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VEGETATION ON EMBANKMENT DAMS
A GROWING CONCERN FOR HYDRO-QUÉBEC

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ABSTRACT:
Hydro-Québec operates 101 reservoirs requiring 571 retaining structures, either concrete or embankment dams. The Quebec Government environmental authorization certificate requires that vegetation be restored near dam construction sites. Even though many of the embankment dams are located in Northern latitudes where the vegetation growth season is fairly short, nearby colonization by alder, birch, aspen, and spruce is well under way. However, dam inspection is hindered by invasive vegetative cover.
An integrated vegetation management program is carried out under the supervision of a team of forestry technicians with the technical support of environmental specialists. This vegetation control strategy implies the use of the proper intervention methods, used at the appropriate location, and at the right time. A five-year recurrent scheme is performed to limit vegetation in selected areas. Mechanical removal of trees and shrubs is usually followed by application of herbicides. However, the recent interpretation of environmental regulations by some local municipalities is very restrictive on herbicide use, in particular near water surfaces. The current Hydro-Québec internal regulation requires clearing of shrubs and trees only on the crest and on selected areas of the downstream face and of the downstream toe area. As time goes by, wide portions of the downstream slope are being invaded. Since some dams are very tall and extremely steep, issues dealing with worker safety, ethics, engineering, ecology, and money need to be resolved.

RÉSUMÉ:
Hydro-Québec opère 101 réservoirs exigeant un total de 571 barrages, soit en béton ou en remblai. Dans ses certificats d'autorisation environnementale, le gouvernement du Québec exige une remise en état de la végétation à proximité des sites de construction des barrages. Même si plusieurs ouvrages en remblai sont situés à des latitudes élevées où la saison de croissance est relativement brève, la colonisation par les aulnes, les bouleaux, les trembles et les épinettes est actuellement en cours. Toutefois, l'apparition d'un couvert végétal important nuit à l'inspection des barrages.
Un programme de gestion intégrée de la végétation est réalisé sous la supervision d'une équipe de techniciens en foresterie avec le support technique de spécialistes en environnement. Cette stratégie de contrôle de la végétation implique l'utilisation de méthodes d'intervention adéquates, utilisées aux endroits appropriés et aux moments opportuns. Un plan récurrent de cinq ans est appliqué au contrôle de la végétation à des endroits désignés. La coupe mécanique des arbres et des arbustes est habituellement suivie de l'application de phytocides. Toutefois, l'interprétation récente des règlements environnementaux par certaines municipalités est restrictive quant à l'application d'herbicides, particulièrement à proximité des plans d'eau. Les encadrements internes actuels d'Hydro-Québec exigent la coupe des arbres et des arbustes seulement en crête et en des endroits restreints du parement et du pied aval. Avec le passage du temps, de vastes portions du parement aval sont envahies. Puisque certains barrages sont très hauts et dotés de pentes raides, des considérations liées à la sécurité des travailleurs, à l'éthique, à l'ingénierie, à l'écologie et à l'administration des budgets doivent être examinées.

1 INTRODUCTION

Hydro-Québec operates 101 reservoirs and 58 power stations in order to produce 34 499 MW of hydroelectric power for its clients. A total of 571 dams are necessary. Many concrete structures are used, but most of the dams are either rockfill or earth embankments.

In 2009, Hydro-Québec was subdivided in five Production Generation territories as shown on Figure 1. They are listed approximately in terms of increasing climate severity:

- Beauharnois-Gatineau,
- Des Cascades,
- Manicouagan,
- La Grande Rivière,
- Saguenay-Lac-Saint-Jean.

Each territory is responsible for the safety of the dams in their area, and adequate budgets must be allowed for maintenance tasks, including vegetation control. Considering the vast surfaces covered, and the various growth potentials associated with the local climate, each territory will be presented individually further in this paper.

Figure 1: Production territories for Hydro-Québec

2 REGULATORY ISSUES

Some legal issues will be briefly covered in the next four sections.

2.1 Dam Safety Act

In 2000, the Government of Quebec enacted the Dam Safety Act (R.S.Q., chapter S-3.1.01). The attendant regulation (c. S-3.1.01, r. 1) to this law was put in effect on April 11, 2002. However, there are no provisions about vegetation control on dams in the law.

2.2 Hydro-Québec Safety Program

It is possible for a dam owner to propose a safety program that is proven to meet or exceed the requirements of the law. Hydro-Québec has successfully submitted such programs in 2003 and 2008, each valid for a five-year period. Considering this, internal regulations supersede portions of the provincial law. Regulation SB-70-01-00, dealing with vegetation control on dams, thus becomes mandatory within Hydro-Québec.

2.3 Legal requirements

2.3.1 Authorisation requirements for new dams

When Hydro-Québec is granted permission to build a new dam, it comes with requirements to naturalize the sites after construction. In Northern climates, there are few choices available to do this. One of them is alders, and this has consequences that will be presented later in this paper.

2.3.2 Authorisation certificates for maintenance of existing dams

In 2005, the Québec Environment Ministry (MDDEP) issued a policy on Lakeshores, Riverbanks, Littoral Zones and Floodplains (c. Q-2, r. 17.3). According to that document, dams and dykes located on the shore of a reservoir constitute the riverbank. In principle, activities conducted on the shore always require an authorisation certificate whether an impact on the environment is expected or not. However, since numerous recurrent interventions are necessary all across Québec, the MDDEP has decided that authorisation certificates will not be systematically delivered. Mechanical vegetation limitation does not require an authorization if it is conducted manually outside of the water, it does not involve soil perturbation, and a fifteen day prior notice has been given to the MDDEP. On the other hand, no intervention permit is required to cut trees for the maintenance of access roads to dams.

The MDDEP has mapped floodplains in some areas of Québec. If the floodplain has not been charted, it is not necessary to request an authorisation certificate to apply pesticides on it. However, on the shore and on the littoral zone, such an authorisation is required. In the absence of a floodplain map, a fifteen meter length is measured along the existing slope from the natural high water level or the maximum reservoir level. The resulting surface along a reservoir is thus subject to the Québec water policy.

Usually, municipal regulations are not applicable to Hydro-Québec in the performance of its basic mission of electricity production. However, when an authorization certificate is required from the MDDEP, municipal regulations do apply because the law demands that Hydro-Québec must obtain

from the municipality a conformity attestation with respect to their regulations. As a result of this, Hydro-Québec must obey municipal regulations in order to perform work in the area near the shoreline. It is to be noted that many local authorities have limited or prohibited pesticide use.

2.3.3 Sensitive elements

Among other things, sensitive elements are constituted of terrestrial or aquatic habitats, endangered or threatened species, drinking water intakes, dwellings, agricultural exploitations or fish farms, outfitters, and holiday resorts. An inventory of sensitive elements must be performed before pesticide application. This is to ensure compliance to existing laws and regulations with respect to pesticide use and environmental protection, as well as commitments made to governmental agencies and to the population at large. Inventories gather valuable information to be used if meetings with the local residents are necessary.

2.4 Professional requirements

The Québec Engineers Act (R.S.Q., chapter I-9) states that dams are in the field of practice of engineers. Thus, engineers must be employed by Hydro-Québec to provide expert opinions on the various dams. Of course, the Code of ethics of engineers (c. I-9, r. 3) is applicable to those hired to perform this task.

3 RECENT EXPERIENCE

The production territories listed in the introduction will be presented in the following sections.

3.1 Beauharnois-Gatineau

This southern region of Quebec provides excellent vegetative growth potential. However, until 2002, vegetation control on dams was not done on a regular basis. Starting in 2003, a forestry technician supervised the implementation of a five-year plan. Large areas were cut down as catching up was required. The MDDEP issued an infraction notice in 2005, stating that work along the bank of a water surface had been done without the proper authorization certificate. Negotiation ensued, and simplified procedures were agreed upon. Mechanical cutting continued between 2005 and 2009 according to the five-year plan. Herbicide was applied near the Ottawa and Gatineau River regions in 2008.

The most commonly used tools for vegetation control are gasoline powered trimmers. The type of vegetative cover changes as the treatment is repeated, going from trees and brushes to herbaceous plants. The growth of the replacement vegetation is extremely quick, and chemical treatment should be done in conjunction with mechanical limitation.

Starting in 2009, tractors with boom mounted trimmers were used with an interesting cost reduction compared to manual labour. In many cases, vegetation control can be performed on the whole downstream slope with two passes, one from the crest, and the other from the downstream toe. Figures 2 and 3 show the before and after situations for a given location. However, there are disadvantages to the tractor mounted equipment: possible damage to the piezometers, rutting in wet downstream toe areas, equipment limitation due to slope angle, potential impact on boulders, and safety preoccupation

for nearby pedestrians. It is to be noted that embankment dam height is often more modest in Beauharnois-Gatineau than in the La Grande Rivière or Manicouagan territories, for instance.

Figure 2: Downstream slope before vegetation control

Figure 3: Slope after vegetation control

Figure 4 presents the areas treated as a function of time. It can be seen that the surfaces are increasing, and are currently in the range of 80 hectares. However, areas near roads, bridges, and powerhouses are included in the total, as well as surfaces cleared near dams.

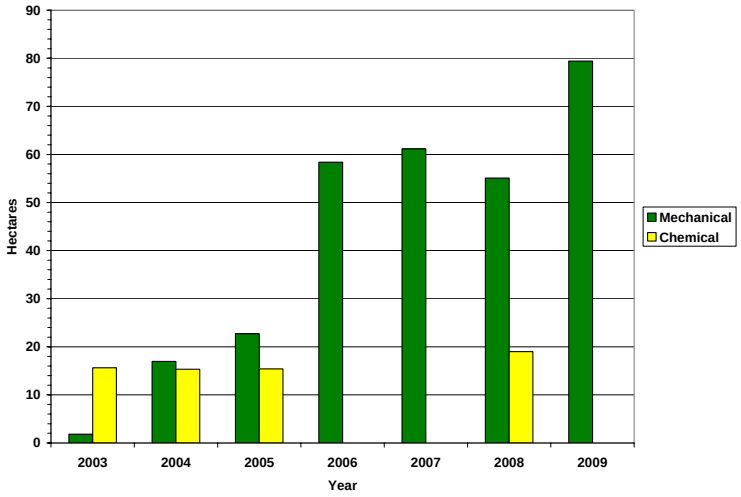

Figure 4: Surfaces with vegetation control for the Beauharnois-Gatineau territory

Only 40% of the areas can be treated with herbicides since authorization certificates cannot be obtained due to the presence of nearby drinking water intakes. Products used include Roundup WheaterMax and VisionMax (Glyphosate). Chemical treatment cannot be used solely by itself since the resulting dead vegetation impedes dam inspection. Prior mechanical cutting and clearing is therefore necessary.

Most of the vegetation control necessary for the Beauharnois-Gatineau territory is located in an urban or a suburban context. Presence of bicycle paths, provincial roads, and of the La Vérendrye wildlife

reserve also raise challenges. Communication with the public therefore becomes a major issue for this production territory.

3.2 Des Cascades

Most of the Des Cascades territory is located in harsher plant hardiness zones than Beauharnois-Gatineau. Prior to 2005, vegetation control was done by each power station foreman. In 2005, a consulting firm provided a global management program for the territory based on a three-year cycle. A technician has followed the activities since that date, now into the second cycle. Figure 5 presents the surfaces treated as a function of time, broken up by control method. Total area to be maintained is in the order of 60 hectares over a three year period.

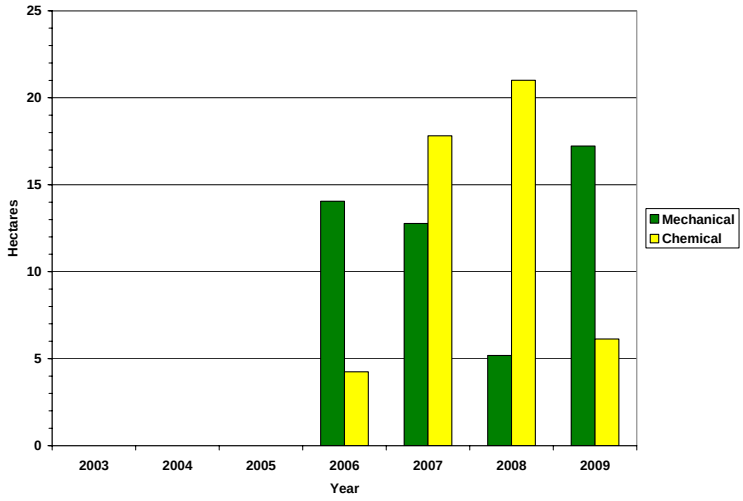

Figure 5: Surfaces with vegetation control for the Des Cascades territory

Embankment dams are not usually very high in the Des Cascades territory. However, many small surfaces need to be controlled over numerous reservoirs located in a large area. Compared to the Beauharnois-Gatineau territory, the vicinity of the population is less critical, even though the same regulations apply with respect to herbicide application.

3.3 Manicouagan

The Manicouagan territory is located further North than the Beauharnois-Gatineau and the Des Cascades territories. Vegetation control has been performed near dam sites in a fashion or another since the late eighties. However, beginning in 2003, a management program for the territory was introduced based on a five-year cycle. A forestry technician supervises the activities. Following the experience gathered in the 2003-2007 period, adjustments were made to account for local vegetation growth in sites relatively close to the St-Lawrence River (Bersimis-2, Outardes-2, see Figure 1). Figure 6 presents the surfaces treated as a function of time, broken up by control method. Total area to be maintained was in the order of 100 hectares until 2008. Since that time, access road maintenance has been added to dam vegetation control, leading to an increase in treated surfaces.

The current highest embankment dam for Hydro-Québec is located in the Manicouagan territory, the Denis-Perron Dam at 171 m tall. Also in the same region, the steepest embankment dam for Hydro-Québec is the dumped rockfill Bersimis Dam with a 1.2H:1V downstream slope. The proportion of tall and steep embankment dams is greater in the inventory of the Manicouagan territory than in the James Bay area (La Grande Rivière and Saguenay-Lac-Saint-Jean territories), even though they are more numerous in the latter.

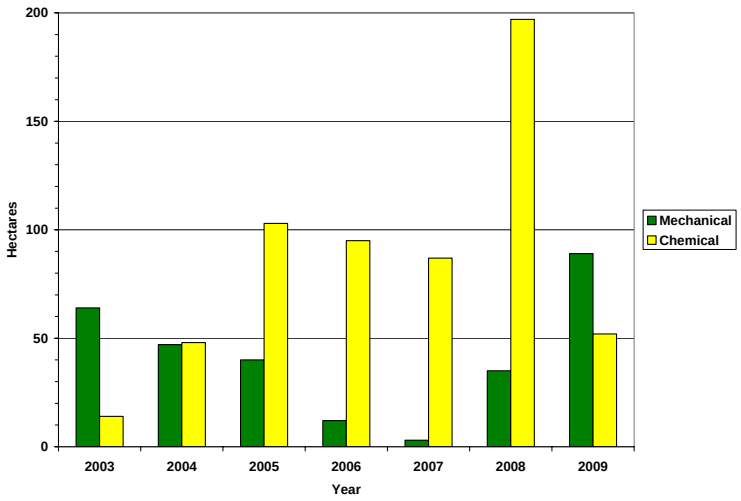

Figure 6: Surfaces with vegetation control for the Manicouagan territory

3.4 La Grande Rivière and Saguenay-Lac-Saint-Jean

The Abitibi and James Bay areas have been separated in two administrative territories in 2009, La Grande Rivière and Saguenay-Lac-Saint-Jean, as can be seen on Figure 1. However, for this paper, they will be presented together.

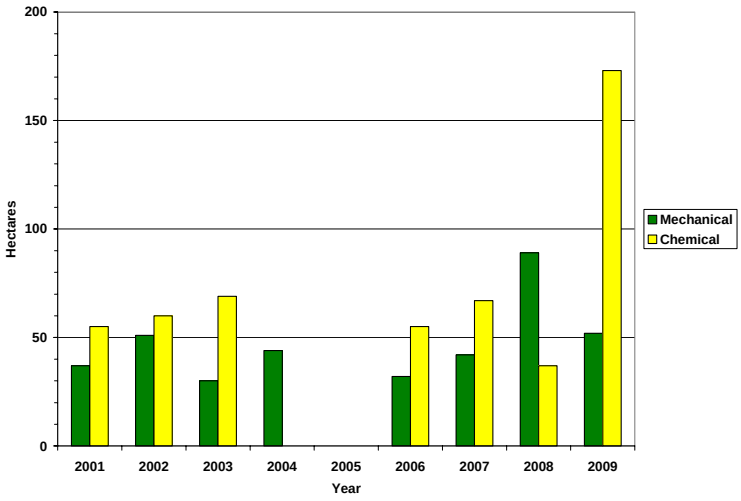

Figure 7: Surfaces with vegetation control for La Grande Rivière and Saguenay-Lac-Saint-Jean territories

Vegetation control was performed under the supervision of various actors between 1997 and 2004: civil technicians, forestry technicians, and temporary personnel. Work was done at that time according to the urgency of the requests, with no inventory of the state of the vegetation, nor any result tracking. Figure 7 shows that about 100 hectares per year were treated mechanically or chemically from 2001 to 2004.

Starting in 2005, two technicians were dedicated to the vegetation control task using the MapInfo software for inventory purposes. A new approach was thus used starting in 2006. After 2008, two other temporary resources were hired during the summer period. Over 700 hectares need to be treated along vast distances (see Figure 1). A total of 380 dams are to be maintained with a total cumulative crest length of more than 178 km. A significant number of the dams are very tall rockfill structures with steep downstream slopes, for example, LG-2 CD-00 with a 168 m height and a 1.6H:1V slope. Another consideration that will discussed later is the widespread use of homogeneous cross sections on recent construction sites, for instance, the LA-1 and LA-2 reservoirs.

According to field observations, vegetation growth is in the range of 100 to 150 cm/year in the upper part of the Ottawa River. For the LG-1, LG-2, LG-3, and Eastmain regions, it is about 70 to 100 cm/year. For LG-4, LA-1, LA-2, and Caniapiscau, it is slightly less than in the previous sector. At the current rate of expenditures, it is impossible to cover the required areas within a five-year time frame. A budget increase is required.

In 2006 and 2007, Garlon 4 (Triclopyr) was used at LG-2 and LG-3. After chemical treatment, herbaceous plants invaded the cleared areas as can be seen in Figure 8. At the left of the photograph, the nearly vertical line is a distance marker seen sideways. It is more than 2 m tall, and it is more than halfway submerged in tall grasses. In 2008, VisionMax (Glyphosate) was used at LG-2, but vegetation growth was intense the next year. In 2009, VisionMax (Glyphosate) and Arsenal (Imazapyr) were used, and results are to be assessed in 2010.

Figure 8: Downstream toe area after vegetation control

3.5 Summary for the five production territories

Table 1 summarizes the main positive and negative attributes for the five production territories in terms of vegetation control in recent years.

Table 1. Summary of positive and negative attributes for the five production territories			
Production territory	Approximate area (ha)	Positive attributes	Negative attributes
Beauharnois-Gatineau	80	Embankments usually of modest height Possibility of using tractors with boom mounted trimmer	Intense growth due to Southern location Herbicides used in only 40% of the area Urban and suburban areas Communication with the public is required
Des Cascades	60	Embankments usually of modest height	Wide geographical dispersal of treated areas
Manicouagan	200	About two decades of experience Historically under good control	Tall and steep embankments present St-Lawrence River influence on plant growth
La Grande Rivière	700	Experience being gained	Numerous tall and steep embankments present Even with slow Northern growth, dams nearly 35 years old show invasive vegetation
Saguenay-Lac-Saint-Jean		Latitude and altitude of Eastern portion of James Bay region enough to reduce, but not stop, plant growth	Numerous tall and steep embankments present Homogeneous dam cross sections are common

4 RECENT CONCERNS

A number of recent concerns will be presented in the coming sections.

4.1 Internal regulation SB-70-01-00 - vegetation control on dams

This regulation states, in principle, that no vegetation is to be tolerated on dams. Designated specific areas are:

- surfaces where signs of anomalous behaviour could manifest themselves,
- drainage ditches, instrumentation locations, access roads,
- places where the root system penetrates the watertight elements, and removal causes damages.

Currently, the concept of selective vegetation limitation is set forth:

- on the downstream slope of embankments, for a minimum distance of 5 m above the downstream toe,
- on the downstream toe area, for a minimum width of 15 m,
- in places recommended by the safety review reports.

Figure 9: Selective vegetation limitation

Figure 9 shows the appearance of a dam after the application of the selective vegetation limitation. It can be seen that shrubs are encroaching on the downstream slope beyond the 5 m cleared area, in spite of the ground being constituted only of rockfill with no organic soil. Even with the slow growth associated with a Northern climate, this 31-year old dam shows invasive vegetation from alders. Such an artificial mass built by man will eventually look like the nearby hills, visible at the left of the photograph, with mature birch, aspen, and spruce. It is fairly obvious that dam inspection is hindered to a certain degree by invasive vegetative cover.

4.2 Diagnosis and visual observation

Part of the Safety Program presented in paragraph 2.2, internal regulation SB-60-00-00 deals with dam surveillance. It requires an expert opinion from the engineers in charge of dam safety. For major structures, it requires a yearly appraisal, along with recommendations about long term maintenance. This diagnosis is based on visual observation as well as on instrumentation data.

Of the 101 reservoirs operated by Hydro-Québec, various engineers considered that vegetation control was seriously deficient for ten of them in 2008. Corrective action need to be taken before vegetation becomes a safety issue for the dams, and an ethical problem for the various engineers.

4.3 Failure modes and visual inspection

Internal regulation SB-60-00-00 considers that the most likely failure modes must be identified for each dam in order to orient surveillance to detect precursor signs of incipient rupture.

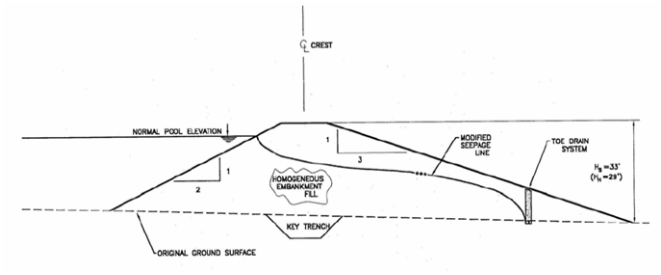

Figure 10: Homogeneous section with toe drain

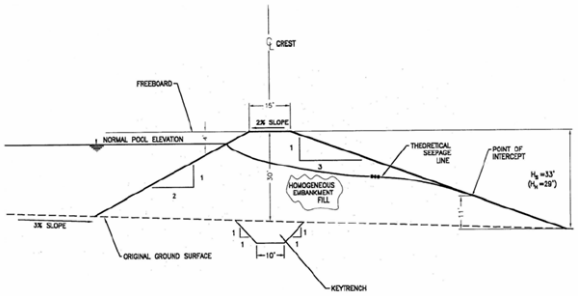

Figure 11: Homogeneous section without drainage

Figure 10 shows an homogeneous cross section that has vertical drainage at the toe. If ever this drain fails to work, the phreatic surface will raise up to the downstream surface like shown on Figure 11. This could lead to potential instability for the dam. If vegetation is permitted to colonize the downstream slope and the downstream toe area, it becomes quite impossible to assess with confidence the efficiency of the drainage and the stability of the dam.

Figure 12 shows a slightly inclined central core with rockfill shells. From a theoretical point of view, no seepage water can exit on the downstream slope. However, the ongoing vegetation colonization shown on Figure 13 is impeding visual observation. While not an engineering problem like the homogeneous case presented in the previous paragraph, it could eventually become an ethical problem for the engineer in charge. Cracks and deformations might become impossible to observe.

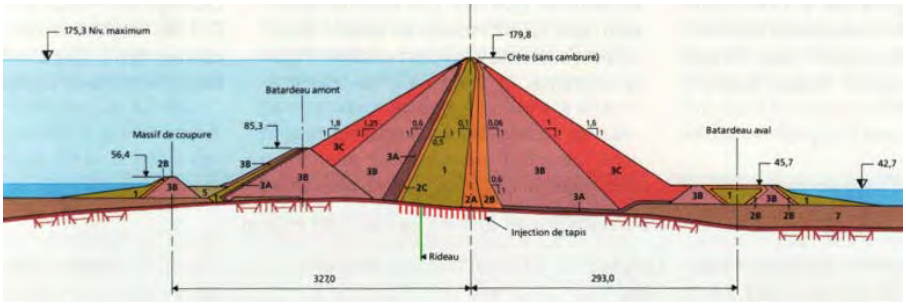

Figure 12: Rockfill cross section


Figure 13: Downstream slope

4.4 Worker safety and visual observation

Another issue to consider is worker safety. When people are expected to perform inspection in situations shown on Figures 14 and 15, it is obvious that great care must be taken in order not to trip on obstacles or to fall in a depression or a ditch. Sending people in such work conditions provides poor inspection quality, and might lead to serious worker injury. Past cases of refusal to perform inspections have been documented.


Figure 14: Downstream slope and toe area


Figure 15: Downstream toe area

4.5 Naturalization of sites after construction

During the first phase of James Bay, the Société d'énergie de la Baie James used more than 7 400 000 alders (SEBJ 1987). Plantations were made in borrow pit areas, in old campsites, and near dams. However, as shown on Figures 9, 13, 14, and 15, alders multiply beyond their initial plantation zones, and are extremely difficult to control. Figure 16 shows the growth on a 30-year old embankment located about 160 km South of the dam shown in Figure 13.

The practice of using alders continues to this day since it is very successful from a vegetation point of view. Figure 17 shows post-construction site naturalization. In the background, the downstream slope of the concrete faced dam is made of fine rockfill that is sloped at 38 degrees up to a 76 m height. The

picture was taken three years after dam construction, but it can be predicted that alders will likely try to colonize the vacant space in the future. Considering the type of dam shell and the very steep inclination of the downstream slope, vegetation control will soon be quite a challenge at this location.

Figure 16: Downstream slope of a 30-year old embankment

Figure 17: Alder plantation near a new dam

4.6 Worker safety and vegetation control

Steep and high slopes make it necessary to consider worker safety for those required to physically travel in these areas during the execution of vegetation control tasks. Even though the cross section of the dam shown in Figure 17 is very efficient in terms of embankment volume, it presents a real challenge to the workers who will have to move safely on the downstream slope in the course of their duties.

5. OTHER UTILITIES

Information requests about vegetation control procedures were sent to other utilities in 2008 and 2009.

5.1 US Army Corps of Engineers

The following excerpt comes from the Dam Safety Vegetation Control Guidance draft from USACE:

> The governing criteria for maintenance of vegetation on the dams, or areas adjacent to, or immediately downstream of dams is to provide ready and adequate visual observation at all times of those areas where signs of potential distress may occur. Any seepage through, around or under the structure must be quickly identified, monitored and controlled to prevent flow that could become detrimental to the safety of the structure. Surface cracks and movements must also be readily observable.

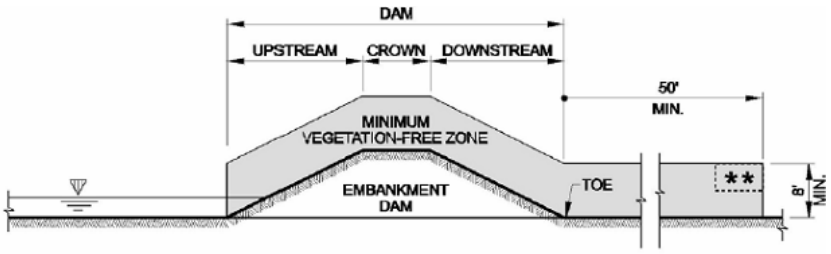

Figure 18: Recommendation from ETL 1110-2-571

Figure 18 comes from ETL 1110-2-571 from USACE (2008). It shows that no vegetation is tolerated from reservoir level down to 50 feet from the downstream toe. An 8 foot height is even specified along all that zone. The concept of the 5 m and 15 m selective vegetation limitation zones presented in Hydro-Québec regulation SB-70-01-00 is totally absent in this USACE document.

5.2 Ontario Power Generation

According to Ontario Power Generation document DS-PRO-13 R02, vegetation control on or near water retaining structures is required to:

> 1. Maintain the integrity of the structures by reducing damage due to root systems that could provide potential pathways for seepage.
> 2. Provide unobstructed thorough inspection of the water retaining structure and ground surface to detect deficiencies.
> 3. Enable personnel safe access for monitoring operations (mitigate tripping hazards and potential eye injuries) (…).
> 4. Enable regular maintenance and remedial works to be conducted more efficiently.

5.3 Manitoba Hydro

Manitoba Hydro provided Hydro-Québec with the Integrated Vegetation Management Plan of one of their dams. Figure 19 and 20 shows respectively the crest and the downstream slope of the dam.


Figure 19: Crest of the embankment


Figure 20 Downstream slope of the embankment

An interesting concept used in their document is the tolerance threshold. For instance, no action is required unless trees and shrubs exceed 10% of the dam surface or are higher than 1,5 m. It is to be noted that low grass is totally acceptable as an inspection surface.

6. CONCLUSIONS

The diagnosis required from the engineers in charge of dam safety within Hydro-Québec is a professional act covered by the Québec Engineers Act and the Code of ethics of engineers.

It is not required to remove all traces of vegetation on embankment dams. Control is required in order to be able to adequately inspect the structure in order to prevent initiation of failure mechanisms. In this sense, low grass cover is acceptable, and the 10% limit on surfaces with trees and shrubs of less than 1,5 m is an interesting threshold to apply.

Worker safety issues need to be considered as soon as possible. A decision about vegetation control on slopes of steep and tall rockfill dams has to be made. The information gathered from other utilities seems to indicate that vegetation on the downstream slope is not acceptable in the state of the practice.

The zone with mandatory vegetation control should exceed in many cases the 5 m on the downstream slope, and the 15 m on the downstream toe area. Vegetation should be totally prohibited on homogeneous embankment dam cross sections. Current Hydro-Québec internal regulation SB-70-01-00 needs to be changed.

In recent years, three or five year recurring vegetation control plans have been successfully implemented in all production territories. Great progress has been made, the environment has been protected, and the laws and regulations have been respected. However, long term funding issues need to be addressed. Considering the number of dams in the La Grande Rivière and Saguenay-Lac-Saint-Jean territories, massive expenditures are to be foreseen to simply catch up with twenty, thirty, or thirty-five years of vegetation growth.

7. ACKNOWLEDGEMENTS

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Hydro-Québec is thanked for the permission to publish this paper.

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