FINAL REPORT

FOOTHILLS MODEL FOREST STREAM CROSSINGS ASSOCIATION

STREAM CROSSING PROTOCOL ASSESSMENT

Submitted to:
Foothills Model Forest
Box 6330
Hinton, Alberta T7V 1X6

DISTRIBUTION:

1 Copy Foothills Model Forest
           Hinton, Alberta

1 Copy West Fraser Mills Ltd.
           Hinton, Alberta

1 Copy Talisman Energy
           Calgary, Alberta

1 Copy Millennium EMS Solutions Ltd.
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ACKNOWLEDGEMENTS

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Millennium EMS Solutions Ltd.
1. INTRODUCTION

In December, 2004, Millennium EMS Solutions Ltd. ("MEMS") was retained by the Foothills Model Forest ("FMF") to provide a review of the existing stream crossing protocols used by various stakeholders within the FMF land base. These stakeholders are currently in the process of finalizing an implementation plan to be delivered under the newly formed Stream Crossing Association ("Association"). Once established, it is anticipated that the Association will be able to rapidly develop plans, implement necessary actions, develop an accurate inventory and mitigate stream crossing issues within the FMF land base.

The review of stream crossing protocols is intended to support the development of a program to complete initial inventories and subsequent maintenance inspections at several thousand stream crossings. The inventories and inspections will be completed by trained technicians. In special cases, the inventory would be completed by a two-person field crew.

The Association will develop and oversee the implementation of new approaches to stream crossing management for a number of crossing owners. Ultimately, the Association hopes to improve the condition of existing and proposed crossings and to enhance the conservation record for participating stakeholders. The Association will operate on behalf of its Members within the existing resource planning and approval process as governed by provincial and federal legislation.

One of the main goals of the Association will be to develop an inspection protocol to establish the current condition of stream crossing based on regulatory standards. This report represents the "first step" in this development and documents the results of a review of stream crossing protocols and assessment criteria in the FMF land base, Alberta, western Canada and the Pacific Northwest states.
2. METHODOLOGY

MEMS was retained to provide a review of existing stream crossing inspection procedures, an identification of commonalities and differences among the procedures and obtain input from regulatory agencies to determine applicable legislative standards. This Scope of Work is detailed in Schedule A of the "Memorandum of Agreement Between MEMS and the FMF" dated January 14, 2005.

2.1 Protocol Review

In order to establish the status of existing assessment procedures, relevant industry, government and non-governmental agency representatives were contacted. This included organizations currently operating within the FMF, within Alberta and throughout western North America. A list of organizations contacted during this study is presented in Table 1.

<table>
<thead>
<tr>
<th>Organization</th>
<th>Protocol Available</th>
<th>Protocol Received</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alberta Chamber of Resources</td>
<td>N</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Alberta Conservation Association</td>
<td>Y</td>
<td>N</td>
<td>Same as Canadian Forest Products</td>
</tr>
<tr>
<td>Alberta Infrastructure and Transportation</td>
<td>Y</td>
<td>Y</td>
<td>Also provided two Assessment Criteria.</td>
</tr>
<tr>
<td>Anadarko Canada Corp.</td>
<td>Y</td>
<td>N</td>
<td>Agreed to send flow chart but it was never received. No protocol available.</td>
</tr>
<tr>
<td>Burlington Resources</td>
<td>Y</td>
<td>Y</td>
<td>Provided flow chart only.</td>
</tr>
<tr>
<td>Canadian Association of Petroleum Producers</td>
<td>N</td>
<td>N</td>
<td>Members have individual protocols.</td>
</tr>
<tr>
<td>Canadian Forest Products</td>
<td>Y</td>
<td>Y</td>
<td>Joint document with ACA</td>
</tr>
<tr>
<td>Canadian National Railways</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Canadian Natural Resources Limited</td>
<td>N</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>City of Edmonton</td>
<td>Y</td>
<td>N</td>
<td>Assessment Criteria only.</td>
</tr>
<tr>
<td>Conoco Philips Canada Ltd.</td>
<td>?</td>
<td>N</td>
<td>No response to requests</td>
</tr>
<tr>
<td>Devon Canada</td>
<td>Y</td>
<td>N</td>
<td>No reply to requests</td>
</tr>
</tbody>
</table>
### Table

<table>
<thead>
<tr>
<th>Organization</th>
<th>Protocol Available</th>
<th>Protocol Received</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental Dynamics Inc.</td>
<td>N</td>
<td>N</td>
<td>No reply to requests</td>
</tr>
<tr>
<td>Fisheries and Oceans Canada – Habitat &amp; Enhancement Branch</td>
<td>Y</td>
<td>Y</td>
<td>Audit of forest road crossings in BC (1996-99)</td>
</tr>
<tr>
<td>Forest Engineering Research Institute of Canada</td>
<td>N</td>
<td>N</td>
<td>No relevant information provided</td>
</tr>
<tr>
<td>Foothills Model Forest</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Highwood Environmental</td>
<td>Y</td>
<td>N</td>
<td>Provided information but no distinct protocol</td>
</tr>
<tr>
<td>Husky Energy</td>
<td>N</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Louisiana Pacific Canada Ltd.</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Luscar Coal Ltd.</td>
<td>N</td>
<td>N</td>
<td>Use CoP and work directly with DFO</td>
</tr>
<tr>
<td>Matrix Solutions Ltd. (Alberta)</td>
<td>Y</td>
<td>Y</td>
<td>Protocol provided by Burlington Resources, Alberta Operations. Suncor Energy Inc. also uses this protocol.</td>
</tr>
<tr>
<td>Matrix Solutions Ltd. (British Columbia)</td>
<td>Y</td>
<td>Y</td>
<td>Protocol provided by Burlington Resources, British Columbia Operations.</td>
</tr>
<tr>
<td>Oregon Department of Fish &amp; Wildlife</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>PetroCanada Ltd.</td>
<td>Y</td>
<td>N</td>
<td>Provided information but no distinct protocol</td>
</tr>
<tr>
<td>Six Rivers NF Watershed Interaction Team</td>
<td>Y</td>
<td>Y</td>
<td>Field Guide</td>
</tr>
<tr>
<td>Suncor Energy Inc.</td>
<td>Y</td>
<td>N</td>
<td>Matrix (Alberta) developed Suncor’s protocol – same as used by Burlington Resources.</td>
</tr>
<tr>
<td>Talisman Energy Inc.</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Washington Department of Fish &amp; Wildlife</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>West Fraser Mills Ltd.</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Woodland Operations Learning Foundation</td>
<td>Y</td>
<td>N</td>
<td>Provided information but no distinct protocol</td>
</tr>
</tbody>
</table>

A total of 14 stream crossing protocols and 3 stream crossing assessment criteria were reviewed in this assignment. The protocols typically were developed to assist resource companies (timber harvesting, upstream oil and gas) assess aquatic issues related to infrastructure development such as roads, right-of-ways and pipelines. The information identified by these protocols was

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generally comprehensive enough to allow for a basic understanding of the physical and biological condition of the crossing.

The assessment criteria documents were developed by regulatory agencies to assist practitioners understand the guidelines and procedures for complying with the respective legislative requirements.

2.2 Commonality Assessment

Upon completion of the review of available stream inspection protocols, a commonality matrix was constructed to illustrate the similarities and differences among the various protocols. The assessment parameters were distilled into five general categories. Table 2 describes these categories. The complete commonality matrix is presented in Attachment 1. Note that the protocols and assessment criteria reviewed for this assignment were categorised by geographic region. Those protocols developed and used by stakeholders with infrastructure in the FMF land base are denoted as “FMF”. Protocols used outside of the FMF land base are denoted as “AB” within Alberta, “BC” within British Columbia, “MB” within Manitoba, “Can” elsewhere within Canada, “Wash” within Washington state, “Oreg” within Oregon state, and “USA” elsewhere within the United States.

<table>
<thead>
<tr>
<th>General Category</th>
<th>Sub-Category</th>
<th>Parameters to Record</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Attributes</td>
<td>Physical, Flow, Crossing and Morphological Data</td>
<td>Watershed characteristics, stream classification, flow conditions, cross section and profile surveys, channel dimensions, etc.</td>
</tr>
<tr>
<td>Sedimentation and Erosion Attributes</td>
<td></td>
<td>Susceptibility to erosion, sediment control measures, etc.</td>
</tr>
<tr>
<td>Biological Attributes</td>
<td>Fisheries, Habitat and Vegetation Data</td>
<td>Fish species presence, habitat mapping and classification, riparian types, etc.</td>
</tr>
<tr>
<td>Crossing Information</td>
<td>Culvert, Bridge or Pipeline</td>
<td>Structure condition, hydraulic controls, approach drainage, crossing dimensions, etc.</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td></td>
<td>Location identification, land use, stakeholder contacts, etc.</td>
</tr>
</tbody>
</table>
2.2.1 Physical Attributes

The physical attributes identified in the protocols included identification of physical, flow (hydraulic), crossing and morphological data. Physical data included watershed-scale attributes such as stream order, drainage area, stream classification and water quality. These attributes can be determined during office-based reviews and are used to scope the scale of the field assessment. Physical attributes to be identified in the field include areas of up-welling or seepage and ice thickness dimensions.

Flow or hydraulic characteristics of most concern when assessing stream crossings, are related to fish passage issues. The 3Q10 flow is often used by Alberta Environment and Fisheries and Oceans Canada (“DFO”) to assess barriers to migration and can be determined from office-based calculations. In the field, velocity, discharge and an evaluation of the stream’s permanence can be completed.

Data related to the type of structure or channel alterations includes crossing-specific information. Cross-section and profile surveys will assist engineering staff with design considerations for new developments or maintenance of existing structures.

Morphological attributes refer to fish habitat in general. An example of a habitat mapping system used throughout Alberta is based on the Habitat Classification System (O’Neil and Hildebrand 1986). This system divides habitats into five primary meso-habitat types and assigns three quality classes to Run, Pool, and Flat habitat with Class 1 being the highest. Substrate characteristics, vegetation, cover elements and fluvial geomorphic measurements are also used to assign habitat quality.

2.2.2 Sedimentation and Erosion Attributes

An assessment of the channel stability and any existing erosion and sediment control measures (both at the crossing location and up slope areas including roadways) is used to identify potential issues related to water quality and fish habitat protection. The protocols describe elements such as aggrading (material deposition) or degrading (scour) channel beds, lateral avulsions (movement of channel into the floodplain) and “nick” points (localised areas that have the potential to initiate erosion and undermine otherwise stable channel banks).
2.2.3 Biological Attributes

Biological attributes are primarily related to fish and fish habitat data within the channel boundaries and the associated riparian communities. Alberta Environment currently uses the provincial Water Act Code of Practice for Watercourse Crossings ("CoP") as the basis for assessing any transportation crossing of a stream. The CoP details the information required for consent to construct bridges and culverts in Alberta. Maps have been produced to accompany the CoP which indicate the classification for streams and their associated Restricted Activity Periods.

Additional information identified in the protocols includes a description of fish species presence/absence (both past and present), life stage, fish morphometrics and natural and artificial barriers to fish dispersal and migration. Identification of spawning, nursing, rearing, feeding and over-wintering potential as well as a documentation of riparian and in-stream vegetation were also included.

2.2.4 Crossing Information

Crossing information to be collected is related to the existing or proposed structure. For the purposes of this study, structures included bridges and culverts. While pipelines were identified on several protocols, the Committee has instructed MEMS not to consider these at this time. The general parameters to be assessed include structure condition, hydraulic controls, approach drainage and overall crossing dimensions.

More specifically, the protocols identify culvert issues such as perched or hanging outlets; inlet, outlet and barrel condition; the presence/absence of debris gates, weirs or baffles; evidence of scour; rust lines; up and downstream channel alignment; and plunge pool or tail water controls.

Bridge information includes structure, approach and abutment condition; interference of structure with flow patterns (constriction); deck drainage; and navigability at normal high water flows (2 m of freeboard).
2.2.5 Miscellaneous

Each of the protocols identified information requirements that were considered to be generic in nature. These included location and identification of the crossings, directions for access, timing, etc. One of the most important items identified was the need for photographs. The CoP stipulates that four are required: one each looking upstream, downstream, and at the left and right stream banks at the proposed crossing location prior to installation of the crossing structure. Additional photographs that depict specific features in the vicinity of the crossing (such as erosion, floodplain condition, upstream debris, etc.) should also be included.

2.3 Regulatory Standards

During the development of the commonality matrix, regulatory agencies were contacted to identify their concerns with the development of new crossings or maintenance of existing structures. Each agency was provided with a list of issues and data requirements addressed in the protocols and was asked to rank each issue as “required”, “useful” or “optional” when reviewing projects under their respective legislative requirements. Information necessary for an approval or authorization review are deemed “required”. Information that would assist reviewers and likely reduce deficiency requests are deemed “useful”. “Optional” information includes those items that would add context to the project. In addition, each agency was asked to provide any additional issues or data requirements not included in the initial list.

DFO is responsible for administering the majority of the federal Fisheries Act. Environment Canada ("EC") has assumed responsibility for Section 36 of the Act for deleterious substances exclusive of sediment. Both DFO and EC's authority extends throughout the entire FMF land base. Only DFO provided a written response with EC verbally indicating that they would require similar information to DFO.

Parks Canada ("PC") is responsible for administering the federal Canada National Parks Act. Authorization under Section 14(3) of the Act is required to conduct any activities within a national park. PC's authority is limited to the Jasper National Park portion of the FMF land base. With respect to watercourses, PC will defer the technical review of proposed activities to DFO.
Transport Canada ("TC") is responsible for administering the federal *Navigable Waters Protection Act*. This Act governs any changes to navigable waters in Canada and may require approval under Section 5(2) to construct a watercourse crossing. TC’s authority extends throughout the entire FMF land base. Determinations of navigability can only be made by an officer designated under the Act.

Alberta Environment ("AE") is responsible for administering the provincial *Water Act*. This Act, and the accompanying CoP, outlines the respective Approval and Notification requirements for watercourse crossings. AE’s (and all other provincial agency’s) authority does not extend into the national park portion of the FMF land base.

Alberta Sustainable Resource Development ("ASRD"), Fish and Wildlife Division, does not have any legislative authority to restrict crossing development; however, as a result of their mandate to protect fish populations, they are generally requested to provide comment as part of the AE review. Any restrictions recommended by the Fish and Wildlife Division may be included in the conditions attached to an AE approval. The Alberta Public Lands Division of ASRD is responsible for administering the *Public Lands Act*. This Act regulates access to watercourse bed and banks and any other public lands in the province. A Temporary Field Authorization may be required when constructing crossings or performing maintenance on existing structures.

Alberta Infrastructure and Transportation ("AIT") is responsible for the development and maintenance of public roads. Should a project in the FMF land base involve a public road, AIT may require the implementation of an Ecological Risk Assessment, Environmental Construction Operation Plan and/or Erosion and Sediment Control Plan.

Alberta Community Development ("ACD") is responsible for administering the *Historical Resources Act*. This Act regulates the development of infrastructure that may affect historically significant sites throughout the province. ACD should be notified of proposed developments in order to make a determination of the potential issues.
3. GAPS AND ALIGNMENTS

Each of the 17 protocols reviewed, focused on a unique set of parameters for both office and field assessment activities. For simplicity, each of the parameters included in the commonality matrix were ranked as “low” (0-5), “medium” (6-11) and “high” (12-17) importance based upon the number of protocols or assessment criteria that required each parameter to be measured.

Generally, those parameters that ranked “low” included fish and fish habitat information such as the identification of sensitive habitats and condition of the bed, banks and the surrounding floodplain. The 3Q10 flow is currently used by regulatory agencies in the determination of fish passage criteria. None of the protocols included a determination of 3Q10 flows. A variety of surrogate measures were used in some protocols; however, none of these have been approved by the regulatory agencies. None of the protocols included an evaluation of navigability and none included a process to identify other stakeholders with potential interest in the site. Fewer than five of the protocols included identification of bridge condition, culvert inlet information or structure clearances.

Channel geomorphology and culvert and bridge hydraulic information was required by approximately half of the protocols. These parameters focused on channel geometry (e.g. width and depth) as well as flow characteristics, such as stage and velocity. Fish presence/absence and passage potential as well as surrounding land use and the need for photographs of the site were rank as “medium” importance by the protocols. Only six of the protocols identified stream classification (Alberta Water Act Code of Practice, Rosgen or otherwise) as required to assess the crossing condition.

Data requirements ranked as “high” importance included only channel width, culvert information (dimensions), watercourse identification and crossing location information. All of the protocols were missing at least one of the required parameters.

Similarly, the regulatory agencies had differing requirements for information needed to apply their respective guidelines, policies and legislation. Each of the parameters were ranked as “low” (0-1), “medium” (2) and “high” (3-4) importance based upon the responses provided by the four agencies.
Areas of concurrence included placing a "low" ranking on the review of sediment and erosion control plans, previous fisheries reports and background information. Common "medium" rankings were placed on structure hydraulics and a review of watershed-scale characteristics. None of the parameters determined as "high" by the regulatory agencies were similarly ranked by the protocols.

Areas of divergence among "medium" and "low" ranked parameters did not exhibit any clear patterns but rather included some elements of physical and biological attributes and crossing structure information. Parameters ranked as "high" by the regulatory agencies were included in less than half of the protocols. These included flow conditions and stage, land use, detailed habitat mapping and small (i.e. non-sport fish) species migration. The latter two parameters were not included in any of the protocols reviewed.
In March 2005, the Project Advisory Group compiled comments related to the organization of the inspection and output reports and the need for definitions and forwarded these to MEMS on April 4. On May 29 2005, R. McCleary (FMF) provided comments on the Draft Report, Foothills Model Forest Stream Crossings Association, Stream Crossing Protocol Assessment prepared by MEMS. The following sub-sections describe these comments.

The Project Advisory Group indicated that the inspection reporting was intended to obtain information for each crossing detailing the environmental performance (fish passage, capacity to pass peak flows and sediment inputs) and safety performance (debris performance, soundness of structure and road surface over the crossing and approaches). The Project Advisory Group also suggested three levels of organization that may have application in the next phase of inspection protocols development including inspection parameter groups (environment and safety), stream type (fish habitat status) and inspection type (initial inventory and maintenance inspection). These approaches for organizing the protocol as described below for consideration by Association members.

4.1 Inspection Parameter Groups

4.1.1 Environmental Performance

Peak flow characteristics for a stream are affected by a variety of factors including topography, drainage area, aspect, disturbance, road development, vegetation cover, soils, geology, and climate. However, due to limited data sets, hydrology for ungauged streams is frequently estimated based on single variate regional analyses that relate flood magnitude to watershed drainage area. Flood frequency estimates can be determined from regional stream flow data.

Hydroconsult (1997) has prepared regional flood curves to determine flood frequency estimates for operational use in the FMF. This model uses Pearson Type III flood frequency magnitudes to derive regional relationships between discharge and drainage area. Golder (2002) has developed a model to predict the magnitude of the 2-year, 25-year and 100-year floods for watersheds within the West Fraser Mills Ltd. Forest Management Agreement area. The model is based on a
standard multivariate regression analysis using the available watershed information (physical and morphological data).

Either of these models can be used to predict hydraulic conditions at any location within the watershed. Flow passage capacity for each culvert or bridge can then be calculated for any return period flow design required by the crossing owner. Fish passage evaluation at each culvert or bridge can then be completed based on the 3Q10 flows. DFO can provide swimming speed criteria based upon the species and life stages present within the watercourse.

Sediment inputs throughout the watershed can initially be assessed by reviewing available aerial photography (past and present); soil, biophysical, NTS, Land Use District, and development maps; previous studies; and anecdotal historical information sources (FMF, West Fraser Mills Ltd., and regulatory staff). Field surveys to quantify the extent of sediment input can be carried out at the crossing location and at any other location identified during the review of available information should these locations be deemed important to the crossing function.

4.1.2 Safety Performance

Safety performance, particularly related to the soundness of crossing structures and condition of road surface over crossings and approaches should only be carried out by qualified transportation inspection engineers certified to practice in Alberta. Having said this, localised erosion, scour, undercutting, or debris blockage observed during crossing surveys should be noted and this information forwarded to the crossing owner’s inspection engineer.

4.2 Stream Type

Fish bearing status of the stream at the location of the crossing and in upstream areas is important for determining whether a fish passage assessment is required as part of the stream crossing inspection. This information is also important for assigning priority for restoring fish passage among a number of crossings. The Committee identified four types of streams (un-mapped, non-fish bearing, fish bearing and fish bearing status unknowns) that will influence what parameters need to be considered during the field surveys. Stream type should be identified during the field visit. Un-mapped streams may be located in swales or have intermittent flow. The CoP maps should also be used to identify streams as un-mapped and therefore requiring a different level of
protection than mapped and classified streams. The presence or absence of fish from a stream at the crossing location should be determined prior to undertaking field inspection if possible. Sources of inventory data include the FMF fish inventory database and ASRD Fisheries Management Information System (FMIS). If no determination can be made, then fish sampling will be required during several seasons (i.e. spawning, rearing, migration and over-wintering).

4.3 Inspection Type

The Project Advisory Group indicated that it is not the intent of the Association to complete crossing inspections to the level required for permit application to the regulatory authorities for the installation of new crossings. Rather, the inspections will gather information for improvements and maintenance of existing infrastructure. To achieve these purposes, it may be useful to consider two types of inspections: the initial inventory and the maintenance inspections.

Definitions of commonly used data and information requirements are included in Section 6 (Glossary) of this report.

4.3.1 Initial Inventory Assessment

The purpose of the initial assessment would be to measure parameters that will not change over time and also to complete the first environmental and safety performance evaluations. The parameters to be included in the initial inventory assessment may depend upon the type of stream and the type of structure at a particular crossing. The exact parameters to be measured would need to be identified by the Association in future phases of the development of the protocol.

4.3.2 Maintenance Inspection

The purpose of the maintenance inspection would be to evaluate specific issues at a crossing that may change of time such as erosion, scour, debris blockage, undercutting, etc. The maintenance inspection for each crossing would be scheduled by the crossing owner based on features of the crossing, severity of storms, persistence of ice during spring melt, etc. The parameter for this rapid assessment would need to be identified by the Association in future phases of the development of the protocol.
5. FUTURE STEPS

Following the review of the protocols and assessment criteria and discussions with regulatory agencies and the Committee, several actions were identified as “next steps” in the development of inventory assessment and maintenance inspection protocols for the FMF land base. These include:

1. Conduct risk assessments to determine structure or crossing failure, sedimentation, and fish passage issues related to each crossing type and each stakeholder’s management requirements. This will include the development of an approach to categorizing various degrees of risk and a systematic process of assessing and integrating professional judgement about potential adverse conditions or events (i.e. a rating of potential effects).

2. Develop simple and practical field and pre-screening techniques to estimate important hydraulic (e.g. culvert capacity) and hydrologic (e.g. runoff and time to concentration) parameters that would otherwise require more intensive assessments. These approximated parameters will be used to assess relative crossing performance (i.e. qualitative) and will not necessarily be used to conduct structure design.

3. Develop a dichotomous flow chart to “drill down” through critical parameters such as fish presence, flow permanence, etc. The flow chart would terminate in a number of scenarios. Each scenario would provide a list of parameters that would be required to be measured. Only “necessary” criteria would be included (i.e. if fish are not present then 3Q10 determination is not necessary). This approach will streamline the crossing assessment procedure and eliminate the collection of redundant or unnecessary data.

4. Contact each of the stakeholders in the FMF land base to determine their respective assessment needs in developing the initial inventory and the maintenance inspection protocols. These two protocols will include different parameters to measure and technical staff qualifications should be developed for each to ensure proper data collection. For example, biological staff may be able to conduct initial assessments while engineering technicians may be required to perform maintenance inspections.
6. GLOSSARY

The definitions provided in this Glossary are taken from Watt (1989), Meehan (1991), Armantrout (1998), and Alberta Infrastructure (1999) unless otherwise indicated.

3Q10: The delay discharge criterion currently used by Alberta Environment, Fisheries and Wildlife Management Division is the discharge of three days duration that has a recurrence interval of 10 years. The 3Q10 can be determined using either of the following procedures:

1. For each year that mean daily flow records are available from the Water Survey of Canada, find the greatest or least flow exceeded for three consecutive days during the period of fish migration at the site.

2. Using various methods of frequency analysis (e.g. log-normal theoretical probability distribution), discharge data can be used to determine the variation of 3-day delay discharge with recurrence interval.

Bankfull depth: depth of water measured from the surface to the channel bottom when the water surface is even with the top of the stream bank.

Bankfull width: channel width between to tops of the most pronounced banks on either side of a stream reach.

Barrier: any physical, physiographic, chemical or biological obstacle to migration or dispersal of aquatic organisms.

Bridge: a structure spanning a watercourse that provides passage.

Cover: structural materials (boulders, logs or stumps), channel features (ledges, undercut banks or vegetation), and water features (turbulence, turbidity or depth) that provide protection for aquatic species.
Cross section: area formed by the width and depth of channel measured perpendicular to the center line of flow.

Culvert: a passage, usually a pipe, constructed beneath a road, railroad, or a canal to transport water.

Ephemeral stream: A watercourse that flows during snowmelt and rainfall runoff periods only. There is generally no channel development and the stream bottom is usually vegetated.

Erosion: process of weathering or wearing away of stream banks and adjacent land slopes by water, ice, wind or other factors.

Intensity-duration-frequency: the relationship between storm intensity (depth divided by duration), duration and frequency (or return period).

Fish: “includes: parts of fish; shellfish, crustaceans, marine animals and any parts of shellfish, crustaceans, marine animals; and eggs, sperm, spawn, larvae, spat, and juvenile stages of shellfish, crustaceans, marine animals” (after Fisheries Act, DFO).

Fish-bearing stream: A stream known to support fish populations at some time of the year.

Fish habitat: (1) aquatic and riparian habitats that provide necessary biological, chemical and physical requirements of fish species at various life stages; (2) “spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes” (after Fisheries Act, DFO).

Invert: The floor or bottom plates of the culvert.

Large woody debris: organic material with a diameter greater than 10 cm and a length greater than 1 m.

Permanent stream: A stream that flows continuously throughout the year.
Passage: an avenue or corridor for fish migration either up or down a river system.

Pool: An area of stream where the water velocity is slow and stream depths are relatively deep.

Riffle: An area of stream where velocity is fast and stream depths are relatively shallow causing broken water.

Riparian area: banks of a watercourse where sufficient soil moisture supports the growth of mesic (moderate moisture requirement) vegetation.

Run: An area of stream where the water velocity is slower than a riffle and stream depths are deeper than a riffle causing less surface turbulence.

Scour: localized erosion of substrate from the streambed by flowing water when water velocities are high.

Sedimentation: The process of subsidence and deposition of suspended matter carried in water by gravity; usually the result of the reduction of water velocity below the point at which it can transport the material in suspended form; sometimes referred to as siltation.

Slope, slope angle, degree of slope, percent slope: The ratio between the change in elevation for a given change in horizontal distance, i.e., rise/run. The slope angle A is determined by \((1/\tan A) = (\text{rise}/\text{run})\).

Spring or seep: A place where water flows from a rock or soil onto the land or into a body of water.

Stream: A watercourse formed when water flows between continuous definable banks.

Stream pattern: The plan form shape of the stream (e.g., meandering, braided, etc.).

Substrate: mineral and organic matter forming the bottom of a watercourse.

<table>
<thead>
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<th>Diameter (mm)</th>
<th>Particle</th>
<th>Diameter (mm)</th>
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May 2005

<table>
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<td>Sand</td>
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<td>Boulder</td>
</tr>
<tr>
<td></td>
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</table>

**Thalweg**: path of a stream that follows the deepest part of the channel.

**Waterbody**: A natural or artificial source of surface water including lakes, sloughs and wetlands.

**Watershed**: region or area drained by surface and groundwater flow in rivers, stream or other surface channels.

**Wetted width**: width of a water surface measured perpendicular to the direction of flow at a specific discharge. Note – widths of multiple channels are summed to represent the total wetted width.
7. REFERENCES

7.1 Protocols


Oregon Department of Fish and Wildlife. 2004. Fish Passage Criteria. Website: http://www.dfw.state.or.us/fish/passage.


7.2 Reports, Assessment Criteria and Regulatory Agency Documents


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8. CLOSURE

This report provides a description of the review of existing stream crossing inspection procedures, an identification of the commonalities and differences among the procedures and the applicable legislative standards required by the relevant regulatory agencies.

We trust the above meets your present requirements. If you have any questions or require additional details, please contact the undersigned.

Millennium EMS Solutions Ltd.

Prepared by:

Senior Environmental Scientist

Jesse Howard BAIEM, T.T., CEPIT
Environmental Specialist

Reviewed by:

Larry Brocke
Principal
ATTACHMENT I – STREAM CROSSING PROTOCOL
COMMONALITY MATRIX