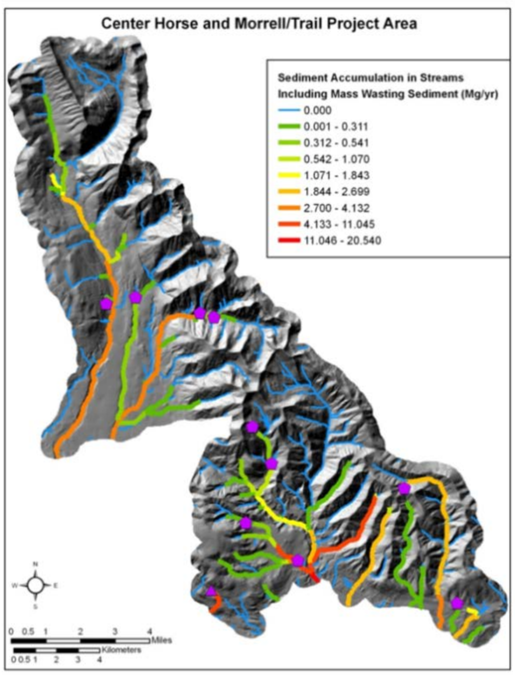

Figure 8: Example of GRAIP predicted sediment delivery rate to streams. Red is higher predicted stream sedimentation, and green and blue less. GRAIP can estimate the how much each sediment delivery feature contributed to the stream sediment. One of the more compelling outputs of GRAIP is that a small percentage of the road system delivers most of the sediment in a watershed (Figure 9). In these 4 watersheds from the western US, only between 2 and 10 percent of observed drain points deliver 90% of the sediment. So managers with this knowledge can target just a small percent of the road system for mitigation or restoration.

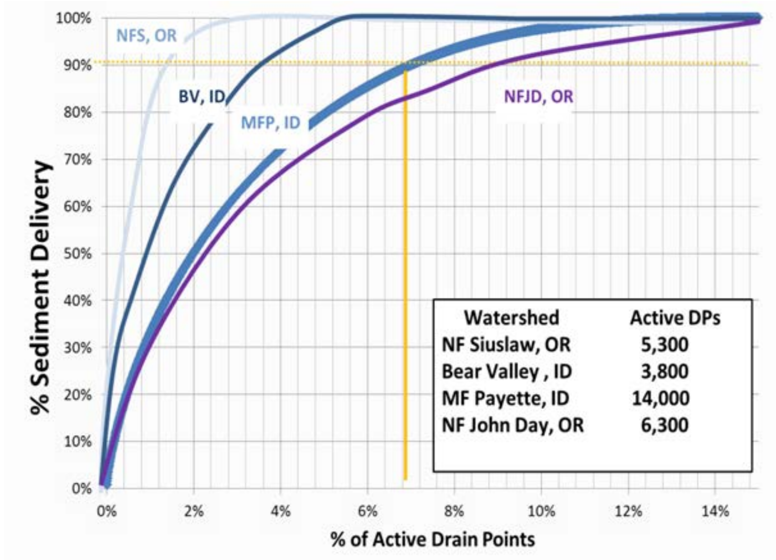

Figure 9. In these 4 watersheds from the western US, between 2 and 10 percent of observed drain points deliver 90% of the sediment.

The second way is to apply GRAIP on a small scale, as a project monitoring tool (e.g. Cissel et al. 2011; Black et al. 2009). A road or set of roads is inventoried before and after a road treatment (such as decommissioning or water-bar installation) in order to determine the effectiveness of that treatment. In this second method, untreated control roads that have similar properties to the treatment roads are also inventoried so that the effectiveness of the treatments can be gauged by reinventorying all of the roads after a large storm event.

GRAIP_lite

The US Forest Service has developed a more broad-scale GIS prioritization tool designed called GRAIP_lite (N. Nelson et al., in press). This tool uses existing road map data, a Digital Elevation Model (DEM) and a small amount of calibration to locate areas at high risk of road sediment delivery. GRAIP_lite is ideally suited to look across a forest (or landscape scale) and pick the few sub-watersheds where you would want more detailed information, whereas GRAIP is well suited to pick out the biggest sediment producing roads and drain points in a few sub-watersheds.

Ecological response to road decommissioning

In addition to sediment production and delivery research and monitoring, there have been a number of recent studies and publications that focused on ecological processes. A recent study looking at soil development on decommissioned roads found that recontouring roads restored both the above-ground and below-ground ecosystem processes (Lloyd et al. 2013). This included orders of magnitude greater root growth, and orders of magnitude greater soil carbon and nitrogen.

For revegetation research, Kolka and Smidt (2004) found significantly greater growth and diameter on yellow-poplar, and greater diameter on white pine on reclaimed roads than control in the upper Midwest. In Montana and Idaho, Grant et al. (2010) found that using native seed mixes resulted in increase overall cover and cover of native species. There was also a decrease in the cover of non-natives compared to control sites. Also, they report that less seed was needed than commonly prescribed addressing a concern by many managers that native seeds are too expensive to use on a broad scale. However, addressing weeds in any disturbance activity continues to be a concern of managers and focus of researchers.

While research is limited on fish, Wegner (1999) found 8% decline in fine sediment, 16% increase in bull trout redds following road decommissioning on the Kootenai National Forest, MT. McCaffery et al. (2007) studied bull trout habitat in the adjacent Flathead National Forest, MT. Streams with roads in use had the highest percent of fine substrate, with decommissioned streams and wilderness streams similar. This effect was highly correlated with the level of regrowth on the former roadbed.

Few wildlife studies exist on decommissioned roads. However, using remotely-triggered cameras, Switalski and Nelson (2011) found that bears were using recontoured roads at a significantly higher rate than on other treatments on the Clearwater National Forest, ID. This was correlated with the amount of fruiting shrubs that recolonized recontoured roads. This study has been expanded region wide on six national forests looking at a suite of animals and using a before-after/control-impact (BACI) study design. Preliminary results show again that black bears are recolonizing roads, but only after two years of the decommissioning treatments. As shown in Figure 10, grizzly bears, while not detected before treatment, have since been detected on two post-treatment sites as well, suggesting benefits to this threatened species as well (A. Switalski, in prep).

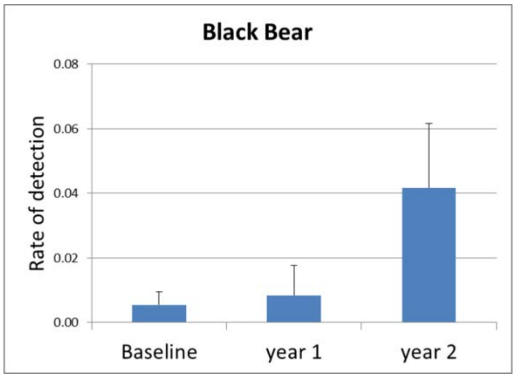

Figure 10: Rate of detection of black bears, before, 1 year, and 2 years after road decommissioning (A. Switalski, in prep.).

Conclusions

Road reclamation has been used extensively in the US and research/monitoring has demonstrated great reductions in erosion following road decommissioning. Recent advances have made inventory and monitoring this effort more effective. For example, GRAIP and GRAIP_lite allow road managers to inventory erosion and sediment delivery into streams and prioritize mitigation and restoration efforts at a range of spatial scales. Studies have found benefits to fish and wildlife habitat; however, more research is needed to measure ecosystem processes and landscape-scale effects over time.

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23. Monitoring fish values at the watershed scale: How do resource roads fit in?

Presenter: Richard Thompson, RPBio, Unit Head of the Ecosystem Conservation Section, BC MoE, Victoria BC
Richard.Thompson@gov.bc.ca

Co-Author: Lars Reese-Hansen, MSc, Watershed Ecosystems Planning Biologist, BC MFLNRO, Victoria BC
lars.reesehansen@gov.bc.ca

Background

Understanding the levels of risk and the actual condition of a watershed in respect to aquatic habitat values is critical to making wise decisions and sustaining productive fish habitat.

Under the *Forest and Range Practices Act* (FRPA), *Oil and Gas Activities Act* (OGGA) and the *Land Act* (LA), the government of BC can protect the social, ecological, and economic fish values in the province by enabling planning or practice provisions under each statue's regulations (e.g., FRPA's Government Actions Regulations or GAR). Under section 14 of the GAR, the Minister of the BC MFLNRO is authorised to designate a watershed as a Fisheries Sensitive Watershed (FSW). Typically these watersheds must meet two broad criteria; they must have 1) significant fisheries values and 2) watershed sensitivity. Watersheds that have received legal designation require Forest Stewardship Plans (under FRPA) or permit holders (under OGAA) to maintain fish habitat values consistent with the objective(s) set by government.

Objectives for Fisheries Sensitive Watersheds and other similar watersheds established under various regulations include:

1. maintain watershed hydrology;
2. maintain stream channel morphology; and
3. prevent cumulative hydrological effects.

A FSW designation acknowledges the considerable benefits derived from BC's fisheries resources. It provides the legal framework that requires operators to undertake activities in FSWs such that operations maintain the natural watershed processes that conserve the ecological attributes necessary to protect and sustain fish and their habitats (Reese-Hansen and Parkinson 2006).

During the development of FRPA, monitoring was recognized as key to the success of a results-based forest management framework. Accordingly, the Forest and Range Evaluation Program (FREP) was established in 2005 with the objective of monitoring the FRPA values identified in legislation (e.g., fish, water). This can help us understand the effectiveness of practices in sustaining these values and meeting the objectives set by government (FREP website http://www.for.gov.bc.ca/hfp/frep/values/index.htm). Fundamental to FREP is the establishment of monitoring protocols that are standardized, repeatable, can be implemented efficiently (recognizing the limited resources available for monitoring), and are scientifically defensible.

Over the last four years a technical working group made up of members from both inside and outside government have been developing an umbrella protocol that builds upon well-established assessment methods such as FREP and other protocols, Watershed Assessment methods, US Environmental Protection Agency (EPA) sampling methods, etc. as well as up-to-date GIS tools.

The protocol employs a two-tiered approach with Tier 1 relying on the use and interpretation of data that exists within GeoBC's spatial warehouse. This data can be augmented in some cases with improved data that may exist for specific watersheds of interest. Tier 2 uses field data collection protocols designed as part of the FREP Fish-Riparian and Fish Passage assessment programs.

The umbrella protocol, currently referred to as the Watershed Status Evaluation (WSE) protocol (Pickard et al. 2014), culminates in a concisely written report aimed at decision makers, resource professionals, and other parties interested in the watershed.

This short paper outlines the methods used to evaluate the status of watersheds with significant fish values.

Methodology

The WSE, through interpretation of results, can be employed to identify or help identify cumulative impacts on the fish, fish habitat and water for fish. This is consistent with one of the overriding objectives set by government in the establishment of a FSW where activities must "prevent cumulative hydrological effects”. The WSE protocol addresses this subject by examining indicators for both risk and condition. The former, referred to as a Tier 1 evaluation, uses a variety of indicators all of which are measured in a GIS environment. The latter, referred to as a Tier 2 evaluation, tailors well-established and accepted field protocols for distributed application within a given watershed. Results from both assessment tiers are then documented in a standardized reporting format designed to convey meaningful information in as concise a manner as possible to natural resource managers, decision makers and others. All three of these steps are discussed further below.

Tier 1 (GIS-based data)

The use of remote-sensing data in watershed analysis can provide an efficient supplement to costly field-based data acquisition. Remote sensing can inform broad-scale monitoring of habitats at high spatial resolutions without causing habitat disturbance (Wieckowski et al. 2008). Remote-sensed data can also be especially important for monitoring watersheds where large size and/or rugged terrain would otherwise limit ground-based measurements and field studies. An increasing number of remote-sensed datasets are becoming available for use, and are frequently projected into GIS software to allow for cost-efficient, long-term analysis of watershed environments. GeoBC currently assembles and provides remote-sensed datasets that can be used to map and quantify forest habitat and to evaluate various elements of watershed condition.

The Tier 1 assessment builds on the original 1995 Forest Practices Code watershed assessment procedures: Interior Watershed Assessment (MoF1995a) and Coastal Watershed Assessment Procedure (MoF 1995b). These guidebooks were developed by a technical working group that consisted of provincial and regional experts and academics. They identified key indicators and standardized benchmarks for assessing watersheds. The Watershed Assessment Procedure (WAP) identifies potential hydrological impacts within a watershed, specifically the potential for changes in peak flows, accelerated surface erosion, changes to riparian zones, and mass wasting events (Sawyer and Mayhood 1998). Combined, these hydrologically relevant impacts represent four impact categories of a WAP which together influence water quality, quantity, and aquatic habitats. Information on these impact categories and aquatic connectivity can provide information to decision-makers and serve as proxy data for assessing overall watershed ecological function as land development continues over time (Gustavson and Brown 2002; Pike et al. 2010). Undesirable changes in these impact categories may suggest a failure in watershed management, thus triggering an investigation into the changes of concern and leading to resultant remediation or mitigation strategies (Gustavson and Brown 2002).

The WSE Tier 1 protocol was developed to provide a comparable assessment based on the Interior and Coastal WAP approaches, but using more readily available remote-sensed datasets, such as road density, equivalent clear cut area, etc. (Porter et al. 2012). Similar to the 1995 WAP approach, the WSE Tier 1 assessment examines indicators in four risk categories: Riparian Buffer, Sediment/Mass Wasting, Aquatic connectivity, and Peak Flow.

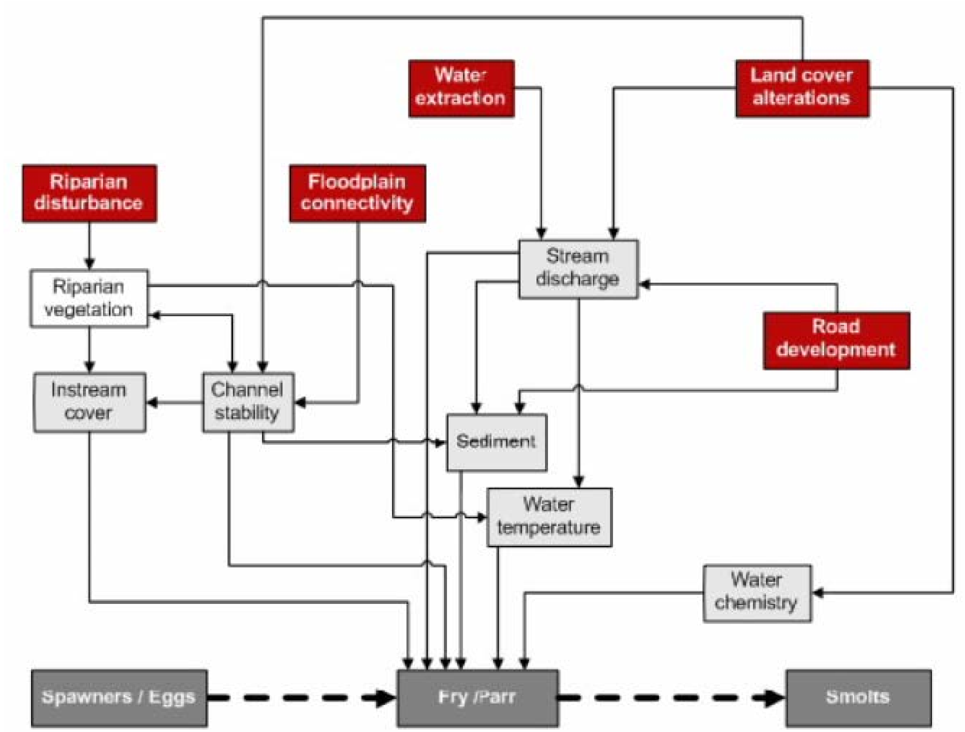

Figure 1. Summary of linkages among upslope (red boxes; riparian floodplain (white or light grey boxes); and stream (white or light grey boxes) pressures on fish habitat and life stage (dark grey boxes) (Modified from Nelitz et al. 2007).

Riparian buffer

- Proportion of stream network harvested (both fish bearing and non-fish bearing stream reaches)
- Road length within 100m of the stream

The riparian buffer impact category incorporates two metrics, portion of streams logged and portion of fish-bearing streams logged, for an overall assessment of risk to the riparian zone within a watershed. The second metric reflects the particular importance of an intact riparian area for maintaining ecological conditions within fish-bearing streams beneficial to the aquatic biological community (e.g., provides nutrients and fish food through plant materials and insects that fall into the stream, regulates water temperature through tree canopy shading, provides a source of large woody debris (LWD) for LWD-dependent reaches to stabilize the stream banks, regulate streambed sediment transport and deposition, reduce water velocities, and create diverse structural habitats such as riffles and pools for fish, and provides streamside vegetation for fish hiding cover (MoF 1995a).

Sediment/mass wasting

- Road density across watershed
- Number of road-stream crossings
- Length of road on unstable terrain
- Number of landslides/mass wasting events

Surface erosion can negatively impact the overall condition of a watershed by disturbing stream banks and channels, and by increasing turbidity and total suspended sediment. Surface erosion typically degrades water quality, and often results in spawning habitat deterioration (Gustavson and Brown 2002). Increased fine sediment in streams can directly affect many aquatic species and decrease net ecosystem productivity.

Mass wasting events can affect stream conditions and aquatic productivity throughout a watershed. Frequency of mass wasting generally increases with expanded forest development due to roads and skid trails constructed and operated in susceptible terrain. These activities often lead to road fill failures, drainage concentration, and diversion of precipitation runoff.

Aquatic connectivity

- Number of road-stream crossings

Land use activities can restrict fish access to and movement within their historical stream networks. Barriers to fish movement can limit spawning and rearing opportunities, and restrict overall habitat availability in a watershed (Gustavson and Brown 2002). Quantifying the effects of barriers to fish habitat accessibility requires determining the number of locations where fish movements are currently blocked and the amount and type of historical fish habitat that has been made inaccessible (Stalberg et al. 2009). Evaluating effects on connectivity broadly across a watershed will require coupling the Tier 1 GIS-based inventory of all potential stream obstructions (e.g., identifying all road-stream crossing locations) on known and potential fish habitat (Mount et al. 2011) with field-based assessments of fish passage probabilities (BC MoE 2011) at a representative sample of stream crossing sites (see Tier 2 protocols described in Pickard et al. 2014). or a census of sites if possible.

Hydrology (peak flow)

- % forest harvested
- Equivalent Clear-cut Area (ECA)
- Road density for entire watershed
- Road density above H_{60} line

Peak flow index: the maximum flow rate that occurs within a specified period of time, typically on an annual or event basis (BC MoF 2001). A peak flow hazard takes the estimated Equivalent Clear-cut Area (ECA) and operational road networks within a watershed into account when describing potential risks for peak flow and channel changes. Road density and ECA are the two primary factors considered because roads and cleared forests can increase peak flow rates during precipitation and melting events (BC MoF 2001). The peak flow index measures the overall sensitivity of a watershed basin to increases in peak flows, with higher flows resulting in an increase of erosive power by streams (Sawyer and Mayhood 1998).

Tier 2 – Field-based data

Field-based data focuses on understanding the current condition of a watershed by collecting information about riparian/instream habitat functions and condition, aquatic connectivity (fish passage), and water quality (coarse/fine sediment production and mass wasting).

Tier 2 Sampling Protocol: In order to build upon and leverage existing work, field-based monitoring for the Tier 2 WSE uses existing FREP and BC MoE published protocols. These rapid assessment protocols have been developed for evaluating the functional condition of streams and riparian areas (Tripp et al 2009), assessing water quality (Carson et al. 2009) and determining impairments to fish passage (BC MoE 2011). Rapid assessment protocols are cost-effective assessments that use semi-quantitative methods including observations, measurements, and estimates to quickly collect, compile, analyze, and interpret environmental indicator data to facilitate management decisions (Barbour et al. 1999; Tschaplinski 2010). The Tier 2 WSE benefits from incorporating FREP and MoE monitoring protocols by: 1) achieving efficiencies in cost of program development and personnel training; 2) establishing data compatibility across sites that are monitored under different programs; and 3) allowing for potential comparisons between FSWs and other designated and non-designated watersheds across the province.

Tier 2 Sample Frame: For Tier 2 monitoring the sampling frame is represented by the complete network of stream reaches (as delineated by the province's 1:20,000 Freshwater Atlas stream hydrology GIS layer) present within each individual watershed (the target population).

Tier 2 Sample Design: Selection of sites for WSE Tier 2 monitoring within watersheds is based on a Generalized Random-Tessellation Stratified (GRTS) approach. The selection of points incorporates within-watershed strata of importance (i.e., stream order and presence/ absence of fish). GRTS is a recent approach that draws on the strengths of both random and systematic sample designs. GRTS designs represent spatially-balanced probabilistic surveys, which were developed by the US EPA under the Environmental Monitoring and Assessment Program specifically for use in sampling natural resources (Stevens and Olsen 2004). A detailed review of possible sampling approaches and a rationale for recommending GRTS for monitoring of FSWs and other designated watersheds is provided in Wieckowski et al. (2008).

The selections of a GRTS sample and subsequent computations have been automated to a great extent. Software packages required to create GRTS designs include survey design (free for download from the US EPA, Aquatic Resources Monitoring website (http://www.epa.gov/nheerl/arm/designing/design_intro.htm), R statistical package, and ArcGIS).

Watershed Status Evaluation reporting

Provincial/Regional Scales: Reporting can be done using assembled data to allow comparisons across watersheds designated as FSWs and across a broader suite of watersheds regionally or provincially. Comparison of watersheds within a given geographic area allows decision makers the opportunity to evaluate and rank watersheds. WSE indicator information, when combined with benchmarks and associated management triggers, can be used to help inform broad land-use decisions and identify potential mitigation actions.

Watershed Scale: Individual watershed assessments will combine Tier 1 data with the results of a full field-based Tier 2 assessment (i.e., stream-riparian, water quality, and fish-passage conditions) to provide an indication of the Watershed Status. This system-based approach to evaluating the watershed is rare and will help confirm the level of fish-habitat risk identified in the Tier 1 assessments and will allow for a better understanding of current conditions on the ground and resolution of any potential legacy influences of past land use activities on streams and fish habitat conditions as well as providing insight into the likely future trajectory for the watershed.

Summary

While the WSE project started with a focus on FSW assessment, it quickly became apparent that the methodology has broader application. Tier 1 analysis can help managers and resource professionals evaluate the general status of land-use pressures on streams and fish habitats within and across watersheds. Such assessments are valid and valuable regardless of the legal designation of a watershed. Tier 1 data also allow managers and resource professionals to compare the level of various activities at more meaningful spatial scales (i.e., watersheds) for fish, as opposed to being restricted to administrative boundaries (e.g., resource tenure, forest district).

The field-based Tier 2 evaluations are generally more time consuming and costly but are made more efficient through the use of existing provincial rapid assessment methodologies, trained staff and ongoing training programs, data systems, and quality assurance processes. The system-based, randomized approach to watershed assessment ensures that each site sampled may be used to make inferences about the broader watershed, vastly increasing the value of each individual sample. Tier 2 assessments are intended for application to a subset of watersheds of interest to help validate conclusions drawn from Tier 1 overviews and to better understand the associated risk to fish and watershed condition.

The Tier 1 and Tier 2 watershed status evaluations will improve our understanding of the impacts of anthropogenic and natural changes on fish and water values, leading to better land-use decisions by management professionals and legislative/policy staff.

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24. Field results from a landscape-level analysis of resource road construction

Presenter: Steve Thompson, Frontline Forest Research Ltd., Nelson BC
reach07steve@shaw.ca

Introduction and Background

Landscape level analysis and auditing relies primarily on airphoto interpretation with limited field checking. Design of cost effective ground truthing is a key element in any large scale landscape review or audit. This presentation describes field results and methods used in a study of 2 large areas in Central and Northern BC, comprising over 600,000 ha, centered around Bear Lake, north of Prince George, and the Big Creek area in the Chilcotin, West of Williams Lake (Figure 1).

The unique approach in this project was applying random site selection using the Provincial Vegetation Resource Inventory (VRI) database. The VRI database was queried through an ArcMap overlay of the study areas. These areas were identified as areas of concern due to extensive harvesting and road construction visible on high resolution aerial photography (Figure 2).

In the field, 18 randomly selected, 5 – 10 year old "in block" haul roads, were surveyed. Roads of this type are defined by the Forest Planning and Practices Regulation as Temporary Access Structures and must be rehabilitated, or counted as soil disturbance in a compliance level soil disturbance survey (FREP Extension Note 28, http://www.for.gov.bc.ca/ftp/hfp/external/!publish/FREP/extension/FREP_Extension_Note_28.pdf), Current operational practice in the B.C. Interior is to designate these roads as Permanent Structures which results in a loss of area in the potentially productive landbase.

The objectives of this project were to:

- Determine the extent and type of road rehabilitation, and management of road drainage.
- Assess the condition of 5 – 10 year old "in block" roads, specifically the level of crop tree restocking, re-vegetation, and erosion within the road prism.

- Evaluate the feasibility of a landscape level random sampling design over large areas as a monitoring and audit tool.

Results

OBJECTIVE #1: Road Rehabilitation and Management of Drainage
Of the 18 field reviewed areas, none of the roads had been rehabilitated, or appeared to be actively maintained. All of the roads surveyed can be characterized as “abandoned roads”.

In general, where drainage structures (waterbars, ditches and culverts) were needed, they were installed when the road was constructed. However, from this review they were generally un-maintained and frequently non-functioning (Photos 1-4).

OBJECTIVE #2: Road Conditions: Crop Tree Regeneration & Road Erosion

Crop Tree Regeneration

The level of crop tree re-stocking was extremely low (Table 1, Photos 3-8). Where there was crop tree regeneration in the road prism, most stems were located in the berm, sidecast, cutbank or ditch, not on the running surface (Photo 8). These areas were either heavily overstocked or understocked, resulting in little effective crop tree growth. On 7 of 9 sites where restocking of the Running Surface was measured, restocking was less than or equal to 200 stems per hectare (Table 1). The method used to tally trees was a modified count of total stems, and over-estimated potential crop trees. It was not the method of counting “well spaced” trees used in a Silviculture Survey. Stocking on the Running Surface was only measured where stocking differences were obvious in the 3 road prism components: Cutbank and Ditch, Running Surface, Berm and Sidecast.

Road erosion

All but one of the surveyed roads had a low erosion impact. Anecdotal observation of adjacent areas confirmed the overall findings of the measured areas. In general, erosion occurred on short sections of road with steep gradients (>10%), or long sections of moderate gradient (6-10%) roads with inadequate drainage control (Photos 1-2).

The topography in the areas surveyed resulted in few steep gradient roads, and few roads with long sections of moderate gradients. In general, there appeared to be a low risk of sediment delivery to stream channels.

OBJECTIVE #3: Sampling Design Assessment and Recommendations

Sampling Design Assessment

A completely random design led to inefficiencies in the field because of the disproportionate amount of time required to access the widely dispersed sample locations versus the amount of time required for measuring the sampling unit, a 500 metre road section. Nonetheless, eighteen sites were sampled in ten field person days. A secondary problem was that in most cases the airphotos available for navigation were several years out of date. Roads needed to access the randomly selected blocks were not always visible, or apparent in the field.

Sampling Design Recommendations

In future studies at a landscape level, a cluster sampling design is recommended. The design concept would be to ensure that 3 - 4 sites could be sampled in one field person day, and that site selection would continue to be unbiased.

The following procedure is recommended:

- Generate a random sampling list that ranks ALL available sites within the study area.
- At each of the top ranked sampling locations, a set of secondary (i.e. clustered) sampling sites would be identified prior to field survey. The secondary sites would be the next highest, randomly ranked, sites that are accessible within the same mainline road network.
- Optimize field time by spending one field day per site cluster (i.e. within the same mainline road network) unless the priority sites identified in #1 are in close proximity.

Summary

Current forest management practice in the B.C. Interior is to designate all forest haul roads as "permanent structures", with an implied commitment to long term road maintenance and loss of the potentially productive landbase. Random sampling of 5-10 year old "in-block" roads, widely distributed in a 600,000 hectare study area, consistently demonstrated no active road maintenance, and extremely low crop tree regeneration.

“In-block” haul roads that do not provide access for a future harvest opportunity are defined as Temporary Access Structures in the Forest Planning and Practices Regulation. These areas may represent up to 4% of the operable landbase. The 2012 ABCPF recommendation for best practices management is that Temporary Access Structures should be rehabilitated, to establish a commercial crop of trees, and control unpredictable hydrologic responses.

Table 1 Summary of Key Attributes

Location	No. of Sites	Median Road Gradient	Median Road Width	Median Stems/ Ha	Exposed Mineral Soil	Veg Cover
Bear Lake Till	6	5.5	8.5	225	14	75
Bear Lake Glacio-fluvial	4	2	6.5	1,000	19	21
Big Creek Till	8	4	6.0	100	50	10

Acknowledgements

Bill Chapman and Chuck Bulmer collaborated with the authour on the design of the project on which this presentation is based. Bill extracted the random site locations from the Vegetation Resources Inventory database.

Bill Chapman, PhD, Soil Scientist, BC Ministry of Forests, Lands and Natural Resource Operations, Williams Lake B.C. Bill.Chapman@gov.bc.ca

Chuck Bulmer, PhD, Soil Scientist, BC Ministry of Forests, Lands and Natural Resource Operations, Vernon, B.C. Chuck.Bulmer@gov.bc.ca

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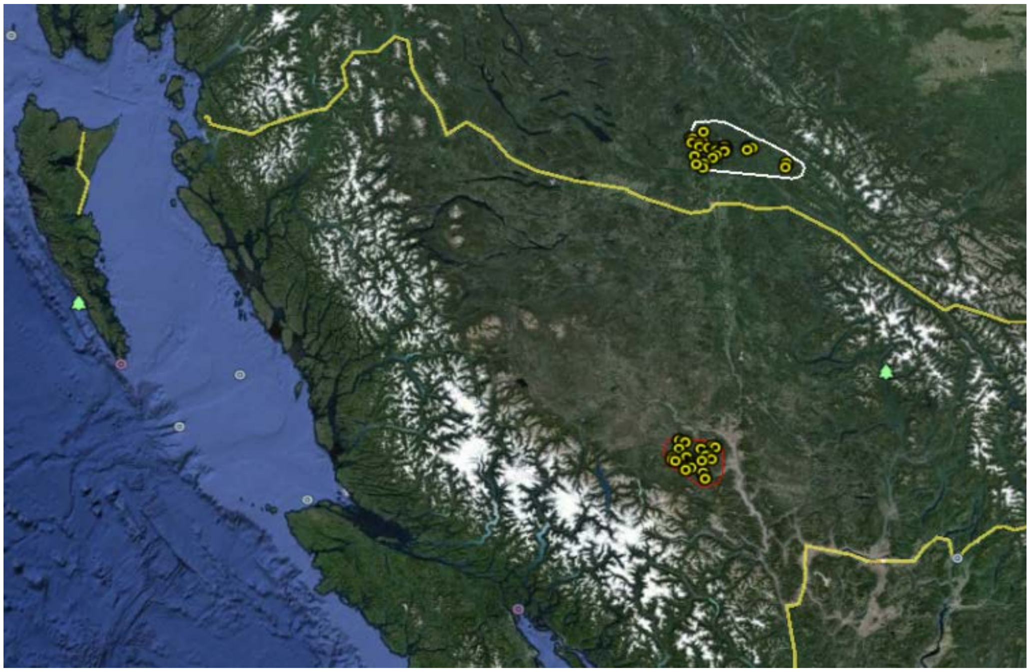

Figure 1: Location of study areas in Central and Northern B.C. comprising 600,00 hectares. Yellow dots show randomly selected locations. Eighteen sites were sampled.

Figure 2: Extensive harvesting and road construction near Bear Lake, north of Prince George

Photo 1: A 14 metre wide, unrehabilitated road on a Moderately Well Drained site in the SBS (Site #8, Bear Lake). Slope in the cutblock was 25%. The cutbank and ditch on the left side were 70 cm deep, and occupied 2.4 meters of the horizontal width. Note the nearby mainline road on the right of the photo.

Photo 2: Blocked ditch on the road above from a small cutbank slump shown at the red arrow. Ponded water here is threatening the road immediately downslope.

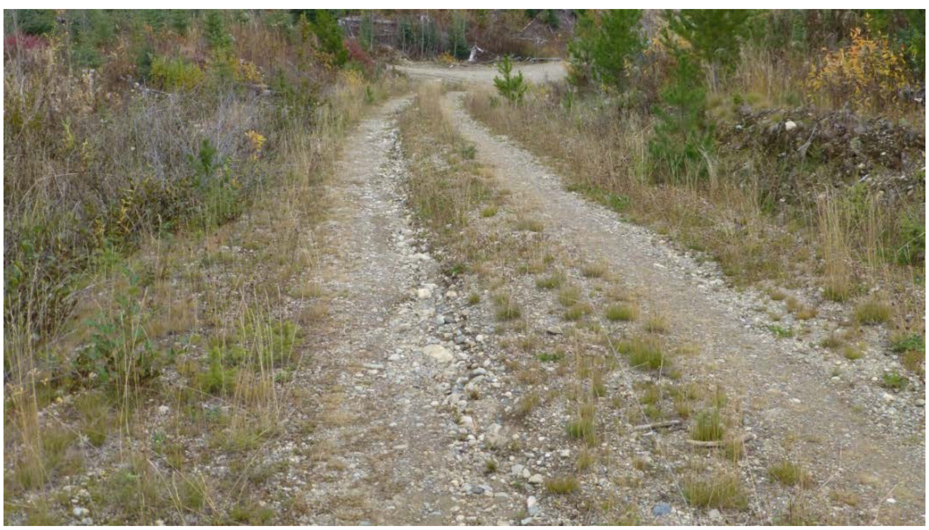

Photo 3: Rill erosion downslope of a non-functioning waterbar. The waterbar at the mainline junction is also unmaintained, and subject to failure putting that road at risk. Due to a series of failed waterbars, water has run continuously for 300 meters.

Photo 4: Close-up of the deep rill seen in Photo 3, nearby the mainline road. This may have resulted from channelized flow in a wheel rut.

Photo 5: Typical "in-block" road on a Moderately Well Drained site in the SBS (Site #7, Bear Lake). There was very little regeneration within the road prism. Soil compaction, competing vegetation and lack of a seed source were probably factors in lack of crop tree regeneration on the road surface. Vegetation cover was 75%. See Photo 6, below.

Photo 6: Abundant regeneration in the adjacent stand to the road shown in Photo 1, above.

Photo 7: In block road with no regeneration on glacial till in the West Chilcotin (Site #8, Big Creek). Abundant regeneration is visible in the adjacent cutblock.

Photo 8: Overstocked Berm, and understocked Running Surface at Big Creek Site #5.

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25. *The benefits and challenges of online resource road bridge management systems*

Les Thiessen, P.Eng., SNT Engineering Ltd., Nelson BC
les@snteng.ca, www.snteng.ca

Transportation infrastructure (e.g., bridges, culverts and retaining walls) represent key parts of operational infrastructure and significant value to the resource industry. In this presentation the focus is on bridge management, however the same argument can be stated for culverts and retaining walls but with a lesser degree of risk.

Effective and efficient management of bridges is required to facilitate economical operations, meet regulatory requirements and voluntary certification requirements. The essential elements are maintaining a register of as-built data, inspections, required maintenance, load ratings and operational use status for all structures in inventory. Efficient retrieval of this information is crucial to effective management. The following information is typically generated for bridges:

- Construction information such as costs, record drawings and photographs.
- Inspection information including load ratings, component inspection comments, channel hydraulics, hazards, work recommendations, items to monitor and photographs.
- Work performed on the structure including inspections, maintenance and rehabilitation with information such as costs, dates and photographs.
- Bridge status and portability information relating to the accessibility and availability to be moved to another site.

When this information is collected and managed through a database, the power of the system lies in the user's ability to query the information. Sample queries include:

- Inventory reports filtered by custom criteria. (Structure number, structure type, location, condition index, etc.)
- Inspection report generation.
- Reports identifying bridge inspections to be completed within a designated timeframe.

- Reports displaying posted load restrictions, recommended bridge replacement dates and projected capital costs.
- Summary of work recommendations, including estimated costs for repairs, new structures grouped by year, structure type, or cutting permit. The filters can be customized for the user.
- Reports summarising work completed (inspection, maintenance, rehabilitation).

Well-managed infrastructure will result in:

- Cost savings through planned works as opposed to being reactive to structure deficiencies;
- Cost savings through effectively using portable structures already in inventory;
- Safe and reliable infrastructure capable of supporting the required level of service;
- Protection of the environment through sediment reduction practices around crossings;
- Planned inspection programs;
- Proactively identification and mitigation of risk to a corporate acceptable level. This appropriately puts some responsibility onto management;
- Reliable information relating to the structures and expenditures made easily available for reporting by staff, contractors, and consultants; and ,
- Accurate capital cost planning and projection.

Typically government agencies like Ministry of Transportation and Infrastructure (MOTI) and Ministry of Forests, Lands and Natural Resource Operations (FLNRO) have led the way in the use of bridge management systems, due to the size of inventory and potential risk associated with bridges. For years, these agencies have realized many of the benefits of a database management system.

I believe, the next step to enhance the benefits is to employ an online system shared by the owners, consultants and users. These management systems can be accessed through a web browser with a permission matrix based on role of the user. An online system has two key benefits:

- Facilitates quick sharing of information with users in multiple locations. New information can be uploaded by staff or consultants and immediately shared with other stakeholders

- The user group can be expanded to multiple offices and easily managed. A permission matrix can allow various users to see selected information. For example a manager of the inventory responsible for capital planning will have different needs compared to an operational person responsible for maintenance. Owners of bridges may want to keep certain management decisions private from the users.

There may be a perception that these systems are exclusive to large government agencies due to the cost of developing the system. However, database programming and applications have recently advanced, so smaller inventory holders (e.g., municipalities, forest licensees and park trail networks) can also realize benefits of effective management.

Currently, structure data is often managed through paper files and spreadsheets. Paper records may be out of date or require collating of information from various files and systems. Furthermore, with paper records there is no efficient way of performing queries on bridge inventory status. Herein lies a level of risk to certain resource road and trail networks.

Enhancements to a database type management system include using a spatial component which will link structures on a map to the bridge database. These maps may be viewed in the field using electronic hand-held tablets and additional data can be easily uploaded by using electronic field forms and photographs.

The key challenge for any computer application is to be user friendly. The system must meet the needs of the user and not be a burden to maintain; otherwise it will not be used. The temptation in a database management system is to record too much detail because creating data fields is easy. A rule of thumb is you may not need the electronic data field if you are not querying or sorting on the field. The management system is not intended to replace the paper or electronic as-built documents; only key information to manage the inventory is required. Data integrity is also crucial. Sufficient resources are required to keep the database up to date. Old or missing data ultimately undermines the efficiency of the system.

Unfortunately, the resources allocated for effective management is limited by decision makers not fully appreciating or understanding the benefits and risk exposure. Nevertheless, there are opportunities to take advantage of the available technology to begin realizing the stated benefits.

26. A Cumulative Effects Framework for BC: Assessing and managing the unintended impacts of resource roads

Presenter: Eric Valdal, MSc, Cumulative Effects Assessment Coordinator, Thompson Okanagan Region, BC MFLNRO, Kamloops BC
Eric.Valdal@gov.bc.ca

Co-author: Doug Lewis, MRM, Resource Practices Specialist, Thompson Okanagan Region, BC MFLNRO, Kamloops BC
Doug.W.lewis@gov.bc.ca

For the past few decades, research has documented both the positive and negative effects of resource roads on a variety of resource values. The effects of extensive road networks with multiple uses can accumulate to have unintended impacts on resource values.

In the Thompson Okanagan Region of BC, government has tested and initiated implementation of a Cumulative Effects Framework (CEF) designed to improve government's ability to assess and manage unintended impacts on the landbase. The CEF includes;

1) Proactive decision support in the form of broad-scale, forward-looking Cumulative Effects (CE) assessment and monitoring information to understand the condition and trend of resource values ,
2) Development of new business processes within government that enable multi-sector cumulative effects assessment and management

Extensive resource road networks will continue to be a significant and enduring part of BC's landscape. Although roads are necessary to ensure continued access to resources and to realize socio-economic benefits associated with BC's backcountry, greater efforts need to be directed at managing unintended impacts. Efforts to manage negative impacts at a landscape-level must be:

1) Informed by broad-scale, strategic CE assessment to identify areas of greatest risk relative to the spatial location of values and historic, current and projected development
2) Directed through strategic evaluation of multi-sector management options designed to achieve intended outcomes for values
3) Implemented through coordinated on the ground activities
4) supported by appropriate policy and regulation
5) Monitored to ensure efforts properly implemented and effective

27. Kettle River Watershed Management Plan: The planning process and riparian threat analysis (Parts 1 and 2)

Kettle River Watershed Management Plan: The planning process (Part 1)

Graham Watt, MSc, Coordinator, Kettle River Watershed Management Plan, Regional District of Kootenay Boundary, Grand Forks BC
graham@cordilleran.ca

The Regional District of Kootenay Boundary (RDKB) is developing a watershed management plan for the Kettle River in BC. The Kettle River Watershed Management Plan (Watershed Plan) is a collaborative initiative supported by a Stakeholder Advisory Group with participation from local and provincial governments and representatives from multiple sectors and organizations from across the region.

A watershed is all the area of land that drains to a common water body – and everything that happens on the land and in the water affects the watershed, to varying degrees. The Kettle River is a 282 km trans-boundary river starting in the Monashees and highlands east of Vernon, flowing through pine and 'Kootenay mix' forests, grasslands and ranches back and forth along the Canada-US border, before entering the Columbia River near Kettle Falls, WA. The size of the watershed is approximately 11,000 sq. km, with the majority in Canada in BC's Okanagan Highland watershed zone.

The purpose of the Watershed Plan is to study water supply, use, quality and aquatic ecosystems (Phase 1 "State of the Watershed" (Summit Environmental Consultants 2012) and plan for the future with recommendations for policies, planning and stewardship. The Watershed Plan is expected to be complete by early fall, 2014, and the RDKB has committed funding for coordination of a three-year implementation phase.

The RDKB undertook watershed planning because there were major uncertainties about how to respond to a combination of issues including water flows (e.g., seasonal low flows and high demand for human use), fish and aquatic ecosystem impacts, and the potential effects of proposed hydroelectric and resort development projects. There was a need for information and guidance for local and senior government decision making, but local leadership was required to obtain funding and initiate comprehensive planning.

The Phase 1 report evaluated several key issues and provided a sound base for planning (Summit Environmental Consultants 2012). Key findings include:

- Water flows are naturally variable, but significant water consumption and habitat constraints increase impacts on fish, aquatic ecosystems and many human uses of water.
- Land use and agricultural practices have contaminated the high demand/high vulnerability Grand Forks aquifer.
- Overall, water quality is fair to good, but some water quality issues have been increasing (temperature, sediment, and pathogens).

A key gap identified in the Phase 1 report was the lack of information on riparian and wetland conditions and overall watershed health and function. The Stakeholder Advisory Group struck a Riparian Working Group to develop studies to fill this gap and provide advice on policy responses and restoration needs. Funding was obtained from Southern Interior Beetle Action Coalition to prepare a Riparian Threat Assessment, which aimed to examine watershed-scale influences on riparian conditions using a combination of GIS assessment and examination of field conditions.

A separate presentation (by Jenny Coleshill) shares initial findings of the Riparian Threat Analysis. At the watershed scale, several issues intersect and need to be considered in concert:

- Local and provincial priorities may differ for land use, resource management, and resource road network planning;
- Rivers move in alluvial floodplains, affecting valley resources, land uses, and emergency management;
- The movement of rivers is connected to the impacts of upstream resource and road-network development – sediment and aggradation, water temperature increases, and low seasonal flows reflect both natural patterns and the cumulative effects of land use activities that change vegetation, harden surfaces, use water, alter water bodies, and cross streams.

The Phase 2 Watershed Management Plan has been built on extensive public and stakeholder involvement and there has been a strong effort made to increase watershed awareness. So far, participation has included regular Stakeholder Advisory Group meetings (30 members), a watershed-wide survey, meetings with the Technical Advisory and Riparian Working Groups, six public meetings and open houses, participation in numerous public events, a regular column in local newspapers, together with an active web and social media presence.

The Watershed Plan (currently in draft form) includes the following key considerations:

- governance and capacity building;
- water flows, use, conservation and storage;
- conserving and restoring wetlands, riparian areas, and upland habitats and ecosystem goods and services;
- protecting land and infrastructure and planning for resilient land use on floodplains
- water quality and source-water protection

The Stakeholder Advisory Group has recognized the vital importance of reliable, quality water and healthy aquatic ecosystems for our communities, and drafted the following vision statement (Watt and Kettle River Watershed Management Plan Stakeholder Advisory Group 2013b):

> **Our communities envision a healthy, resilient and sustainable Kettle River watershed, with a landscape that functions to meet community needs and values, and communities that act as stewards of the watershed.**

This vision statement is accompanied by three overarching goals:

1) Healthy aquatic ecosystems sustain native biodiversity and aquatic life;
2) Safe and secure water supports healthy communities; and
3) Reliable, quality water supplies support a sustainable economy and food system.

In the Watershed Plan, each goal includes sub-goals that relate to topics such as water-flow patterns, water quality, habitat, drinking water, shoreline stability and community values, based on input (Figure 1) by residents and stakeholders from a watershed-wide survey in 2012-2013 (Watt and Kettle River Watershed Management Plan Stakeholder Advisory Group 2013a).

Figure 1. Word cloud of key concepts in results of 2012-2013 survey of watershed residents.

Strategies based on these goals (and sub-goals) are articulated in a series of discussion papers available on the kettleriver.ca website:[3]

- Developing local water governance
- Water conservation, drought management, and water regulation
- Aligning stewardship and beneficial management practices initiatives to protect water quality and source water
- New relationship with the water's edge – riparian set-backs, restoration, and flood-plain planning
- Promoting ecosystem-based management of all resources

The Kettle River Watershed Management Plan is expected to be complete in fall 2014. Phase 3 (Implementation) will be undertaken by a team composed of public, stakeholder and government representatives.

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Kettle River Watershed Management Plan: Riparian threat analysis (Part 2)

Jenny Coleshill, RPBio, Project Coordinator, Granby Wilderness Society, Grand Forks BC
jenny.coleshill@granbywilderness.ca

Introduction

Riparian areas are of high value for both the wildlife habitat and ecosystem services they provide. The Phase 1 Background Technical Assessment of the Kettle River Watershed Plan identified that information on riparian areas was lacking. Thus, a Riparian Working Group was established to help in making recommendations around information gaps, research needs, and policy development of riparian issues in the watershed. To do this, a riparian threat analysis was initiated. The goal of the assessment is to gain an understanding of the status of riparian areas across the watershed and the purpose is to identify landscape- and site-level threats.

Approach

We are using two approaches, first conducting a course-scale analysis using GIS and following up with fine scale on-the-ground riparian assessments across the watershed. The course-scale analysis looked at the proportions of land use and status of riparian areas within the watershed. This includes the proportion of riparian area falling into protected, timber, urban, agriculture and historical mining areas. It also includes the proportions of riparian area falling under the jurisdiction of each municipality and regional district. We are applying measures and indices commonly used to evaluate watershed-level disturbances and cumulative effects such as road densities and the number of road-stream crossings (MoF 2001). The fine-scale analysis, commencing the summer of 2014, will conduct riparian health assessments on the ground across the watershed.

Preliminary results

The Kettle River Watershed has not experienced the development pressures as seen in neighbouring watersheds such as those in the Okanagan. A course-scale comparison of land uses and disturbances that occur within 100 m of riparian features (lakes, wetlands, streams) indicates that Urban Lands and Agriculture have the smallest footprints in riparian areas compared to the extensive Mountain Pine Beetle Disturbance and Historical Openings (forest harvesting). The footprint of resource roads falls between (see Figure 1) with 84.9 km^2 of resource roads falling within 100m of riparian features which translates to 2.5% of riparian areas being roaded.

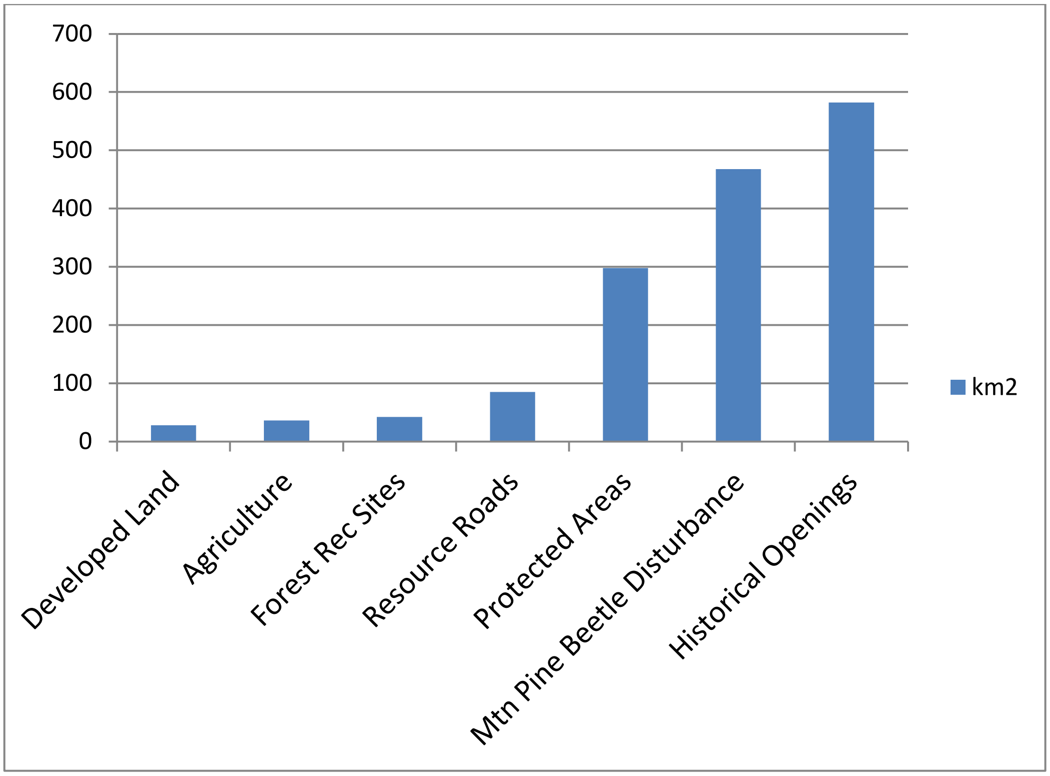

Figure 1. Comparing land use and disturbance types in riparian areas (within 100 m of all aquatic features)

Resource roads

The density of roads within 100 metres of stream riparian areas is 1.75 km/km^2 relative to only riparian areas and .0.69 km/km^2 relative to the entire watershed (Porter et al. 2012). The footprint of resource roads in the entire watershed is 3%, with a total length of these roads being 15,190.70 km.

In total (resource roads and highways), there are 10,941 road-stream crossings in the watershed. Of these crossings 10,120 are resource roads. Most of these resource road-stream crossings are on 1st order streams (7,397). An example of how these road-stream crossings look at the landscape scale can be seen in Figure 2.

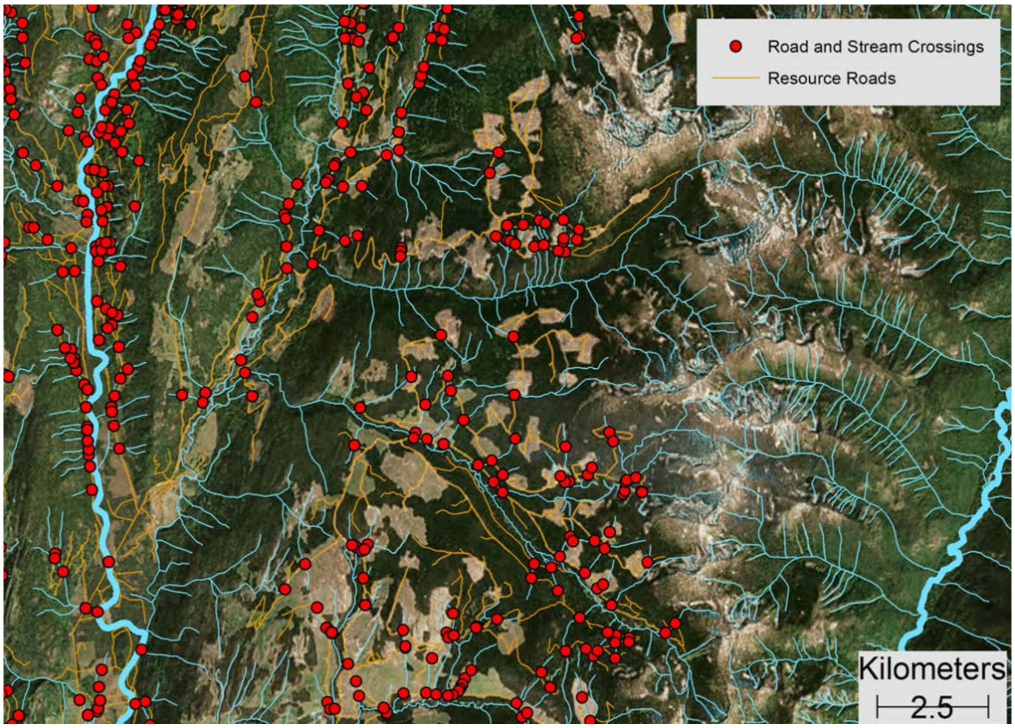

Figure 2. GIS Analysis of road-stream crossings in the Kettle River Watershed. Shown are both the Kettle River in the west and the Granby River in the east within Granby Provincial Park**.**

Outcomes

The Riparian Threat Analysis provides background, context, and baseline information for policy development in the watershed plan; identifies threats in GIS spatial layers; aids in the selection of references sites for restoration and restoration needs; and will enable stratified sampling for Phase 2 field assessments.

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28. Legacy roads and the long term concerns about terrain stability: Analyzing the hazards and mitigating the risks

Presenter: Peter Weisinger, P.Geo., Westrek Geotechnical Services Ltd, Salmon Arm BC
pweisinger@westrekgeotech.com

Co-Authors:
Kevin Turner, P.Eng, FEC, Westrek Geotechnical Services Ltd, Kamloops BC
kpturner@westrekgeotech.com

Paul Ross, RPF, Tolko Industries Ltd., Lumby BC
Paul.Ross@tolko.com

The interior of BC has a long and rich history of logging (and other resource development), in some areas dating back to the late 1800s. Throughout the years, logging and transportation methods evolved and changed, but this legacy has left its mark on the landscape in the form of an often very dense and complex network of roads and trails. These are sometimes referred to as "legacy roads".

Legacy roads are frequently difficult to discern, even on modern high-resolution images, and as a result, often go unnoticed during the planning stages of contemporary harvesting activities. In Tolko's operating areas in the Okanagan Shuswap Natural Resource District, new harvest development often takes place on areas where timber has re-grown in previously harvested areas. Sometimes even multiple passes of logging and associated road building are encountered.

In conducting terrain-stability assessments in the interior, it is well known that the primary concern with respect to reducing instability on steep slopes is management of hillslope water runoff. Within (and down-slope) of new timber developments, we have often found networks of legacy roads and trails that have perturbed natural water runoff patterns. Legacy roads have created widespread drainage diversions, many of which have led to considerable erosion, sediment production and landslides. In some cases, this has resulted in significant damage to natural resources, private property and infrastructure, and in some instances fatalities.

Where natural drainage patterns have disrupted by legacy roads and trails, when it's possible, Tolko and Westrek have developed strategies for restoring natural drainage patterns. Problems with individual roads/ trails directly associated with new development can often be addressed as part of the terrain stability assessment process. However, legacy roads are so widespread and numerous, that there are simply not enough resources to investigate and mitigate all of the problems.

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29. Forest Practices Board investigation: Community watersheds, from objectives and practice requirements to results on the ground

Del Williams, RPF, Manager, Audits and Investigations, BC FPB, Victoria BC
del.williams@gov.bc.ca

This investigation is about how well forestry and range use provides for the protection of drinking water as required under the *Forest and Range Practices Act* (FRPA). The investigation focuses on how the requirements for drinking water are being met in a sample of 466 designated areas, referred to as community watersheds (CW). These areas are designated CWs because the provincial government decided these watersheds require special forest management for the protection of drinking water.

The investigation sampled 48 of the 131 CWs where some amount of resource road or forest harvesting activity has occurred under FRPA. Investigators examined how each forest licensee addressed government's CW objective in licensee Forest Stewardship Plans (FSP).and followed through with the commitments in those FSPs.

In 12 of the 48 watersheds sampled, investigators field-assessed watershed condition and determined whether on-the-ground forest and range practices complied with rules. The Board also explored whether FRPA legislation provides clear direction to forest and range users; if government is monitoring forest and range practices on the ground; and how the provincial government decides which watersheds need special forest management.

This Forest Practices Board (Board) investigation found several significant weaknesses and some positive aspects in how drinking water is protected in CWs.

Clarity of FRPA requirements and government approval of Forest Stewardship Plans

The Board investigation indicates:

- For the protection of drinking water, some legal requirements in FRPA are too limited in scope or unclear.

- When government approved the FSPs containing CWs, it did not always ensure the Plan content met FRPA requirements. For instance, three of the 47 government-approved FSPs that the Board examined did not address the CW objective. Also, not all commitments made in the FSPs were measurable or verifiable as required. This means it may be difficult for government to enforce adherence to these commitments.

Commitments made in Forest Stewardship Plans

Most forest licensees retained a professional to complete some type of watershed assessment prior to harvesting or road construction. However, deficiencies were identified in those professional assessments. Of the 31 assessments in the Board's sample:

- 11 did not follow the content for the assessment as described in the FSP;
- 26 considered, to varying degrees, the hydrological effects of FRPA and pre-FRPA forest activities over the entire watershed; and
- six considered the potential effects of planned forest development on water (quality, quantity or timing of flow) in relation to the licensed waterworks—key elements of the CW objective.

Most results and strategies provided meaningful content because they were intended to assess hydrological responses associated with planned forest harvesting. However, for 41 of 44 FSPs, the results or strategies were not sufficiently detailed for investigators to conclude if they were consistent with the CW objective.

Compliance with drinking water-related practice requirements on the ground: Field sample of 12 Community Watersheds

Board findings indicate that woodlot licence holders and range agreement holders met the requirements of the FRPA legislation.

Forest licensees met the requirements to retain buffers adjacent to streams, lakes and wetlands, and to provide water licensees with at least 48 hours notice of planned road construction or deactivation.

However, with respect to resource roads, Board investigators observed little evidence of measures to minimize erosion and control sediment deposition into streams. In three of 12 watersheds, investigators found road practices to be unsound. In four of 12 watersheds, licensees did not meet all of the requirements that provide for protection of drinking water quality, including prevention of landslides, road maintenance and maintenance of natural surface drainage patterns.

Monitoring achievement of the Community Watershed objective

While, government has a program to monitor water quality, it does not specifically monitor the effectiveness of forest and range practices to protect drinking water quality generally or in CWs.

Designation of Community Watersheds and use for drinking water

Government has draft guidelines for designating or delisting CWs. Since 2004, six additional CWs were designated and one was delisted.

In 16 of the 48 CWs, the source of drinking water has changed from a stream to a well or lake. Of the 16 CWs, seven still maintain the stream intake as an emergency back-up supply.

In seven of the 12 CWs that were field-assessed, the watershed condition is being affected primarily by pre-FRPA forest harvesting and, to a lesser extent, FRPA-related activities and other land uses such as mining and private land as well as recreational activities, such as off-road vehicle use.

This investigation identified several weaknesses in FRPA and how it is being implemented by forest licensees. In summary, the Board investigation distinguished issues related to the FRPA requirements, approval of FSPs, monitoring of drinking water, and licensee plans and practices undertaken. Together, these issues have the potential to compromise effective achievement of government's objective for CWs.

The Forest Practices Board recommends:

- strengthening FRPA requirements for the protection of drinking water;
- strengthening the content and approval of FSPs;
- ensuring the content of professional assessments is meaningful;
- monitoring protection of drinking water; and
- updating the status of CWs.

Reference

BC Forest Practices Board. 2014. Community Watersheds: From objectives to results on the ground. 2014. Special Investigation Report FPB/SIR/40. http://www.fpb.gov.bc.ca/SIR40_Community_Watersheds_From_Objectives_to_Results_on_the_Ground.pdf

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Posters

Improving environmental performance of resource roads in sensitive areas: Strategies, designs and state-of-practice for crossing wetlands and pipelines

Allan Bradley, RPF, P.Eng, Associate Research Leader, Resource Roads Group, FPInnovations, Vancouver BC
allan.bradley@fpinnovations.ca

Clayton Gillies, RPF, RPBio, Senior Roads Researcher, Resource Roads Group, FPInnovations, Vancouver BC
clayton.gillies@fpinnovations.ca

Two of the most sensitive sites that resource roads must occasionally cross are wetlands and buried pipelines. FPInnovations' work focussing on wetland areas has been in response to industry's proactive desire to improve environmental performance. Resource roads may impede hydrologic connectivity in wetlands with a result that nearby water levels and vegetation are altered. FPInnovations, with the forest industry, Ducks Unlimited Canada and Dalhousie University, are conducting numerous field trials of wetland crossing structures across Canada. Long term monitoring has been established to help assess environmental and structural performance of these roads. FPInnovations has also been documenting the North American state of practice for resource roads crossing wetlands. This presentation will highlight the field trials, select wetland crossing designs, and operational guidance for matching wetland classification to the appropriate strategy for drainage.

Pipelines represent an extremely sensitive and high risk crossing location. The integrity of pipelines is paramount and forces acting at depth under resource road crossings are not well documented. Accordingly, pipeline owners are conservative when specifying resource road crossing requirements and these can vary with both pipeline type and site conditions. FPInnovations, in order to make crossing requirements more predictable, has surveyed the state of practice of pipeline crossings to document issues, design elements of the crossings, and planning and operational strategies for minimizing construction delays and cost. FPInnovations is modeling pipeline integrity to develop a set of standard crossing designs that are applicable for the range of resource road pipeline crossings.

FPInnovations installed strain gauges on 4 sections of scrap pipe. The pipes were buried at either 0.75 cm (two pipes) or 1.2 m (two pipes). Two methods of compaction were done around the pipes resulting in a 4 by 4 test matrix. The pipes which were laid parallel to one another and approximately 5 m apart were driven over by various heavy equipment (lowbed truck empty, lowbed with equipment on, water truck, shop truck, etc.). The results from the strain gauges will be presented along with discernible trends in the data generated by the test matrix.

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Environmental impacts of resource roads

Patrick Daigle, MSc, RPF (retired), Science Emeritus, BC MoE, Victoria BC
P.Daigle@telus.net

Resource roads present land, forests, and road managers with numerous challenges. Among the challenges, environmental impacts of roads are of major concern.

Resource roads can have direct or indirect impacts on:

- Ecosystems (e.g., water, soils, riparian and wetland areas, altered hydrologic regimes)
- Plants and their habitats (e.g., due to the increased competition from non-native invasive species)
- Animals and fish and their habitats (e.g., due to habitat fragmentation and altered wildlife behaviour)
- The accumulating effects of resource roads along with other resource human-caused pressures, such as timber, mineral and energy development.

For more details about the impacts of resource roads on the environment, check the following references:

Daigle, P. 2010. A summary of the environmental impacts of roads, management responses, and research gaps: A literature review. Journal of Ecosystems and Management 10(3): 654-89. http://jem.forrex.org/index.php/jem/article/view/File/38

__________. 2012. The diverse environmental impacts of roads on ecosystems, wildlife, and their habitats. In conference summary: Resource Roads in BC: Environmental Challenges at the Site Level: 4-9. Columbia Mountains Institute of Applied Ecology. http://cmiae.org/wp-content/uploads/Resource-roads-2012-conference-summary.pdf

Erosion and sediment control practices for forest roads and stream crossings

Clayton Gillies, RPF, RPBio, Senior Roads Researcher, Resource Roads Group, FPInnovations, Vancouver BC
clayton.gillies@fpinnovations.ca

Natural resource industries are continuously looking to improve their environmental performance and maintain their Social License with respect to management of the land base. The protection of water and aquatic habitats is of great importance. FPInnovations has a practical operations handbook about erosion and sediment control; see the reference below.

The poster highlights the modes of erosion and the importance of understanding these modes in order to better prevent erosion. Sediment containment methods will described. For erosion and sediment control professionals, there is an emphasis on preventing erosion as compared to containing and collecting sediment. The poster outlines practical and operational examples for use at specific areas along a road network, such as ditches, road surface, cut slopes, fill slopes, culverts and clear-span structures. The poster is intended as an information source for those working in the natural resource industries and government agencies, as well as contractors.

Reference

Gillies, C. 2007. Erosion and sediment control practices for forest roads and stream crossings: A practical operations guide. FPInnovations. FERIC Division, Advantage 9(5).

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Recent landslides in the Kootenay-Columbia: Lessons from the past

Peter Jordan, Geomorphologist, BC MFLNRO, Nelson BC
Peter.Jordan@gov.bc.ca

Steve Thompson, Frontline Forest Research Ltd., Nelson BC
reach07steve@shaw.ca

In steep terrain, small drainage diversions from abandoned or inadequately maintained roads and trails can sometimes lead to very large landslides. Events can still occur on roads that have been abandoned for 30 or more years. Several examples are presented from the Kootenay-Columbia region; these illustrate the range of problems encountered.

References

BC MFLNRO. 2013. Engineering Manual. Engineering Branch. http://www.for.gov.bc.ca/hth/engineering/documents/publications_guidebooks/manuals_standards/Eng-Manual.pdf

Jordan, P. 2001. Regional incidence of landslides. In proceedings: Watershed assessment in the Southern Interior of BC. BC Ministry of Forests (MoF), Forest Science Program, Working Paper 57: 174–208. http://www.for.gov.bc.ca/hfd/pubs/docs/Wp/Wp57/Wp57-06.pdf

Jordan, P. and J. Orban (editors). 2002. Terrain stability and forest management in the interior of BC: Conference proceedings. BC MoF, Forest Science Program, Technical Report 003. http://www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr003.htm

Vyse, A. et al. 2010. Forest practices. In: Compendium of forest hydrology and geomorphology in BC: Chapter 5: 111-131. http://www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh66/Lmh66_ch05.pdf

Wise, M. et al. (editors). 2004. Landslide risk case studies in forest development planning and operations. BC MoF, Research Branch, Land Management Handbook 56. http://www.for.gov.bc.ca/hfd/pubs/docs/lmh/Lmh56_HiRes.pdf

Identifying near-surface peatland flow altered by roads in northeast Alberta for restoration opportunities

Lisa Kinnear, PBio, RPBio, AMEC Environment and Infrastructure, Edmonton AB
lisa.kinnear@amec.com

Highway 63 forms part of the Alberta provincial highway network which connects the Athabasca oil sands to the Alberta Capital Region. Since originally constructed in the early to mid 1960's, development in and north of Fort McMurray has lead to an increase in traffic and an increased number of over-dimensional loads destined for the oil sands, resulting in the need for upgrades to existing roadways. Upgrading of the existing two-lane highway to four-lane freeway was proposed to address traffic demands and concerns over the safe operation of Highway 63.

AMEC was retained by Alberta Transportation to conduct an assessment of peatlands along a portion of Highway 63 south of Fort McMurray and adjacent resource roads. The assessment was intended to identify potential opportunities to off-set peatland losses resulting from highway twinning by restoring altered near-surface groundwater flow in peatlands.

The study considered peatlands along over 90 km length of existing roads. Areas of peatland bisected by the study roadways were assessed for indicators of altered near-surface flow through the review of available high resolution digital imagery and extensive comparison of historic air photos (in stereo), dating from 1951 to 2005. Field inventories were conducted in the summer of 2013 to ground-truth air photo interpretation and delineate the zone of altered near-surface flow within the subject peatlands. Field assessment included data collection relating to near-surface hydrology, soils, and vegetation along hydrologic gradients extending up to 300 m away from the existing roads.

The study confirmed that the highway and adjacent resource roads have affected peatland near-surface drainage within a number of fen peatland communities. Delineated areas of altered near-surface flow were mapped using geographic information systems (GIS) software, based on results of the aerial imagery interpretation as well as analysis of collected field data. Based on the results of the assessment, the restoration potential was qualitatively/quantitatively rated for each site based on study results to aid in prioritization of peatland restoration efforts.

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The effects of roads and human use of roads on grizzly bears and the implications to recovery of at-risk grizzly bear populations

Grant MacHutchon, MSc, RPBio Wildlife Biologist, Trans-Border Grizzly Bear Project, Nelson BC
machutchon@uniserve.com
http://www.transbordergrizzlybearproject.ca/

Humans are the major cause of mortality in most grizzly bear (*Ursus arctos*) populations and the majority of human-caused mortality occurs near roads or human occupied areas. Human road access and development in grizzly bear range leads to increases in direct and indirect impacts on bears.

Direct mortality may occur from legal hunting, mistaken identity kill, self-defense kill, malicious killing, poaching, management control kill, landowner defense-of-life and property kill, and vehicle or train collisions.

Indirect road effects, such as a change in a bear's risk of mortality or a change in the suitability or security of habitat, may occur through habitat loss or alteration, displacement from important habitat, and habitat or population fragmentation.

The persistence of at-risk grizzly bear populations in BC and Alberta requires management of human use to reduce human-caused mortality to sustainable levels and protection or active management to secure sufficient quantity and quality of grizzly bear habitat.

I suggest limiting human use of roads through access management, particularly for backcountry roads, is a more effective strategy then trying to change human behavior for ensuring grizzly bear survival as it reduces the frequency of contact between people and bears. It also is the most effective strategy for providing security for high-value grizzly bear habitat.

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Natural processes for the restoration of alluvial systems

David Polster, MSc, RPBio, Polster Environmental Services Ltd., Duncan BC
d.polster@telus.net

Degradation of riparian areas can be traced to a wide variety of causes from urban developments to industrial activities, including mining forest harvesting. Soil bioengineering, where living plant materials are used to perform some engineering function, can be an effective tool in restoring damaged riparian areas.

Soil bioengineering can be used to treat unstable banks where modified flow regimes or riparian clearing has caused accelerated erosion. Soil bioengineering can be used to treat sites where excessive sediment deposition such as from placer mining has modified flow patterns. Soil bioengineering treatments can be used to trap sediments and to re-establish the functions of riparian vegetation including increasing bank root densities, providing shade, organic matter and insects for aquatic systems. The pioneering plants used in soil bioengineering initiate the successional processes that will eventually see later successional forests develop on the site. Soil bioengineering treatments are well adapted to implementation by local stewardship groups and can provide an opportunity for low costs riparian restoration.

This poster describes soil bioengineering techniques that can be used to treat degraded riparian areas. A variety of case studies from western Canada are presented.

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Road response by grizzly bears in the Selkirk and Purcell Mountains

Michael Proctor, PhD, Wildlife Biologist, Trans-Border Grizzly Bear Project and Birchdale Ecological, Kaslo BC
mproctor@netidea.com

Excessive densities of forestry roads have been shown to influence grizzly bears in many jurisdictions. Access management has been one management tool to minimize those negative impacts and has been a cornerstone of recovery management in threatened US grizzly bear populations.

However, restrictions to backcountry road use in BC remains the single most unpopular management tool available to land use managers where it might be useful.

We realize that such an unpopular tool requires support from very clear science if it is going to be used in BC to aid in the recovery of threatened grizzly bear populations. We have accumulated a suitable GPS radio collar sample (60 bears) across the threatened S Selkirk and Yahk grizzly bear populations and in the adjacent S Purcell Mountains over the past 10 years. We are investigating (among other questions) road response by grizzly bears in these populations and those in adjacent US jurisdictions. Our suite of GPS data was collected from areas with varied road management regimes in one of three categories:

- private land with 30 years of access management (Darkwoods forest property south of Nelson),
- BC provincial lands with no access management, and
- adjacent US portions of these ecosystems with access management.

Here we address the question: Do road densities and the proportion of roadless habitat in home ranges really matter to female grizzly bears? Our analysis is not entirely complete, but when looking at adult females bears we found that they selected home range that contained road densities of 0.65 km/km^2 on average from an available road density of 1.1 km/km^2 across our study area. This result is consistent with studies in other jurisdictions, including some that have shown a relationship of road density to adult female survival, providing a plausible data-based mechanism for the impact of excessive roads on grizzly bear populations.

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Displays

Hoskin Scientific

Grant Barr, Burnaby BC. gbarr@hoskin.ca www.hoskin.ca

Central Kootenay Invasive Plant Committee

Matt Chilakos, Nelson BC. mchilakos@ckipc.ca www.ckipc.ca

McElhanney Consulting Services

Wil Moroz, Penticton BC. WMoroz@mcelhanney.com
Ryan Gibbard, Cranbrook BC. rgibbard@mcelhanney.com
www.mcelhanney.com

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Summary of comments from conference evaluations

The following is a summary of the results obtained from our evaluation forms organized according to the questions asked. Note that we had approximately 70 evaluation forms returned, but not every person responded to every question so the number of responses listed below do not add up to the number of people who attended the event. Long answers are not summarized here for brevity sake, but have been reviewed by the organizing committee.

1. How well did the conference meet your expectations?

No response to this question:	3
Responses indicated:	
Exceeded expectations	2
Fully met expectations	22
Met most expectations	26
Met only a few expectations	4
Did not meet any expectations	0

2. Key things learned at this conference? Are there things you'll do differently in future?

No response	6
Responses related to:	
Road impacts on:	
Grizzly bears	16
Cumulative effects	14
Fish passage	12
Human safety	11
The environment in general	11
Slope stability (landslides, sediments)	6
Road management:	
Rehabilitation/ restoration	13
Legacy roads	11
BC *Natural Resource Roads Act*	8
Road inventories	4

Compliance and enforcement relating to roads	4
Other:	
Citizen science relating to roads	4
Mixed comments	8

3. Other comments about this conference?

No response	12
Overall event logistics:	
Well organized	21
Good facility/food	11
Poor hotel service (food, washroom)	4
Distracting tech issues (cmptr, mic)	4
Program content:	
Diverse, knowledgeable speakers	18
Good mgmt of speakers time	16
Good networking opportunities	6
Some speakers were "rushed"	5
Want speakers from other sectors	5

A couple of other suggestions: organize road conferences again in the future; provide break-out groups for discussion of potential solutions.

4 & 5. If there's a future resource roads conference, what topics do you want included?

(Many people did not respond to these two questions. Other people provided numerous comments.)

Road management:	
Road rehabilitation/ restoration techniques	20
More emphasis on 'solutions'	17
Planning (cradle-to-grave)	11
Funding thorough road management	10
Impact mitigation techniques	9
Access management	8
Legacy roads	7
Update: BC *Natural Resource Roads Act*	5
Get other groups involved (e.g., energy, mining)	8

Road impacts on:	
Wildlife	11
Soil and water	8
Fish passage	6
Wetlands, riparian areas	4

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