FOREST PRACTICES CODE

of

BRITISH COLUMBIA

Coastal Watershed Assessment Procedure Guidebook (CWAP)

Interior Watershed Assessment Procedure Guidebook (IWAP)

Second edition
Version 2.1

April 1999

BRITISH COLUMBIA
Ministry of Forests

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Preface

This guidebook has been prepared to help forest resource managers plan, prescribe and implement sound forest practices that comply with the Forest Practices Code.

Guidebooks are one of the four components of the Forest Practices Code. The others are the *Forest Practices Code of British Columbia Act*, the regulations, and the standards. The ***Forest Practices Code of British Columbia Act*** is the legislative umbrella authorizing the Code's other components. It enables the Code, establishes mandatory requirements for planning and forest practices, sets enforcement and penalty provisions, and specifies administrative arrangements. The **regulations** lay out the forest practices that apply province-wide. **Standards** may be established by the chief forester, where required, to expand on a regulation. Both regulations and standards are mandatory requirements under the Code.

Forest Practices Code guidebooks have been developed to support the regulations, however, only those portions of guidebooks cited in regulation are part of the legislation. The recommendations in the guidebooks are not mandatory requirements, but once a recommended practice is included in a plan, prescription or contract, it becomes legally enforceable. Except where referenced by regulation, guidebooks are not intended to provide a legal interpretation of the *Act* or regulations. In general, they describe procedures, practices and results that are consistent with the legislated requirements of the Code.

The Watershed Assessment Procedure Guidebook is referenced in the Operational Planning Regulation (OPR) for the procedures and protocols required for a watershed assessment for the purpose of providing watershed-level management recommendations for forest development plans in an area where a watershed assessment is required.

The following parts of this guidebook must be followed exactly as detailed in order to complete a watershed assessment for the purpose of the OPR section 14:

1. Section 2: WAP Components, the subsection The Watershed Advisory Committee, pages 3–5; and the subsection Watershed Report Card, page 11. The other subsections of Section 2 must be addressed but there is a range of options or outcomes available to the professional practitioner.
2. Section 3: Administrative Issues, pages 14 – 19.

These portions of the Watershed Assessment Procedure Guidebook which are to be followed exactly as stated **are identified by a bar along the page margin labeled with the specific regulation being referenced, as well as a change in the text typeface.**

The information provided in each guidebook is intended to help users exercise their professional judgement in developing site-specific management strategies and prescriptions designed to accommodate resource management objectives. Some guidebook recommendations provide a range of options or outcomes considered to be acceptable under varying circumstances.

Where ranges are not specified, flexibility in the application of guidebook recommendations may be required to adequately achieve land use and resource management objectives specified in higher-level plans. A recommended practice may also be modified when an alternative could provide better results for forest resource stewardship. The examples provided in many guidebooks are not intended to be definitive and should not be interpreted as being the only acceptable options.

Contents

* Operational Planning Regulation

Tables

Figures

Forms

Introduction

Operational Planning Regulation 14(1)

OPR 14(1) A watershed assessment is required before any forest development plan is prepared for a community watershed. Assessments may also be requested jointly by a Ministry of Forests district manager and a designated environment official in watersheds that are determined to have significant sensitivity, significant downstream fisheries values, or licensed domestic water users. A district manager can also require a watershed assessment for any situations in which he or she deems it to be necessary.

The Watershed Assessment Procedure (WAP) is an analytical procedure to help forest managers understand the type and extent of current water-related problems that may exist in a watershed, and to recognize the possible hydrological implications of proposed forestry-related development or restoration in that watershed.

The WAP considers the cumulative effects of forest practices on the aquatic environment. The assessment of hydrological impacts focuses on: 1) the potential for changes to peak streamflows; 2) the potential for accelerated landslide activity; 3) the potential for accelerated surface erosion; 4) channel bank erosion and changes to channel morphology as a result of logging the riparian vegetation; 5) the potential for change to the stream channel; and 6) the interaction of all of these processes, an evaluation of which indicates the sensitivity of the watershed to further forest development. The assessment also draws attention to natural processes occurring in the watershed. Using the results of a WAP, forest managers can make recommendations to prevent or mitigate the impacts of forestry-related activities in the watershed. Results can also be used to guide watershed restoration activities.

Operational Planning Regulation 14(2)a

OPR 14(2)a To accommodate the hydrological differences that exist between the coast and the interior of the province, the WAP differs slightly in some of its components. These differences are indicated in text by “CWAP” (Coastal Watershed Assessment Procedure) and “IWAP” (Interior Watershed Assessment Procedure).

This guidebook is intended to provide direction to all professionals—hydrologists—required to conduct watershed assessments. It is assumed that the individual conducting the assessment will use his or her professional judgment and experience in selecting methods best suited to the specific goals of the assessment and the characteristics of the specific watersheds and clients. It is also assumed that he or she will use judgment to determine how to incorporate non-forestry land uses, such as cattle ranging, recreation or mining, into the assessment.

Section 1: Watershed Assessment Procedure Overview

The purpose of the WAP is to provide watershed-level recommendations for forest development plans, based on an assessment of the potential for cumulative hydrological effects from past and proposed forest harvesting and road building. The WAP can also be used to provide integrated watershed information to other planning and operational programs. Presented in this guidebook is a description of the procedure as it is used in the preparation of forest development plans. Users may adjust the procedure as needed when applying it to watershed restoration projects and non-forest development plan uses.

There are six fundamental WAP components:

1. **Watershed Advisory Committee:** a technical group formed to provide specific watershed information.
2. **Compilation of Existing Information:** a compilation of aerial photographs and 1:20 000 scale map information of the development history of the watershed and inventories.
3. **Field Assessments:** reconnaissance-level, field-based assessments of stream channel stability, sediment sources and riparian condition.
4. **Watershed Report Card:** a tabular summary of the field assessment results.
5. **Watershed Report:** a comprehensive report by the hydrologist of the watershed's state of health, based on field assessments and review of existing information.
6. **Forest Development Plan Recommendations:** specific recommendations made by the hydrologist for the forest development plan.

Size of watershed appropriate for WAP

The watershed assessment procedure is most suitable for watersheds between 500 and 50 000 ha in area (5–500 km^2). Watersheds smaller than 5 km^2 can be better assessed through a detailed field assessment, because impacts are usually site specific rather than cumulative at this scale (e.g., erosion sites, potential impacts to springs). Larger watersheds must be divided into component sub-basins for the method to be meaningful.

The technical components of the WAP are to be completed by a "qualified registered professional," as described in Section 3: Administrative Issues, under "Professional Qualifications." Throughout this guidebook, the hydrologist is the qualified registered professional.

Section 2: WAP Components

The Watershed Advisory Committee

Operational Planning Regulation 14(2)

The Watershed Advisory Committee is not a regulatory requirement of the WAP, but it is usually included in the WAP process under Ministry of Forests or Ministry of Environment, Lands and Parks policy.

A first step of the WAP is to organize a Watershed Advisory Committee. The committee is a technical group, typically made up of about 10 members representing resource interests in the watershed. Its purpose is to focus on the hydrological implications of forest development in the watershed and to make recommendations for the forest development plan based on these implications. **The committee is not a public participation forum.**

Role of the Watershed Advisory Committee

The committee has three main tasks:

1. To identify issues and provide background information to the hydrologist conducting the watershed assessment.
2. To review the hydrologist's report to check that the information provided and issues raised by the committee during technical meetings have been satisfactorily addressed.
3. To provide additional advice to the prescribing forester about how the hydrologist's recommendations can be incorporated into the forest development plan to best protect watershed values, if appropriate.

Members and Responsibilities

Membership in the Watershed Advisory Committee and member responsibilities are recommended as follows:

Forest licensee

- provides meeting logistics
- contracts the hydrologist who will carry out the watershed assessment
- prepares the forest development plan

Ministry of Forests

- chairs Watershed Advisory Committee meetings

Ministry of Environment, Lands and Parks

- may jointly chair committee meetings with the Ministry of Forests in joint approval areas
- provides information on licensing, flood histories and water quality

Water-user representative (preferably one, but at most two)

- represents the water licensees and is selected by the management group for the community water system
- provides history of water use, water quality and flooding, as well as relevant local knowledge about the watershed

Operational Planning Regulation 14(2)

Department of Fisheries and Oceans representative (if anadromous fish are present in the watershed) and/or *Ministry of Fisheries representative* (if other coded fish are found in the watershed)

Environmental health officer or alternate representative

Additional members can be added where they contribute to the technical nature of the WAP (e.g., range users, riparian landowners). Participation on committee is voluntary. If any agency, licensee or user group representative chooses not to participate, the process can proceed without that input. In addition, the roles identified above should be considered flexible. For example, the Watershed Advisory Committee may select any individual member it wants to chair the process.

Position of the Hydrologist

The hydrologist is not a member of the Watershed Advisory Committee, but participates in all of its meetings. His or her responsibilities are to:

- complete the assessments and the watershed report in a timely and cost-effective manner;
- make specific recommendations concerning the forest development plan; and
- assist the forest licensee in incorporating the recommendations into the forest development plan.

Meetings

The forest licensee should initiate the WAP process by sending a letter to the prospective members of the Watershed Advisory Committee, inviting their participation. This letter should identify the members of the committee and the professional hydrologist who will undertake the technical work. An information session for water users may be required before the WAP is officially initiated.

All meeting decisions should be documented in minutes.

The decisions of the committee should be reached by consensus. Where this is not possible, consensus also includes the “lack of dissension” by all participants—that is, any one party may disagree with a decision but choose not to “block consensus.” Dissenting opinions should be documented in the minutes.

Technical Meeting #1

The first meeting is important because it outlines for all members the correct course to be followed. However, it is optional, depending on the circumstances. It is also possible to consider more than one non-community watershed at this meeting. A formal meeting is not always required. In some cases, it is appropriate for the hydrologist to use other means such as phone calls, e-mail and fax to obtain the necessary background information from Watershed Advisory Committee members.

Operational Planning Regulation 14(2)

Objective:

To familiarize the hydrologist with all the relevant issues, and to decide on the points of interest and watershed sub-basins to be the focus of the WAP (see Appendix 1). The discussion should include:

- the history of resource development and natural disturbances;
- the history of water quality and quantity issues and availability of monitoring, research or inventory data;
- the history of downstream flooding and debris-flow implications;
- a description of the water systems;
- identification of the location of fish habitat;
- an overview of the watershed restoration planned and completed;
- a description of the proposed development; and
- the delineation of sub-basins (or the review of sub-basins already delineated) with a clear understanding of how residual areas will be assessed.

Technical Meeting #2

After the draft watershed report and hydrologist's recommendations have been reviewed by the Watershed Advisory Committee, the committee and the licensee forester who is preparing the forest development plan should meet.

Objective:

To discuss the findings and provide additional input to enable the licensee forester to prepare the forest development plan. The watershed report and the recommendations should be made available to the Watershed Advisory Committee at least 2 weeks before the meeting.

The following background information for all completed WAPs should be kept on file with the forest development plan:

- minutes of all decisions and dates of meetings;
- names and telephone numbers of committee members;
- copy of the hydrologist's report; and
- all written comments provided by the committee to assist the licensee forester with preparing the forest development plan.

Compilation of Existing Information

This component of the WAP involves compiling the available biophysical, resource and forest management data to provide an overview of the watershed. Most of this information can be compiled by the forest licensee. Once the watershed overview is complete, the maps and data are given to the hydrologist to use in the final assessment.

The following data are normally compiled:

- the most recent aerial photograph coverage available;
- 1:20 000 TRIM topographic maps with 20-m contours;
- descriptions of areas of unstable and potentially unstable terrain (such as five-class terrain stability mapping);
- descriptions of populated flood and known debris flow hazard areas;
- the contours corresponding to zones dominated by rain, transient snow and snowpacks (CWAP);
- the contours corresponding to dominant snowmelt zones (IWAP);
- locations of community water intakes;
- all aquatic features, including all known fish streams;
- watershed and sub-basin boundaries;
- tenure or private land boundaries;
- forest cover maps showing areas of past harvesting and all existing roads (including their name and number, ownership, active or inactive status, licensee obligation vs. non-status, and level of deactivation complete);
- where available, geographic information system (GIS) reports with data on ages of logging and tree heights in second growth, to allow computation of equivalent clearcut areas (ECA);
- location and description of other significant water diversion structures (e.g., dams, dikes);
- proposed cutblocks (by opening number, area, elevation range) and proposed road construction for the period covered by the plan; and
- access plans showing roads proposed for deactivation and roads to be kept for long-term access.

Assessment Component

In conducting a WAP, the hydrologist will normally undertake the following assessments:

- peak flow and hydrological recovery
- sediment source survey
- reconnaissance channel assessment procedure
- riparian assessment

Suggested methods for the assessments are described below. Additional example methodologies are described in the appendices. The hydrologist should select methodologies and methods of data presentation that are best suited to the goals of the assessment. The methods discussed here illustrate the level of detail and accuracy expected in each assessment.

Peak Flows and Hydrological Recovery

The peak flow hazard, which takes into account an estimate of the equivalent clearcut area (ECA) index of the watershed and the total non-deactivated road network in the watershed, is one way of describing the potential risk for channel change. Note: The ECA methodology (outlined in Appendix 2) produces an approximated outcome based on limited data. The results should not be used in isolation, but considered with other factors when the impact of timber harvesting on stream channels is being assessed.

Information on stand height and canopy closure of regeneration is required in order to estimate the hydrological recovery of second-growth stands. Usually the stand height information available from forest inventory databases is adequate. However, if it is not, a field reconnaissance may be needed. There are cases where ECA is not a consideration—for example, where there are low levels of logging or where streamflows are artificially controlled. The hydrologist will need to judge whether the ECA estimation is relevant. In some situations, the hydrologist's efforts may be better focused on other important factors.

The hydrological recovery table (Table A2.2, Appendix 2) assumes full stocking of the stand. Corrections may be needed if there are significant areas that do not have full stocking.

An assessment of peak flow hazard would typically take into account the following for the entire watershed and at the basin or sub-basin level, depending on the point of interest:

- historical flood frequency and timing of significant major flood events;
- natural disturbance regime and implications on peak flows;
- peak flow hazard from openings in the watershed by elevation band;
- peak flow hazard from the road network; and
- evidence in the stream channel about the influence of peak flows on channel form and processes, and the implications of further harvesting or road development on peak flows.

Sediment Source Survey

The sediment source survey is a reconnaissance-level inventory of significant contributors of fine-grained and coarse-textured sediment within the watershed. Forestry-related sediment sources are primarily associated with landslides, gullies, stream channel bank erosion, and the road network.

The survey is completed by using a combination of input from the Watershed Advisory Committee, aerial photographs, road inventories, ground surveys and aerial over-flights to identify sediment point sources and those portions of the road network that have a potential to deliver significant and/or persistent sediment loading to a stream. Additionally, the hydrologist may conduct ground truthing surveys of suspected sources of significant sediment loading. It is not necessary to field survey all roads—only portions of the road network—to confirm the sediment hazard.

An example methodology for a road sediment source survey is described in Appendix 3. Other methods that arrive at a map product with a similar accuracy and level of detail are acceptable.

Typical outputs from the sediment source survey are:

- A 1:20 000 map showing:
  - major point sources of sediment (material originating from relatively localized areas, commonly streambanks, gullies and landslides); and
  - the road network that identifies road elements with high chronic sediment delivery to streams.

- A spreadsheet that lists the following information for each point source:
  - type of disturbance (e.g., landslide, gully, terrace bank, etc.);
  - location of disturbance;
  - origin (clearcut, road, natural);
  - degree of revegetation on disturbed areas; and
  - sediment delivery to a stream.

The survey report should discuss:

- the spatial distribution, nature and severity of sediment sources in each of the sub-basins;
- a comparison of logging-related sources to natural sources and other resource developments;
- the primary fate of the sediment (e.g., how much of the sediment is delivered to the stream network, sediment routing characteristics of the receiving channel);
- the terrain types of special concern (e.g., erosion-prone terrain);
- the extent and success of rehabilitation efforts; and
- opportunities for rehabilitation.

The written evaluation should be used to rank the sediment hazard for each of the sub-basins as Low, Moderate, High or Very High; and the evaluation must include a clear justification for the assigned hazard level.

Reconnaissance Channel Assessment Procedure (ReCAP)

In a ReCAP, channel stability is evaluated along mainstem alluvial stream reaches and major tributary channels of the watershed and its sub-basins. The assessment involves examining historical aerial photographs, conducting an overview field inspection, and carrying out site visits to selected channel reaches to identify any obvious changes in stream morphology.

Components

1. *Historical aerial photographic analysis* of alluvial stream reaches to document obvious channel disturbances, locations of major sediment sources and locations of disturbed riparian areas.

This is not required on streams too small to be seen on aerial photographs. Appendix 4 is an example of a classification system commonly used for categorizing disturbance type. Historical aerial photographs, scanned and displayed at a common scale, provide an effective method of illustrating and measuring rates of channel change in selected reaches.

2. *An overview field survey* of the mainstem and major tributary streams in each sub-basin and the mainstem stream of the watershed.

On larger streams this can be effectively conducted by helicopter. On smaller streams, where tree canopy obscures the channel, the field overview should be conducted by ground survey of selected reaches. Reaches should be selected based on the following criteria:

- their susceptibility to disturbance (alluvial reaches);
- their accessibility;
- their sensitivity (e.g., reaches occurring at tributary junctions or gradient breaks, reaches below landslides, reaches with riparian logging).

The following information should be recorded for each reach:

- channel type, using a suitable stream classification system (an example is the classification system described in the Forest Practices Code Channel Assessment Procedure [CAP] Guidebook, 1996);
- extent and type of channel disturbance by reach; and
- the overall level of disturbance, based on the field indicators of disturbance identified in that reach (e.g., CAP guidebook has a suitable description of field indicators that can be used to identify the channel type and disturbance state).

3. *A more detailed investigation.* If a high level of channel disturbance is observed, the hydrologist may decide that visits to selected channel reaches are warranted to investigate channel conditions, upslope causes or the two.

Outputs

The outputs of the ReCAP should include:

- a map showing all disturbed reaches, disturbance types, and the extent of disturbance for all mainstem streams;
- a description of the stream channel types and the general sediment transport and deposition processes in the watershed;
- a description of historical flood flows, historical channel change and trends in stream channel stability;
- a reach-by-reach description of current stream channel stability and disturbance types and of the impacts of that instability on aquatic resources and property;
- probable causes of any identified stream channel instability; and
- hazard evaluation of each sub-basin mainstem.

The ReCAP outputs are used by the hydrologist in preparing the specific WAP recommendations. The written evaluation must rank the level of stream channel disturbance for each of the sub-basins as Low (undisturbed), Moderately disturbed, or Severely disturbed. The evaluation should also include a clear justification for the assigned disturbance level.

Riparian Assessment

A riparian assessment for a WAP determines the role of riparian vegetation and wood debris in maintaining channel stability and channel structure, and how, in the watershed in question, this role has been affected by logging.

Components

A riparian assessment would normally include:

- an initial assessment of logged riparian areas from aerial photographs and forest cover maps;
- identification of reaches where riparian vegetation has a critical role in channel stability (alluvial reaches either previously logged or identified on future plans);
- field observations (during the ReCAP) of channel bank erosion of logged alluvial reaches, the effectiveness of second growth to stabilize channel banks, and the presence or absence and function of large woody debris jams; and
- a comparison of historic aerial photographs to determine the temporal trend in channel stability as the riparian zone has been logged or has revegetated.

Outputs

The outputs of the riparian assessment should include:

- a map (using the ReCAP map as a base map) showing all mainstem and sub-basin mainstem reaches where logging of the riparian vegetation has resulted in impacts to the channel (i.e., bank erosion, channel widening, loss of functioning large woody debris, etc.);
- a written evaluation in which the impacts related to loss of riparian vegetation are ranked as None, Low, Moderate or High; with a clear justification for the assigned level; and
- recommendations for riparian protection in areas of proposed logging.

Watershed Report Card

Operational Planning Regulation 14(2)

The watershed report card is a summary of specific environmental indicators compiled by the hydrologist from the field assessments and resource maps. It provides a quick reference of consistently measurable indicators that: aid the hydrologist in making interpretations; allow comparisons to be made between watersheds; and provide a measure for checking or auditing watershed assessment results. Suggestions on how to prepare a report card are provided in Appendix 5. The final step is to compile all of the data for each sub-basin of the watershed. See Table 1 as an example.

The hydrologist will use the report card, together with the field assessment maps, to develop hazard ratings for peak flow, sediment sources, riparian function and channel stability. He or she will then use these ratings in making specific recommendations for the forest development plan.

Table 1. Typical watershed report card

1. Percentage of watershed harvested, corrected for ECA (%)
2. ECA by important elevation bands (% and ha)
3. Total road density (km/km^2)
4. Length of road as High sediment source (km)
5. Total number of landslides (total numbers of point sources, road related, etc.) entering streams
6. Length of road on unstable slopes (km)
7. Number of stream crossings
8. Length of stream with non-functional riparian forest (km and %)
9. Length of stream with disturbed stream channel (km and %)

Cumulative Effects and Discrete Effects

The hydrologist's assessment must also consider the cumulative effects of sediment sources, riparian conditions and peak flow increases—as well as the effects of discrete events at specific sites—on stream channel stability and on the sensitivity of the watershed to further forest development. Because these factors vary with location in the watershed, their relative significance should be discussed, particularly at the point of interest.

The hydrologist should identify:

- the implications for channel stability of the combined effects of landslides, riparian conditions and peak flows; and
- the implications for sediment production and delivery of the peak flow hazard and surface erosion hazard.

Watershed Report

The hydrological assessment is documented in the watershed report, prepared by the hydrologist. The report should allow readers to follow the logic of the analysis easily, from the characterization of the watershed to the specific recommendations and conclusions.

Included in the watershed report should be a discussion of the following points:

- issues that triggered the analysis and resource concerns specific to the watershed;
- the dominant hydrological processes;
- the basic morphological characteristics of the watershed (hillslope/upland attributes important to downslope/downstream coupling), of the streams, and of the general sediment erosion, transport and deposition processes;
- the current hazard levels for each hydrological category and the evidence for each hazard level;
- the natural condition expected for the watershed as a result of disturbance regime and recent climatic events;
- changes in the watershed and their probable causes;
- the implications of all of the above for watershed management, including specific recommendations for each component of the proposed forest development plan (these must enable reviewers to address amendments to the forest development plan between WAP updates);
- the hydrological risks of further timber harvesting or road construction in the watershed;
- specific recommendations for hazard mitigation (these should state clearly how the recommended actions will reduce hazards); and
- recommendations for the 3-year updating of the WAP.

The hydrologist should chose methods of presenting data that best suit the specific watershed and goals of the assessment.

Generally, the watershed report will also include the following appendices:

- watershed map showing sub-basins, important runoff generation elevation bands, points of interest and fish streams;
- sediment source map;
- ReCAP map showing channel reaches and riparian conditions;
- a summary of proposed roads and cutblocks for forest development plans;
- hazard tables for each sub-basin and the entire watershed; and
- watershed report card.

Monitoring

Monitoring is not normally an outcome of a WAP. Only in rare situations may a monitoring program be justified, to detect changes in the watershed that are the result of site-specific or cumulative upstream impacts. Even then it should only be initiated with careful consideration of time and space scales, methods and the financial implications of setting up and continuing such a program.

Where a monitoring program is recommended, the design must be explicit with respect to identifying objectives, methods and feedback mechanisms to forestry operations. Responsibilities and funding must also be clear.

Forest Development Plan Recommendations

The hydrologist's recommendations for the forest development plan should consider the following:

- the severity of the hydrological risk;
- the hydrological implications for water quality in the community watershed water supply and fish habitats;
- the trend of the watershed condition (including disturbance regime hazards);
- future harvesting opportunities and road infrastructure; and
- remedial work for high hazard sediment sources, if needed.

The forester preparing the forest development plan should advise the hydrologist of relevant objectives in higher level plans. For example, if bull trout conservation has been identified as an objective in a land and resource management plan, then recommendations that conserve the unique water quality and stream channel stability requirements of bull trout are appropriate.

Recommendations coming out of the watershed assessment should be limited to the hydrological management of the watershed specifically as it concerns the preservation of water and aquatic values as affected by peak flows, sediment sources, riparian condition or channel stability.

As well, recommendations for the forest development plan can be linked to remedial work, if problems in the watershed (such as high sediment loads from roads or logging-related landslides) persist from past forest development. For example, further logging may be supportable if watershed restoration measures are implemented and determined to be effective in addressing the logging-related sediment sources.

Once the hydrologist has prepared the recommendations, they must be reviewed by the Watershed Advisory Committee. The hydrologist, the committee and forester preparing the forest development plan may then decide to meet to consider the hydrological implications of the recommendations. The plan is then completed and submitted to the district manager.

Section 3: Administrative Issues

Completing the Forest Development Plan with a WAP

Operational Planning Regulation 14(2)

The following steps are required for completing a forest development plan in an area where a watershed assessment is required:

1. The district manager notifies a licensee that a WAP is required for the watershed (e.g., a community watershed, a watershed with significant downstream values, or another critical watershed identified by the district manager and, where required, the designated environment official).

2. The district manager and the licensee identify a coordinator for the WAP process.

3. The licensee contracts with a hydrologist.

4. If Ministry of Forests or Ministry of Environment policy requires that a Watershed Advisory Committee be involved, the coordinator contacts the committee members and organizes a meeting to review the watershed history and to provide the hydrologist with watershed assessment information.

5. The hydrologist completes the WAP report and hydrological recommendations and distributes them to the prescribing forester and Watershed Advisory Committee members for review before the final committee meeting.

6. The committee members notify the hydrologist if they have concerns with the report or hydrological recommendations and let the coordinator know if they would like to hold a final meeting.

   If they agree with the report and hydrological recommendations and there is no need for a final committee meeting, the hydrologist can then simply forward the report and recommendations to the prescribing forester, adding a note that a final meeting is not requested by the committee.

   If a final Watershed Advisory Committee meeting is deemed necessary, the hydrologist presents the WAP report and hydrological recommendations to both the committee and the prescribing forester preparing the forest development plan. The committee can also provide additional comments to the prescribing forester during this presentation, with a follow-up written summary. The hydrologist may choose to revise the WAP report and hydrological recommendations if new information has become available or if alternative risk management strategies are desirable.

Operational Planning Regulation 14(2)

7. The prescribing forester prepares the forest development plan. In doing so, he or she must consider both the hydrologist's recommendations and the comments received from Watershed Advisory Committee.

8. The licensee makes the forest development plan available for review under Section 27 of the Operational Planning Regulations. The plan must state that it is consistent with the results and recommendations of the WAP.

9. The prescribing forester submits the forest development plan to the district manager and designated environment official for approval, together with a statement that the plan is consistent with the hydrologist's WAP report results and recommendations (or, as appropriate, the reasons that the plan is not consistent) for community watersheds or portions of watersheds designated as community watersheds.

10. The district manager (and designated environment official, where required) reviews the licensee's summary of how the WAP recommendations were incorporated into the forest development plan, as part of making a determination about the plan.

Forest Development Planning

When to Do a Watershed Assessment

OPR 14(2) As of December 15, 1998, all WAPs must be completed before any forest development plan in a community watershed is submitted, unless the district manager and designated environment official agree that one is not required.

Operational Planning Regulation 14(1)

OPR 14(1) A watershed assessment must be redone every three years. It is not necessary to redo those components of the assessment that are not expected to have changed in the intervening period.

Operational Planning Regulation 14(4)(a)

OPR 14(4)(a) Assessments may be requested jointly by a district manager and designated environment official in watersheds that are determined to have significant watershed sensitivity and that have significant downstream or licensed domestic water users. A district manager can also require a watershed assessment in situations where it is determined to be necessary.

WAPs may also be requested for other watersheds where the district manager determines an assessment is necessary. This may include watersheds where there is a risk to human life, public infrastructure and public and private property associated with flooding, or where there is stream channel instability that may be the result of cumulative effects in the watershed.

Operational Planning Regulation 14(1)

Definitions

Significant watershed sensitivity means the watershed has a history of landslide, erosion or channel stability problems, or it has had a sufficiently high rate of cut in the past 20 years that hydrological problems are anticipated by the district manager and designated environment official. In some physiographic areas, mass wasting and channel instability may be so common that all watersheds in that zone are designated as sensitive. The WAP is best applied on a watershed where a potential for cumulative impacts exists—for example, usually a watershed where:

- at least 20% of the watershed's area has been logged during the past 25 years (or the 25 years that include the 5 years of proposed development); **and**
- a significant number of landslides that entered the stream channel are known to have occurred; **or**
- stream channel stability problems are evident; **or**
- over 25% of the riparian forest along either bank of the main stream channels has been logged over the past 40 years; **or**
- landslide problems are anticipated due to recent harvesting on unstable terrain.

Significant fisheries values means the watershed has been identified by the district manager and designated environment official as having a unique or important fish stock. Direction can be taken from a higher level plan, such as a land and resource management plan or a landscape unit plan, where conservation of a specific fish stock has been identified as one of the objectives of the plan.

Operational Planning Regulation 14(2)

Prioritizing Watersheds

All community watersheds must have a WAP, unless they have been exempted by the district manager and designated environment official. WAPs carried out in other watersheds are discretionary. It is not worthwhile to assess watersheds in which there are no forest development plans, only a low level of past forest development has occurred, or no apparent hydrological problems exist. However, it is desirable to schedule discretionary watersheds for WAPs based on the likelihood of hydrological problems (see the definition of "significant watershed sensitivity").

It is recommended that representatives from the Ministry of Forests, Ministry of Environment, Lands and Parks and the Department of Fisheries and Oceans, with the advice of forest licensees where appropriate, cooperatively develop annual work plans for completing the discretionary WAPs over a 5- to 10-year period.

Operational Planning Regulation 14(2)

Watersheds with More Than One Licensee

Responsibility for conducting a WAP lies with the licensee who is submitting the forest development plan. Where there are two licensees operating in a watershed, both of whom are submitting plans, then they should cooperate in conducting a single WAP, with a single Watershed Advisory Committee and both licensees represented. The licensees should discuss the cost of the assessment and determine an equitable cost-sharing arrangement.

In situations where two licensees have tenure in a watershed, but only one is active, the inactive licensee should still be encouraged to participate in the WAP. Recommendations made by the Watershed Advisory Committee may have operational implications for both licensees, so both should be represented on the committee.

Private Land

While WAPs apply only to forest tenures on Crown land and not to private land, it is highly recommended that information on other land uses be obtained during a WAP. The entire contributing drainage basin must be considered when the hydrological functions of a watershed are under evaluation.

If possible, information about roads, cutblocks and sediment sources within the private lands portion should be obtained. This may involve consulting landowners or seeking their voluntary participation on the Watershed Advisory Committee. The best option, however, may simply be to take the information from the most recent aerial photographs of the watershed. If the private land is Private Managed Forest Land, a management plan can be made available from the BC Assessment Authority, with the consent of the owners. See Appendix 2 for recommendations on including private land in peak flow hazard calculations.

WAPs Completed Before April 1998

Between June 15, 1995, and April 2, 1998, a large number of WAPs were completed, both for forest development planning and for watershed restoration purposes. These WAPs followed the first methodology presented in the 1995 Forest Practices Code CWAP and IWAP guidebooks.

The previous WAPs fall into one of the categories below:

Operational Planning Regulation 14(1)

OPR 14(1) **WAPs with round tables and low hazard Level 1 results**

If the WAP was conducted under the guidance of a round table, or the Level 1 results (except for surface erosion) all indicated hazard scores less than 0.5, then the WAP is considered to be valid for 3 years after the date of completion. When that time period is over, a new WAP should be conducted using the 1999 procedures.

OPR 14(1) **Code-required WAPs with no round table and low Level 1 results**

The recommended procedure is to create a round table in each district that can “batch process” the old completed Level 1 results. For example, a district Watershed Advisory Committee can be set up to deal with all of the community watersheds in a licensee’s chart area. The committee should include the community watershed representatives

Operational Planning Regulation 14(1)

from each affected watershed. Where all of the hazard scores are less than 0.5 and the results have been reviewed by this district round table, then the WAP is considered to be valid for 3 years from the date of completion. When that period is over, a new WAP should be conducted using the 1999 procedures.

Operational Planning Regulation 14(5)

OPR 14(5) Code-required WAPs completed to Level 1, but hazard scores are greater than 0.5

Where WAPs have been completed, with or without round tables, and any hazard indicator is greater than 0.5, there is an option to field-verify the Level 1 scores. If the high hazard scores are confirmed, then a Level 2 is required. If the Level 2 is completed and the round table has made its recommendations, then the WAP is considered to be complete and is valid for 3 years. After the WAP is updated, the 1999 procedures should be followed.

Where field-verified WAP Level 1 hazard scores are greater than 0.5 and no Level 2 has been completed, then the WAP is not considered to be complete. The Watershed Advisory Committee should determine whether further work is required and, if it is, the assessment should be completed following the 1999 procedures.

OPR 14(5) WAPs required where significant forest development has occurred since a previous WAP

A new watershed assessment may be requested by the district manager if there has been a significant amount of terrain instability within the watershed, or if the extent of timber harvesting or road construction or modification operations within the watershed has been significantly greater than was considered in the original WAP.

WAPs not required under the Code (including Watershed Restoration Program WAPs)

Many WAPs were completed under the Watershed Restoration Program, but usually only to Level 1. The results from these WAPs may be used to fulfill Forest Practices Code obligations in community watersheds and designated fishery watersheds, according to the rules described above. Other WAPs have been conducted to investigate various land management concerns in watersheds that were not required under the Code. There is no obligation to revise the results of these WAPs.

Professional Qualifications

Operational Planning Regulation 14(2)

The person completing the watershed assessment report must be a qualified registered professional, qualified in forest hydrology and with experience in watershed cumulative effects assessment. It is also desirable that he or she have expertise in mapping slope processes, terrain types and fluvial geomorphology.

Definition

Qualified registered professional means, with respect to an activity for which this procedure requires a hydrologist, a person who:

(a) has appropriate education and experience to carry out the activity, and

(b) is a member of, or is licensed by, a regulatory body in British Columbia that has a legislated authority to regulate its members or licensees performing the activity.

The hydrologist must have a basic knowledge of forest harvest systems and forest road engineering. The watershed assessment report must be signed and sealed by the hydrologist who carried out or accepts responsibility for the work; and the hydrologist conducting the watershed assessment should understand that reviews are anticipated.

Conclusion

This version of the Coastal and Interior Watershed Assessment Procedures represents another advance for watershed management in British Columbia. The increased reliance on hydrologists now allows assessments to be based on professional judgment that fully integrates watershed processes and forest land use.

This document describes the level of detail and scope expected in watershed assessments. It also outlines the composition and role of the Watershed Advisory Committee, which is established to provide the complete range of water resources input to the hydrologist and specific suggestions to the forester completing a forest development plan. The result will be comprehensive plans and prescriptions that are tailored to maintain the hydrological integrity of individual watersheds.

References

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Appendices

Appendix 1: Identification of stream orders, sub-basins, and the point of interest

For many applications of the WAP, it will be necessary to subdivide large watersheds into smaller units. In cases where the watershed of analysis is relatively small (e.g., approximately 1000 ha), subdividing it into smaller sub-basins will not likely be necessary. Although all hydrologists will be fully knowledgeable with identifying stream orders and sub-basins, it is important that all practitioners use common terminology and similar methods (e.g., dealing with face units in a uniform manner). Furthermore, since stream ordering is map scale dependent, the required map scale must be specified.

Sub-basin Identification

Maps at 1:20 000 scale are to be used for watershed assessment purposes.

A watershed will commonly include sub-basins and face units:

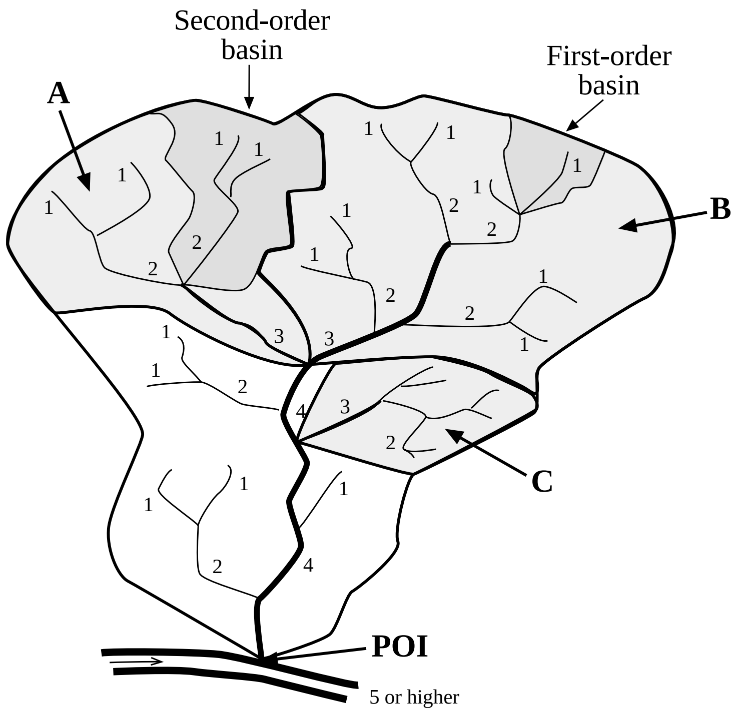
- In watersheds being assessed for fishery concerns, it is most common to consider the watershed area upstream of the most upstream fish-bearing reach to be a single sub-basin and not to further divide that sub-basin into smaller units. However, in addition, any sub-basin that discharges directly into a fish-bearing stream reach should be assessed individually.
- Face units are those hillslope areas that drain directly into the length of stream containing the point of interest (POI), but have no mapped channel (i.e., no first-order stream mapped at 1:20 000 scale). These areas drain either by subsurface flow or by very small ephemeral (seasonal) streams. Small, lower-order tributaries and face units should be included in Level 1 calculations in the residual category.

In the example given in Figure A1.1, Dome Creek is a salmon-bearing river that flows directly into the Fraser River. The POI is the confluence of Dome Creek and the Fraser River. Dome Creek at this point is fourth order. Here then, the Dome Creek watershed should be subdivided into:

- sub-basin A
- sub-basin B
- sub-basin C
- the residual

The residual in this case is everything outside sub-basins A, B and C, but within the Dome Creek watershed.

Figure A1.1. Stream ordering technique. **The entire watershed is a fourth-order watershed. Sub-basins A, B and C are third-order watersheds.**



Point of Interest Determination for Community Watersheds

The following are guidelines for establishing the POI for a community watershed. Information on how to determine where water system intakes are and how to determine water use is also included. The final decision on where to locate the POI should be made at the initial round table meeting.

Point of Interest Determination for Intakes on Streams

- When there is only one community intake on a stream, the POI is at the water intake. If there is more than one licensed community intake, the POI is established at the lowest intake on the system.
- If a cluster of licenses exists some distance downstream of a community intake and meets criteria set out, the POI should be moved downstream. If there is more than one intake associated with the community watershed, the POI should be set at the lowest intake in the cluster.

Point of Interest Determination for Intakes on Lakes

Although the WAP was developed to assess stream watersheds, it may also be applied to lake watersheds. Two examples of where it may be used:

- for a community intake in a very small lake (lake surface area less than 5 km^2); and
- for a community intake situated in a lake close (within 0.5 km) to a point where a stream enters the lake.

In the first example, it may be appropriate to set the POI at the outlet of the lake. In the second, it may be appropriate to set the POI at the confluence of the stream or streams that could impact the water quality at the intake (or intakes). Deciding the lake POI will have to be undertaken on a site-specific basis. The Watershed Advisory Committee should make the determination.

Point of Interest Determination for Fisheries Watersheds

In watersheds being assessed through the WAP for fishery concerns, it is common to establish two POIs:

- The first POI is established at the most downstream fish-bearing stream reach in the watershed. This is commonly the ocean or a lake, or at the stream's confluence with another river.
- The second POI is established at the farthest upstream reach of a fish-bearing stream. The watershed area upstream of this upper POI is commonly considered a single sub-basin for analysis, and is not usually subdivided further unless the Watershed Advisory Committee considers it necessary to do so. Any sub-basin discharging directly into the fish-bearing stream reach (i.e., between the lower and upper POIs) is considered to be an individual sub-basin and should be assessed separately.

Appendix 2: Peak flow factors: equivalent clearcut area (ECA) and road density

The ECA methodology used here to estimate changes in peak flow produces an approximation based on limited data; it must not be used in isolation, but can be useful in combination with other factors to assess the impact of timber harvesting on stream channels. There is little evidence to link channel disturbance with ECA alone, in isolation from other effects such as riparian logging and changes to sediment supply. ECA values should not be a management target.

Definitions

Streamflow is surface runoff, flowing in a stream channel, which is derived from rainfall, snowmelt or a combination of the two.

Peak flow is the maximum flow rate that occurs within a specified period of time, usually on an annual or event basis.

Low flow is the minimum streamflow that occurs during the course of the year, as a result of summer drought or winter freezing.

Hydrological recovery is the process by which regeneration restores the hydrology of an area to pre-logging conditions. Complete hydrological recovery incorporates many hydrological components, including the recovery of snow accumulation and melt characteristics, recovery of precipitation interception during storms, and recovery of evapotranspiration. In British Columbia, the most important component of the hydrological recovery involves snow accumulation and melt characteristics (snowmelt recovery) because peak flows in both interior and coastal areas tend to be generated by conditions of radiation snowmelt and rain-on-snow. Therefore, snowpack recovery is used as an index of true hydrological recovery.

Equivalent clearcut area (ECA) is the area that has been harvested, cleared or burned, with consideration given to the silvicultural system, regeneration growth, and location within the watershed.

ECA and road density are the two primary factors considered in an evaluation of the potential effect of past and proposed forest harvesting on peak flows. This appendix suggests a method of collecting and presenting the appropriate information for interpretations.

Equivalent Clearcut Area

Refer to Table A2.1 to characterize harvested or disturbed areas in the watershed.

Table A2.1. Assumptions for ECA calculations

Not satisfactorily restocked areas:	Clearcut with 0% recovery.
Individual tree selection: <20% basal area removal 20–40% basal area removal 40–60% basal area removal 60–80% basal area removal >80% basal area removal	 Assume 100% recovery. Assume 0.2 of area harvested (e.g., 1 ha of 35% removal = 0.2 ha ECA). Assume 0.4 of area. Assume 0.6 of area. Clearcut with 0% recovery.
Small opening: < 1H[a](<0.05 ha)[b] 1H–3H (0.05–0.5 ha) 3H–5H (0.5–1.2 ha)	Assume 0.5 of area (e.g., 20 x 0.05 ha openings = 1 ha cut = 0.5 ha ECA). Assume 0.7 of area. Assume 0.9 of area.
Strip cuts: <2H (50 m) 2H–3H (50–75 m) width 3H–4H (75–100 m) width > 4H (>100 m) width	 Assume 0.6 of area (e.g., 1 ha = 0.6 ha ECA). Assume 0.7 of area. Assume 0.8 of area. Assume 1.0 of area.
Private land:	Include in total sub-basin area and ECA.
Open range:	Include in total sub-basin area, but do not include range land as ECA (most range land is naturally open grassland and should not be tallied as ECA).
Burn sites:	Clearcut with recovery factors for regeneration. If a burn produces a stand similar to a partial cut, use the partial cutting recovery factors.
Large landslides:	Clearcut with the appropriate recovery factors.
Utility corridors:	Clearcut with 0% recovery.

a H refers to average tree height.
b This assumes a tree height of 25 m. If tree height is substantially greater, opening sizes can be increased by calculating the opening size for circular openings.

The rationale for Table A2.1 is as follows. Harvesting systems that maintain a canopy are not weighted as heavily on an ECA per unit of basal area removed as a clearcut, because the remaining canopy shades the snowpack. There is a moderate hydrological benefit in maintaining a canopy and this is reflected in Table A2.1. Therefore, twenty 0.05-ha openings are considered 0.5 ha of clearcut rather than 1 ha. The basis for this lower ECA is the reduced melt rates in these openings.

Model results conducted by the Ministry of Forests indicate that about 1 tree height (1H) opening on flat ground receives less than 10% of the incident light that a full opening would receive.[1] A 2H opening would receive 30% of incident light and a 3H opening about 65% of incident light. These model results are also reflected in empirical snow accumulation and melt rate measurements. Although the small openings collect more snow, that snow melts very slowly and a reduced ECA is appropriate. The hydrologist should recommend various partial cutting systems on a site-specific basis. Small openings are most appropriate in watersheds where low flow is a problem and the water user wishes to prolong the melt season. It should be used with caution upslope of unstable terrain where the objective is not to prolong the melt season.

Table A2.2 shows snowpack recovery factors resulting from forest regeneration. Research is currently being conducted in British Columbia to better understand and quantify snowpack recovery. This work is exploring the relationship between tree canopy development, stand canopy height and snow accumulation and melt. Revisions to Table A2.2 will be considered as new information becomes available.

Table A2.2 indicates that below a height of 3 m, trees are not effective at providing interception storage or at providing a buffer from radiation snowmelt or rain-on-snow processes. Thus, recovery starts at a stand height of 3 m. At a canopy height above 9 m, the regenerating stand begins to approach full recovery. However, full recovery is unlikely in second-growth plantations, because canopy structure will be different than in old growth, even at rotation ages. Note, too, that the recovery relationship given in Table A2.2 assumes full stocking. Often, regeneration is patchy, particularly at heights below 7 m. If this is the case, then the coverage of that regeneration must be taken into account.

1 Based on the Clearcut Light Model (CLIMO) work done by Ralph Adams (1999), Light in small forest openings, Internal Report, B.C. Ministry of Forests, Kamloops, B.C.

Table A2.2. Hydrological recovery for fully stocked stands that reach a maximum crown closure of 50%–70%.

Average height of the main canopy (m)	% Recovery
0 – <3	0
3 – <5	25
5 – <7	50
7 – <9	75
9 +	90

Location of harvested, cleared or burned areas within a watershed is the third key factor in determining ECA.

For the CWAP, three elevation bands are chosen to represent the dominant streamflow generation processes operating in the watershed being assessed. In the lower elevation band, peak flows tend to be generated by rainfall (the rain-dominated zone); in the middle band, by rain-on-snow (the transient snow zone); and in the upper band, by a combination of radiation snowmelt and rain-on-snow (the snowpack zone).

The hydrologist must determine the elevational ranges of these bands for the area in which the watershed is located. For example, studies at Russell Creek on northeast Vancouver Island and at Chapman, Gray and Roberts creeks on the Sunshine Coast have shown that the rain-dominated zone corresponds to the 0- to 300-m band, the transient snow corresponds to the 300- to 800-m band, and the snowpack zone corresponds to the area above 800 m. Different elevational bands may apply on other parts of the coast. For instance, on the west coast of Vancouver Island, the elevational bands are generally higher and lower on the North Coast. Farther north (e.g., in the Kitimat area), the highest instantaneous peak flows are generated by autumn rain-on-snow events. In this area, snow is characteristically present at sea level, so there is no rain-dominated zone. The hydrologist may choose to weight the ECA calculated within each elevational band differently, depending on the important peak flow generating mechanism, but the weighting factor must be justified.

For the IWAP, watersheds are also divided into elevational bands to account for the vertical variability in runoff generating mechanisms. Although this is commonly based on the location of the “H60” line-defined as that elevation above which 60% of the watershed lies (the watershed area above the H60 line is considered to be the source area for the major snowmelt peak flows)—other values can be used, provided the hydrologist justifies the decision.

Calculating the ECA

To calculate ECA, use 1:20 000 forest cover maps to locate logged or disturbed areas. Determine the location of the areas relative to the specific bands for the IWAP or the CWAP. Determine the height of regeneration in each logged or disturbed polygon. Heights may need to be extrapolated if reference material is not up-to-date (ensure that these extrapolations are field verified). Refer to Table A2.1 for factors relating to the type of disturbance. The area of each opening will then have to be reduced by the appropriate percent snowpack recovery, as shown in Table A2.2. The following relationship relates the ECA of an opening to its recovery status and the area of opening:

$$ECA = A \cdot C\,(1 - R/100)$$

where A is the original opening area, C is the proportion of the opening that is covered by functional regeneration, and R is the recovery factor from Table A2.2.

Use Form 1 or Form 2 to calculate ECA.

Form 1. ECA calculations by sub-basin for the IWAP.

Sub-basin name	**Below specific elevational line**			**Above specific elevational line (major snowmelt zone)**			**Snowmelt index (C+F)**
	A ECA (km^2)	**B** ECA ÷ total sub-basin (km^2/km^2)	**C** Weighted ECA (B X *I*1)	**D** ECA (km^2)	**E** ECA ÷ total sub-basin (km^2/km^2)	**F** Weighted ECA (E X *I*2)	
Residual							
Total watershed							

Note: The *I*n is a factor that accounts for the vertical variability in snowmelt within the watershed. The *I* value used must be justified by the hydrologist.

Form 2. ECA calculations by sub-basin for the CWAP.

Sub-basin name	Rain-dominated zone			Transient snow zone			Snowpack zone			Snow melt index (C+F+I)
	A ECA (km^2)	**B** ECA ÷ total sub-basin (km^2/km^2)	**C** Weighted ECA (B X *C1*)	**D** ECA (km^2)	**E** ECA ÷ total sub-basin (km^2/km^2)	**F** Weighted ECA (E X *C2*)	**G** ECA (km^2)	**H** ECA ÷ total sub-basin (km^2/km^2)	**I** Weighted ECA (E X *C3*)	

Note: The *Cn* is a factor that accounts for the vertical variability in runoff generation mechanisms within the watershed. The *C* value used must be justified by the hydrologist.

Road Density

Roads can influence peak flows in several ways. Ditchlines intercept subsurface flows and transfer the water to streams much faster than through the soil. The compacted surfaces of roads reduce infiltration and transfer intercepted precipitation and snowmelt to ditchlines, and hence to streams. Roads can also intercept and transfer surface water. While adequate cross-drain structures should reduce the impact of this on peak flows, an effect can still be possible. Determining road density is therefore an approach to assessing the potential impact on peak flows. As with harvested areas, the location of a road within a watershed is considered to be significant. Use Form 3 or Form 4 to present road density information for interpretations.

Form 3. Road inventory and density information for the IWAP.

Sub-basin name	Sub-basin area (km^2)	Road in major snowmelt zone		Road for entire sub-basin	
		Length (km)	Density (km/km^2)	Length (km)	Density (km/km^2)
Residual					
Total watershed					

Form 4. Road inventory and density information for the CWAP.

Sub-basin name	Sub-basin area (km^2)	Road in major snowmelt zone		Road for entire sub-basin	
		Length (km)	Density (km/km^2)	Length (km)	Density (km/km^2)
Residual					
Total watershed					

Appendix 3: Sediment source survey

The sediment source survey is a field assessment carried out by the hydrologist to estimate the surface erosion hazard in a watershed. The objectives of the survey, presented in Section 2 of this guidebook under the heading "Assessment Component," can be met through a number of different field procedures. This appendix describes one method that results in an acceptable level of detail. However, other methods shown by the hydrologist to be appropriate can also be used.

Point Source Survey

The first step is to identify the significant sediment sources observable on 1:20 000 scale (or larger scale) aerial photographs in the following categories:

- landslides and debris flows larger than 0.05 ha;
  Each landslide should be marked from initiation point to terminus. Each landslide should also be numbered and this number cross-referenced to the spreadsheet on which is recorded landslide type, initiation point (including reference to cause-natural, forestry related, or other land use), delivery route, magnitude of past and ongoing sediment delivery, surficial materials, disturbed area, and degree of revegetation.
- torrented stream channels;
- gullies with evidence of sidewall or channel failure; and
- large ravelling streambank terraces.

The second step is to plot this sediment source survey information on a 1:20 000 TRIM base map, using symbols to represent the sediment sources.

Sediment Hazard from Roads

One method of assessing surface erosion hazard is described below; the intended level of detail is evident. Other methods shown by the hydrologist to be appropriate can also be used.

The first step is to identify sediment sources from roads, observable on 1:20 000 (or larger scale) aerial photographs. These sources might include:

- slides from road fills;
- long unvegetated road fillslopes;
- unstable or large unvegetated cutslopes;
- erosion at crossing structures;
- road sections with steep grades that connect to streams; and
- road sections close to or encroaching on stream channels.

The second step is to plot this information on a 1:20 000 TRIM base map. It is useful to overlay terrain stability or soil erosion mapping on this map, showing areas of moderate to high hazard of instability or erosion.

A table or suitable legend should accompany the map, describing each source and the relative level of sediment delivery. Note that the significance of a sediment source depends on the capability of the receiving water to transport the incoming sediment downstream. Relatively small sediment sources can have a major effect on small streams, whereas much larger sources can have minimal effect on large stream channels. The assessment report must discuss the relative significance of the various sediment sources on the streams within the watershed.

Tables A3.1 and A3.2 suggest methods of describing sediment production and delivery. Note that some sources produce sediment on an ongoing basis, such as wash from an active haul road or chronic erosion of a road fill, whereas others are discrete events that produce a large quantity at the time of occurrence but little after that. The description of the sediment sources should indicate which sources are chronic and which are discrete events.

Table A3.1. Potential sediment production from forest roads

Class	Annual sediment production: median (m^3/km of road element)	Annual sediment production: range (m^3/km of road element)	Average road rill length by width (cm^2)	Description
1	0.1	<0.3	10 x 0.1	almost unnoticeable rills
2	1	0.3 – 3	10 x 1	light erosion (typical of well armoured low-use roads)
3	10	3 – 30	50 x 2	moderate erosion (typical of erodible materials, average maintenance, high use roads)
4	100	30 – 300	100 x 10	severe erosion, access difficult with a 4x4 but not impossible
5	1000	300 – 3000	200 x 50	severe gullying, impassable but repairable
6	10 000	>3000	1000 x 100	total washout, road gone

Each road element should be assigned a potential sediment production class.

The photographs used in Figures A3.2 through A3.6 illustrate typical examples of each road erosion class.

Figure A3.1. Example of sedimental production class 1, see Table A3.1 (sediment production = 0.1 m^3/km/yr).

Figure A3.2. Example of sediment production class 2 (sediment production = 1.0 m^3/km/yr).

Figure A3.3. Example of sediment production class 3 (sediment production = 15 m^3/km/yr).

Figure A3.4. Example of sediment production class 4 (sediment production = 70 m^3/km/yr).

Figure A3.5. Example of sediment production class 5 (sediment production = 1,000 m^3/km/yr).

Only sediment that is delivered to the stream is important for WAP purposes. Sediment delivery classes are shown in Table A3.2.

Table A3.2. Classification of sediment delivery from forest roads to stream channels

Class	Description
1	No or minimal delivery of sediment from roads to any stream system. Sediment commonly delivered to forest floor, with no surface runoff evident or expected during the wet season.
2	Moderate level of sediment delivery. Sediment delivery partially is connected from the stream network. Disconnected by flat terrain and/or discontinuous drainage routes. Low gradients and discontinuous nature of the connecting drainage routes lead to deposition of most of the sediment originating on the roads.
3	High level of sediment delivery. Sediment delivered intermittently to the stream network via either or both ditch drainage or surface runoff routes. Low gradients and intermittent nature of the connecting drainage routes lead to partial deposition of the sediment originating on the roads.
4	Very high level of sediment delivery. Sediment delivered either directly to the stream network or along efficient ditch drainage or surface runoff routes.

With the values derived from Table A3.1 and Table A3.2, use Table A3.3 to determine the sedimentation hazard. Only the high (H) and very high (VH) road elements need to be coloured on the sediment source survey map. This is not intended to be an inventory of the entire road network

Table A3.3. Sedimentation Hazard

	Sediment Delivery			
Sediment Production	**1**	**2**	**3**	**4**
1	L	L	L	L
2	L	L	L	M
3	L	L	M	H
4	L	M	H	H
5	M	H	H	VH
6	H	H	VH	VH

Note that the L, M, H and VH rankings can be revised for each sediment production-delivery combination by the hydrologist, based on local experience, but all revisions must be justified.

Appendix 4: A method for classifying stream channel stability

The WAP describes the outcomes required from a reconnaissance stream channel stability survey. Different methods exist for conducting this survey and for making the stability interpretations. This appendix describes one method, which is based on an overview application of the principles discussed in the Channel Assessment Procedure (CAP) Guidebook. Other methods shown by the hydrologist to be appropriate can also be used.

Methodology

The reader must be familiar with the CAP guidebook to use this methodology.

Map Exercise

- Construct a longitudinal profile of the mainstem channel (plot of elevation versus horizontal distance) using 1:20 000 TRIM maps.
- Identify and label major channel reach breaks on the longitudinal profile and topographic map, according to the methodology in the CAP guidebook.
- Identify the location of the following features on the profile:
  - major stream junctions,
  - domestic water supply intakes,
  - reach numbers, and
  - average reach gradient.

Aerial Photograph Analysis

- Compare the most recent, large scale (e.g., larger than 1:20 000 scale) aerial photographs of the watershed with those taken just before logging. If at all possible, use three ages of photography. Look for the following characteristics:
  - the likely CAP classification (where this can be discerned from the aerial photographs) of all reaches;
  - any reaches with obvious channel disturbances;
  - locations of major sediment inputs; and
  - locations of disturbed riparian areas.

Field Procedures

- Using the map of the channel network and labeled reaches, conduct a helicopter survey or ground survey of the sensitive alluvial reaches.

- For each reach of the mainstem, record:
  - the channel type according to the CAP guidebook;
  - the channel width category;
  - extent of channel disturbance; and
  - the channel state, or overall level of reach disturbance, based on the field indicators identified in that reach. The channel state ranges from stable or undisturbed (S), through moderately disturbed (DM and AM) to severely disturbed (DS and AS). The typical types of disturbance associated with each channel type are summarized in the CAP guidebook.

- Complete the aerial survey of all mainstem and important tributary channels.

- On the basis of the aerial photograph and map exercises and helicopter overview flight, decide which reaches need to be visited to make a detailed CAP classification. These are usually restricted to the severely disturbed reaches. See the CAP guidebook for the procedures for conducting a detailed CAP investigation.

Appendix 5: Completing the watershed report card

The hydrologist completes the watershed report card after finishing the field assessments. The report card information is tabulated for each sub-basin and residual area as well as for the entire watershed. Instructions for completing the form are given below. It is expected that the hydrologist may modify the report card as necessary for specific watershed conditions, while still ensuring that the basic elements of the report card are addressed.

1. **Total area harvested.** Report as a percent of the watershed harvested.

2. **Equivalent clearcut area by elevation band.** Refer to Appendix 2 for suggestions on determining ECA, particularly concerning the different runoff generating elevation bands.

3. **Total road density.** Report by (1) total kilometres of road and (2) total kilometres of road divided by total watershed area.

4. **Length of road in High and Very High erosion class.** Report the total length of road mapped as H or VH on the sediment source map.

5. **Total number of landslides.** Count the number of landslides mapped on the sediment source map.

6. **Length of roads on unstable terrain.** Measure the length of road that occurs on areas with terrain stability class 4 or 5 (done on detailed maps) or that is classified P or U (as done on reconnaissance maps) as shown on the forest development plan map.

7. **Number of stream crossings.** On the forest cover map or a TRIM base map, count all stream crossings by mapped roads.

8. **Percent of S1, S2, S3 or S4 streambanks logged.** From the riparian assessment map, report the total high riparian impact stream length. Report the length of “one side logged” streams and “two sides logged” streams separately.

9. **Length of disturbed stream channel.** From the Reconnaissance Channel Assessment Procedure (ReCAP) survey, report the total length of disturbed stream channel in kilometres and as a percentage of the total channel.