Achieving successful road performance and reducing the environmental impact of resource roads in wetland environments

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SUMMARY

Canada's forested landscapes feature numerous wetlands, such as fens, bogs and swamps, which present environmental and operational challenges during the planning, construction and maintenance of resource roads. The effects of these roads on the many ecological functions of wetlands are of increasing concern to Canada's resource-based industries, governments, communities and conservation organizations. Wetlands provide many ecological functions, such as water and carbon storage, filtering of precipitation during groundwater recharge, maintenance of downstream flows, support for plant communities, and wildlife habitat. The low bearing capacity of in situ soils and the high soil moisture levels that dominate wetland environments necessitate optimized planning strategies, properly designed road infrastructure and cost-effective construction methods to achieve successful road performance. The inadequate bearing capacity of subgrade materials and the placement and installation of drainage and water-crossing structures needed to provide continued hydrologic function, are two key challenges for resource roads across wetlands. This paper will describe the development and evaluation of resource road management and construction techniques and the application of alternative products and materials through the implementation of short and long-term environmental impact studies and road performance evaluations. Examples of foundation design solutions, site monitoring results and performance indicators will also be presented. The implementation of FPInnovations research results are expected to mitigate potential environmental impacts and reduce life cycle costs of resource roads and to be readily adopted by resource road construction personnel.

Introduction

The construction of resource roads that pass through wetlands (such as fens, bogs, and swamps) can create numerous environmental and operational challenges for road managers. In addition, the impact of these resource roads on the many ecological functions of wetlands is of increasing concern to Canada's resource-based industries and governments.

Wetlands provide many ecological functions such as water and carbon storage, filtering of precipitation during groundwater recharge, maintenance of downstream flows, support for plant communities and wildlife habitat. When a resource road is built through a wetland, the wetland's hydrologic functions may be compromised, with various possible negative outcomes (figure 1).

The impact on tree health and vigour in the wetland area surrounding a new road is the most common visible clue that the hydrology of the site may have been altered. A decrease in tree health on one side of the road may be the result of flooded conditions caused by the road blocking the natural wetland drainage patterns. The wetter conditions on the upstream site may cause vegetation to die off and be replaced by species that are better suited to the wetter conditions. Many practitioners have suggested that declines and changes in vegetation have not been consistent across the landscape. This may indicate how different wetland systems and their related hydrologic function (lateral, stagnant or fluctuating flows) are affected.

Figure 1. A resource road under construction across a conifer swamp.

There are many planning, construction and maintenance challenges associated with resource roads in wetland environments. Inadequate bearing capacity for the road sub-base and the installation of drainage and water-crossing structures are common challenges. If adequate bearing capacity cannot be obtained by means of appropriate engineering to sustain the anticipated level of vehicle traffic, the road may not be usable. Roads that cross wetlands such as peatlands, where the soil continuously sinks or settles, may require ongoing maintenance and as a result, may not be cost-effective or may have seasonally restricted use. Drainage structures that underperform due to the lack of adequate bearing capacity or due to sinking or settling of the road may also require replacement.

Planning

Planning tools can be used to build resource roads in more favorable locations that will minimize the impacts to wetlands. For example, within the landscape of the Canadian Boreal Plains Ecozone, it is difficult to entirely avoid crossing wetlands so where and how often to cross a wetland is a significant planning constraint. The use of aerial photographs can aid in road location planning, as well as remote-sensing tools such as LiDAR. By combining LiDAR-derived digital elevation maps with additional mapping tools (e.g., depth to the water table, wetland delineation, vegetation maps), a cost-effective and accurate tool can be made available to planners. Such tools can reveal features of the surface water, sensitive aquatic habitats, and the connectivity of habitats and other features of the landscape, thereby permitting appropriate choices of road locations, crossing structures, and construction techniques.

A resource road built to cross a wetland at the narrowest location would seem to expose the smallest proportion of the wetland complex to adverse impacts. Wetland bank (edge) stability must also be assessed during planning as it will have significant impacts on where the road should enter the wetland. The concept of “island-hopping”, in which the road is positioned to take advantage of small stable areas (islands), may also prove beneficial during location planning.

When the ground is frozen it provides greater bearing capacity and there are minimal water flows to consider. In some cases, this may suggest that seasonal roads are the most appropriate solution. Careful attention needs to be given to halting travel on the road when the weather starts to warm and the ground begins to thaw. Serious damage to a wetland can occur if the thawed ground becomes rutted or compacted in such a way as to alter the summer hydrologic conditions.

Installation of effective water management structures

The principal challenge to construct resource roads across wetlands is building the road to the required road standards while maintaining the natural wetland water movements. Maintaining the natural wetland water processes can be a challenge given the complexity of the many wetland types and characteristics existing in Canadian forests. The following provides an overview of some of the key methods that are in use and are currently being studied for further refinement and development.

Culverts

If culverts are used to maintain flows of water through a wetland, they must be placed in locations that will allow the water to flow freely to down gradient locations. As wetlands can have very slow rates of water movement, any blockage of this flow can impact wetland hydrology. A section of road built with a single culvert placed along a wetland crossing may not be adequate as such slow-moving systems require unhindered passage of water. Numerous culverts may need to be installed along the road where it passes across the wetland (figure 2). Since flows and water levels tend to change in response to weather patterns, culverts may be needed at various installation depths to account for seasonal variations in the depth of the water. In addition, culverts may need to be embedded or partially buried in order to provide for the subsurface flows frequent in wetlands.

Figure 2. A resource road under construction with multiple culverts.

Permeable fill (Aggregate mattress)

The road base may be constructed from angular pieces of large aggregate, which allows water to pass through the voids of the aggregate (figure 3). Geotextile may be required to separate the road material from the underlying large angular aggregate to help prevent fine soil particles from migrating into the voids and impacting the ability for water passage. One of the main concerns with this method of wetland crossing is that there may be insufficient soil bearing capacity required to prevent the aggregate from sinking into the underlying organic wetland soils. The use of geosynthetics may be required to improve the road foundation and to prevent sinking of the permeable fill. Other materials such as wood fibre (chips) may also be considered for use.

Figure 3. Angular aggregate may be used as permeable fill to facilitate wetland water movement.

Corduroy

Resource roads built across wetlands with low bearing capacity have often used a corduroy surface created by laying numerous logs parallel to one another and perpendicular to the direction of travel (figure 4). This method has primarily been used as a low-cost alternative to improve the bearing capacity for the road base but the ability of the log voids to allow for water passage are now being considered. The logs, placed in parallel, allow water to flow between them and add to the water passage capabilities of the road. Geotextile may be required to separate the road material from the underlying corduroy to help prevent fine soil particles from migrating into the voids and impacting the ability for water passage. Corduroy may also be placed as a bundle in a section of the road to act in order to facilitate water passage in a designated section of the road.

Figure 4. Corduroy installed to provide for water passage through a road.

Methods to improve foundations for culverts

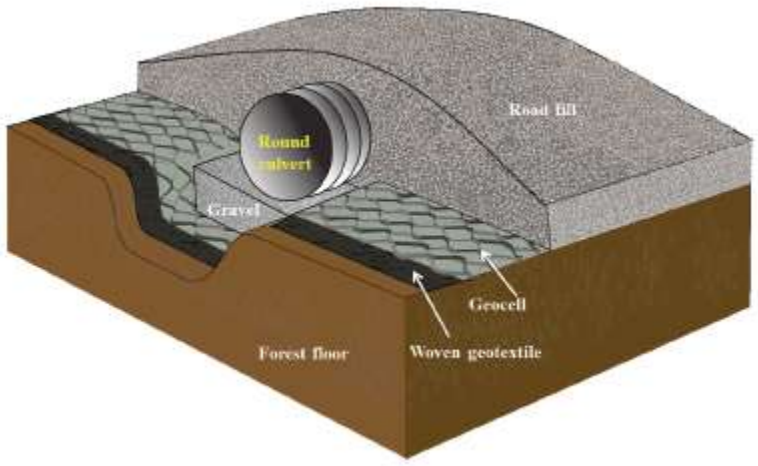
The installation of a water-crossing structure on soils with poor bearing capacity can cause numerous issues with road and structure performance and can compromise the ability of the structure to meet fish passage or aquatic habitat protection requirements. A common result is that a culvert may partially or completely sink into the soil as it is driven downward by the weight of the overlying fill. This is often most evident at the centre of a culvert, which leads to a banana shaped culvert with its ends higher than its centre. This can impede the structure's ability to provide adequate passage for water, fish and aquatic species.

In most cases, the selection of foundation improvement options is made by company or contractor staff and is primarily based on past experience. When installations require large structures with high construction costs, engineering consultants will often be retained to provide geotechnical designs for the structure. However, for smaller, low-cost structures, the installation will typically be performed by company or contractor personnel, who rely primarily on prior experience in dealing with challenging foundations. In these cases, engineering designs will not be complete, so readily accessible information on recommended general construction and design methods is critical to help these personnel achieve the required foundation conditions.

The application of geosynthetics products such as geogrids, geocells and high strength woven geotextiles have applications in improving foundations for small culverts. Many resource road managers are already familiar with the use of geosynthetics to strengthen the road base but require assistance in order to develop new designs specific four culvert and other structure foundations. The applications of geosynthetics in this application are not well documented and designs may not be readily available. For this reason, further study on recommended designs and long-term monitoring is required before implementation on resource roads can be expected.

In addition to the application of geosynthetics, the use of onsite material such as aggregate or logs may also be considered as materials in culvert foundation designs. Onsite materials can offer low procurement costs and can decrease the overall time required to complete the installation. When used along with geosynthetics, low-cost, effective culvert foundation designs may be achieved (figure 5).

Figure 5. Geosynthetics and native materials can be used in culvert foundation designs.



Conclusion

Canada's forested landscapes feature numerous wetlands, such as fens, bogs and swamps, which present environmental and operational challenges during the planning, construction and maintenance of resource roads. Until recently, the impact of resource roads on wetland processes has not been well understood and has not been a focus of environmental impact mitigation efforts. However, as the network of resource roads expands, not only in order to support traditional forest operations use of these roads, but also for mining and oil and gas exploration and activities, the need to better understand the potential impacts of these roads and possible mitigation methods requires further research. The research needs must be multi-level to include both innovations in resource road construction methods and technology and the understanding of wetland ecology and processes present in Canadian forest regions. FPInnovations is working in partnership with various levels of government, environmental organizations and the Canadian resource industries to develop enhanced road construction and management practices that consider the important ecological values of wetlands.