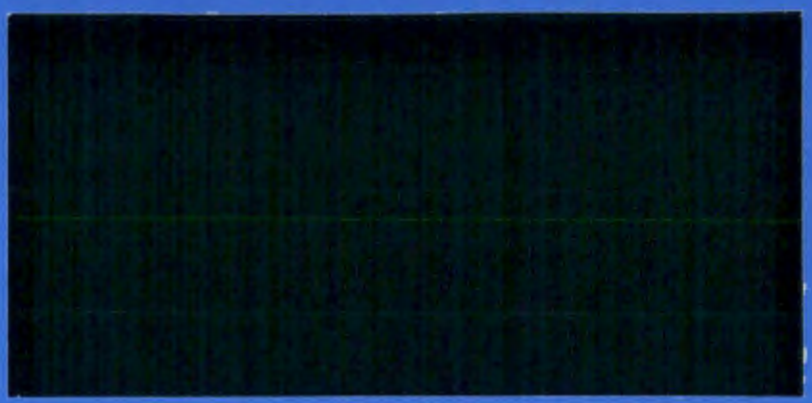
Projet de réfection de la digue de la centrale des Cèdres dans la MRC Vaudreuil-Soulanges



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GESTION DE LA VÉGÉTATION SUR LES DIGUES ET BARRAGES

REVUE SOMMAIRE

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II

GESTION DE LA VÉGÉTATION SUR LES DIGUES ET BARRAGES

REVUE SOMMAIRE

Présentée
à

Hydro-Québec

B99122-620

Décembre 2002

RAPPORT D'ÉTUDE : SOMMAIRE

Titre (pour citation) : MEUNIER, D., J. DOMINGUE, et F. GAUTHIER. 2002. *Gestion de la végétation sur les digues et barrages, revue sommaire.* Étude réalisée par le Groupe conseil GENIVAR pour Hydro-Québec. 11 pages + annexe.

Résumé :

Hydro-Québec possède un important parc d'infrastructure composé, entre autres, de plus de 800 barrages et digues.

Le but de cette étude est d'effectuer une revue sommaire de l'information disponible concernant la gestion de la végétation sur les digues et barrages.

Afin de documenter cette pratique, une recherche d'information par Internet a d'abord été effectuée. Parallèlement, une recherche bibliographique a été menée par l'Institut national de la recherche scientifique (INRS) de l'Université du Québec à Sainte-Foy. Par la suite, plusieurs gestionnaires de digues et barrages ont été contactés dans le but de compléter l'information obtenue.

Selon une étude effectuée aux États-Unis, malgré le fait que tous les États considèrent que les arbres et les arbustes représentent un problème pour la sécurité de leurs barrages, la moitié de ces barrages présentent des arbres ou des arbustes sur leur surface. Cette étude révèle également que 24 des 48 États ayant répondu au sondage possèdent des politiques ou des procédures opérationnelles qui définissent les standards concernant la présence de végétation sur les barrages, les autres États n'ont pas de procédures formelles. La présence d'arbres ou de végétation indésirable s'explique principalement en raison de considérations financières, environnementales, légales ou esthétiques.

Les raisons évoquées pour maîtriser la végétation sur les digues et barrages sont : les dommages potentiels à l'intégrité structurale ou à la surface des barrages causés par l'intrusion des racines ou la chute des arbres, les difficultés accrues lors des inspections des infrastructures ou encore, les dommages causés par les galeries et terriers des rongeurs protégés par la végétation.

Les différentes méthodes utilisées pour maîtriser la végétation sont principalement l'abattage ou l'annelage des arbres de forte taille, la tonte des surfaces gazonnées ou couvertes de végétation herbacée, l'arrachage manuel de la végétation arbustive ou arborescente de petite taille, la coupe avec ou sans traitement de souche ou encore, l'application de phytocides.

Quelques recherches sont présentement en cours concernant de nouvelles méthodes pour maîtriser la végétation, mais celles-ci sont actuellement coûteuses et peu fiables dans l'ensemble.

Mots clés : Barrages, digues, maîtrise de la végétation, gestion de la végétation, sécurité, herbicide,

LISTE DE DISTRIBUTION : Interne/Externe. Décembre 2002

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TABLE DES MATIÈRES

Page

LISTE DES ANNEXES

1.0 INTRODUCTION

Hydro-Québec possède un important parc d'infrastructures composé, entre autres, de plus de 800 barrages et digues.

Dans le cadre de la réalisation de ce mandat, Hydro-Québec a mandaté le Groupe conseil GENIVAR afin de réaliser une revue sommaire de l'information disponible concernant la gestion de la végétation sur les digues et barrages.

Ce document présente donc la méthodologie utilisée ainsi que les résultats de cette recherche.

2.0 MÉTHODOLOGIE

Afin de documenter la pratique en matière de maîtrise de la végétation sur les digues et barrages, une démarche méthodologique en deux étapes a été appliquée. On a d'abord procédé à la recherche d'information à l'aide de deux moyens, soit directement par Internet et en réalisant une recherche bibliographique qui a été menée par l'Institut national de la recherche scientifique (INRS) de l'Université du Québec à Sainte-Foy. Par la suite, plusieurs gestionnaires de digues et barrages ont été contactés dans le but de compléter l'information obtenue.

La recherche par Internet et la revue de bibliographie ont été réalisées à l'aide des mots clés suivants :

- dam, dykes, levees or embankments, vegetation management;
- dam vegetation control;
- dam safety management;
- gestion de la végétation sur les digues ou barrages;
- maîtrise de la végétation sur les digues ou barrages;
- sécurité sur les digues et barrages.

Les contacts directs ont été faits auprès d'une dizaine de gestionnaires de digues et barrages qui ont été sélectionnés à la suite de la consultation de l'information obtenue à l'étape précédente.

3.0 RÉSULTATS DES RECHERCHES

La recherche sur Internet a permis de consulter les sites de plusieurs organismes, départements, ou associations regroupant ou représentant des gestionnaires de digues et barrages. La liste des principaux sites Internet qui ont retenu notre attention est présentée à la section 4.0 du présent document.

La recherche sur Internet a permis de constater que la très grande majorité des sites faisaient référence à l'Association of State Dam Safety Officials (ASDSO) et que l'information était souvent similaire d'un site à l'autre, peu importe l'organisation. Les organisations présentant l'information la plus pertinente sont localisées aux États-Unis. Il s'agit de :

- Association of State Dam Safety Officials.
- New York State Department of Environmental Conservation.
- Wisconsin Department of Natural Resources.
- California Dam Safety.
- Ohio Department of Natural Resources.
- Pennsylvania Department of Environmental Protection.
- Virginia Department of Conservation and Recreation.
- Arkansas soil and water conservation commission.
- New Jersey Department of Environmental Protection.

Parmi les documents les plus pertinents obtenus de la recherche Internet, mentionnons un document de l'ASDSO intitulé « Current problems, practices and policies on tree and woody plant penetration of dams » (Tschantz, 2000). Ce document est d'ailleurs résumé à la section 3.1 du présent rapport.

La recherche bibliographique a permis d'identifier près de 300 références qui ont été passées sommairement en revue. Plus spécifiquement, deux d'entre elles ont fait l'objet d'une consultation plus approfondie, en raison de leur plus grande pertinence. Il s'agit de Shields and Gray (1992) et de Shields *et al.* (1990).

Enfin, de l'ensemble des gestionnaires contactés, quatre ont participé de façon plus marquée à la documentation du sujet à l'étude. Les coordonnées de ces gestionnaires sont présentées à la section 5.0 du présent document.

Les résultats des recherches et des consultations sont présentés ci-après sous trois rubriques distinctes, soit : 1º Portrait de la situation en Amérique du Nord, 2º Principales raisons pour la maîtrise de la végétation et 3º Méthodes de maîtrise de la végétation utilisées ou en développement.

3.1 Portrait de la situation en Amérique du Nord

Les recherches n'ont pas permis d'identifier de document synthèse traitant de la problématique de gestion de la végétation sur les digues et barrages au Québec et au Canada. Cependant, un tel document a été produit aux États-Unis, il s'agit d'un rapport intitulé : « Current Problems, practices and policies on tree and woody plant penetration of dams ».

Cette étude, dont la version intégrale se retrouve en annexe 1, traite du pourcentage de barrages importants (7,6 m de hauteur ou plus de 20 ha de superficie de réservoir) ayant des arbres, ainsi que les divers problèmes, pratiques et politiques des associations sur la sécurité des barrages présents dans les 50 États des États-Unis. Les principaux résultats sont les suivants :

- la moitié des barrages réglementés possèdent des arbres ou arbustes problématiques sur leur surface. Certains États estiment même qu'il s'agit de 90 à 95 % de leurs infrastructures qui supportent ce type de végétation;
- tous les États considèrent que les arbres et les arbustes représentent un problème pour la sécurité de leurs barrages;
- 24 des 48 États ayant répondu au sondage possèdent des politiques ou des procédures opérationnelles qui définissent les standards concernant la présence

de végétation sur les barrages. Les autres États ne possèdent pas de procédures formelles;

- les principales raisons évoquées pour expliquer la présence d'arbres ou de végétation indésirable sur les infrastructures sont :

    - le manque de ressources financières par les propriétaires (13 États);
    - les restrictions environnementales au niveau de l'utilisation des herbicides près des plans d'eau (10 États);
    - les questions légales (6 États);
    - l'esthétique (5 États).

- 29 États ont indiqué avoir suffisamment de documentation concernant l'effet négatif et même la rupture de certains barrages causée par la présence de végétation indésirable;
- les coûts pour maîtriser la végétation arbustive et arborescente sur la surface d'un barrage peuvent varier entre 2 500 et 25 000 dollars par hectare, en fonction de divers facteurs;
- la plupart des experts s'accordent pour dire que des travaux de recherche plus élaborés devraient être faits afin de déterminer la relation entre la végétation indésirable et les divers éléments pouvant affecter la stabilité des barrages.

3.2 Principales raisons de la maîtrise de la végétation

Selon la grande majorité des sources d'information et des gestionnaires consultés, il appert que la végétation herbacée n'est pas nuisible aux digues et barrages. Certaines sources affirment même qu'elle favoriserait la stabilisation des matériaux de surface. Par contre, selon les mêmes sources, la végétation arbustive et arborescente ne doit pas être tolérée sur les digues et barrages. Les principales raisons évoquées sont les suivantes :

- dommages potentiels à l'intégrité structurale des barrages par l'intrusion des racines augmentant les risques de fuites et d'érosion par l'eau;

- dommages à la surface des barrages par le renversement ou la chute des arbres;
- difficultés accrues lors des inspections des infrastructures (visibilité, sécurité);
- dommages causés par les galeries et terriers des rongeurs protégés par la végétation;
- ombrage retardant le développement de la végétation herbacée.

Plus spécifiquement, selon les représentants consultés de la compagnie Alcan au Saguenay-Lac-Saint-Jean, le premier 15 m situé au pied de leurs infrastructures (principalement en béton) doit être totalement dépourvu de végétation arbustive et arborescente afin de faciliter les inspections. Dans la région de Churchill Falls, où la politique en est une de tolérance zéro vis-à-vis la végétation arbustive et arborescente, les travaux de maîtrise de la végétation sont faits systématiquement tous les ans. Pour ce qui est de BC Hydro en Colombie-Britannique, les traitements manuels et mécaniques peuvent être répétés jusqu'à 3 fois par année afin de maintenir le pourcentage de recouvrement de la végétation indésirable à un niveau inférieur à 5 %, sur la surface des digues et barrages.

En contrepartie, certains auteurs soutiennent que la végétation ligneuse de petite taille (arbustes et petits arbres ayant une bonne masse racinaire de surface) serait plus efficace que la végétation herbacée uniquement afin d'augmenter la stabilité de certains types de sol par rapport aux glissements de terrain (Shields and Gray, 1992).

3.3 Méthodes de maîtrise de la végétation utilisées ou en développement

En raison du rôle que joue la végétation herbacée dans la stabilisation des matériaux de surface, les différentes méthodes énoncées ci-après concernent donc principalement la maîtrise de la végétation arbustive ou arborescente. Par ailleurs, l'information recueillie auprès des personnes contactées a permis de faire ressortir l'importance de diminuer l'utilisation des phytocides et de trouver des méthodes plus acceptables sur une base environnementale.

Les principales méthodes utilisées sont les suivantes :

- abattage ou annelage des arbres de forte taille;
- tonte pour les surfaces gazonnées ou couvertes de végétation herbacée;
- arrachage manuel de la végétation arbustive ou arborescente de petite taille;
- coupe avec ou sans traitement de souche;
- applications de phytocides tels : Roundup, Garlon 4 et Tordon 101, selon les spécifications des fabricants.

Quelques recherches sont présentement en cours concernant de nouvelles méthodes de maîtrise de la végétation. Il s'agit de :

- brûlage à l'aide de torches (ne tue pas les racines et pertes de contrôle potentielles);
- utilisation de vapeur d'eau ou d'eau chaude (végétation avec système racinaire superficiel, peu fiable et coûteux);
- utilisation de mycoherbicides sur la végétation feuillue (effets limités, bons résultats sur les aulnes et peupliers, mais peu efficaces sur les bouleaux et érables);
- ensemencement de gazon ou de végétation herbacée;
- exposition des semences et du feuillage à la lumière infrarouge (aucun effet sur les racines et très coûteux).

Ces différentes méthodes sont donc coûteuses et peu fiables dans l'ensemble.

4.0 ADRESSES DES PRINCIPAUX SITES INTERNET CONSULTÉS

www.dec.state.ny.us/website/dow/bfp/ds/ds.htm

www.damsafety.org/homr.aspx

www.dnr.state.wi.us/org/water/wm/dsfm/dams/erosion.html

www.damsafety.water.ca.gov/index.htm

www.engr.utk.edu/civil/people/tschantz.htm

www.ohiodnr.com/water/pubs/fs_div/fctsht28.htm

www.dep.state.pa.us/dep/deputate/watermgt/WE/FloodProgram/Floodlines/Fall1998.pdf

www.dep.state.pa.us/dep/deputate/watermgt/WE/FactSheets/Dam/fs1909.htm

www.dcr.state.va.us/sw/dsveget.htm

damsafety.water.ca.gov/tech-ref/rjb-paper.pdf

www.landandwater.com/features/vol45no1/vol45no1_2.html

www.state.ar.us/aswcc/DAMRULES.htm

www.state.nj.us/dep/nhr/engineering/damsafety/faq.htm

5.0 PERSONNES CONTACTÉES

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Téléc. : (418) 699-3357

6.0 REFERENCES BIBLIOGRAPHIQUES CONSULTEES

Bold, T. E. Jr. and Batcheler, N. S. 1997. *Vegetation control on earthen embankment dams.* Proceedings of the 1997 ASDSO annual conference. 1997. pages 331 à 338. 6 p.

Marks, B. D. et a*l.* 2001. *Plant and animal penetration of earthen dams.* Proceedings of the 2001 ASDSO technical seminar. 2001. 185 p.

Shields, F. D. Jr. and Gray, D. H. 1992. *Effects of woody vegetation of sandy levee integrity.* Water resources bulletin. 1992. vol 28, No 5, pages 917 à 931. 15 p.

Shields, F. D. et a*l.* 1990. *Study of vegetation on revetments. Sacramento River Bank Protection Project. Phase 1.* Literature review and pilot study. 1990. 137 p.

Tschantz, B. A., 2000. *Current problems, practices and policies on tree and woody plant penetration of dams.* In Dam safety 2000. Proceedings of the 2000 ASDSO annual conference. pages 102 à 113. 12 p.

Annexe 1

Current problems, practices and policies on tree and woody plant penetration of dams (Tschantz, 2000)

CURRENT PROBLEMS, PRACTICES AND POLICIES ON TREE AND WOODY PLANT PENETRATION OF DAMS

Bruce A. Tschantz, P. E., University of Tennessee, Knoxville

Introduction

According to the 1998-99 National Inventory of Dams (NID) data, there are approximately 76,700 dams of significant size[1] and hazard category in the 50 states (USCOE, 1999). Most of these dams are regulated by the jurisdictional states, but many are not because of specific exemption clauses or different size or hazard restrictions. Because some states have lower size definitions for their dams than used for the NID count, the actual number of state-regulated dams is much higher -- about 94,000. In Tennessee, of approximately 1000 inventoried dams, over 40% are *not* subject to regulation because of statutorily named county exclusions or agricultural use exemptions. Most of these unregulated dams and some of the regulated dams in Tennessee have troublesome trees and brush growing on their faces and crests. Some states estimate that as many as 90 - 95% of their regulated dams have trees. Figure 1 illustrates the general magnitude and range of the tree growth on regulated dams in 48 states where this information is reported (ASDSO, 2000).

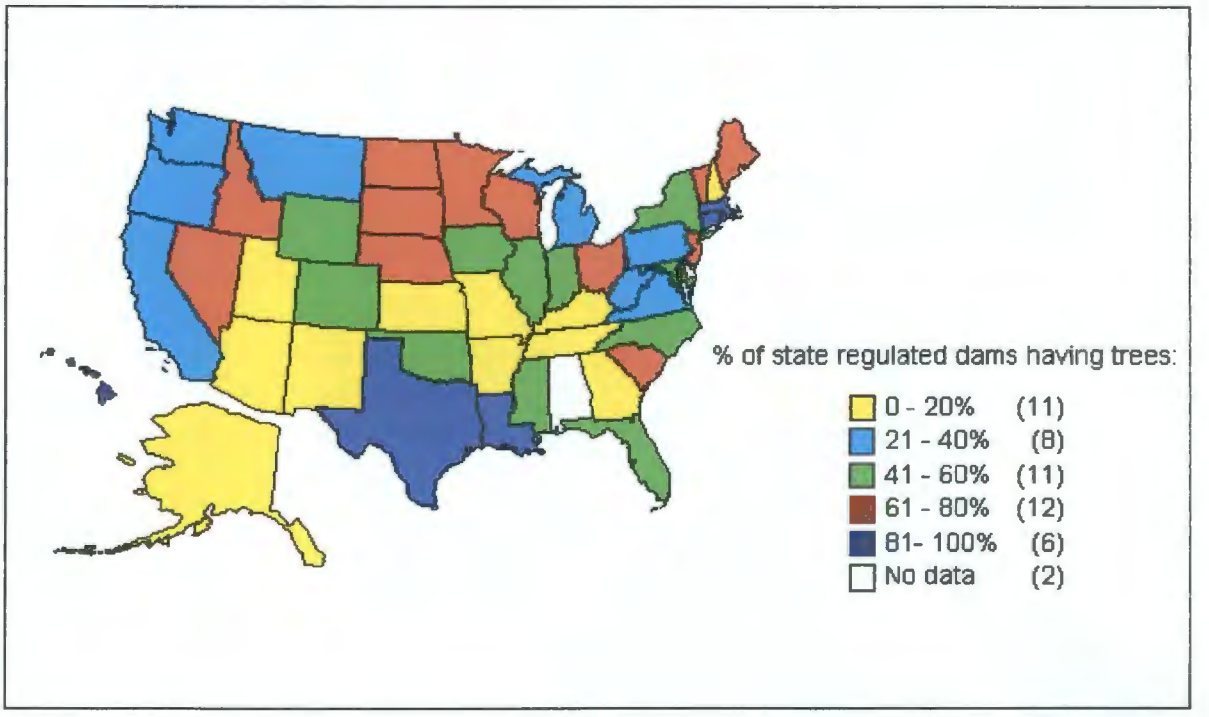

Figure 1. Estimated percentages of state-regulated dams having trees.

[1] Inclusion in the National Inventory has been defined under P.L. 99-662 and P.L. 92-367 to include dams that are at least 25 ft. high or 50 acre-feet of storage (excluding low hazard dams less than 6 ft. high or 15 acre feet of storage) and dams that due to location may pose a significant threat to human life or property in event of failure.

Most dam safety engineers, including state and federal officials, consultants, and other experts involved with dam safety, agree that when trees and woody plants are allowed to grow on earthen dams, they can hinder safety inspections, can interfere with safe operation, or can even cause dam failure. In the past, engineers and dam safety experts have not always been in agreement about the best way to prevent or control growth, remove trees, or repair safety-related damages caused by trees and woody vegetation.

From November 30 - December 2, 1999, a joint ASDSO/FEMA-sponsored workshop was held in Knoxville, Tennessee, for purpose of inviting a panel of experts to discuss various problems, policies, and practices associated with plant and animal penetrations of earthfilled dams. This paper will discuss the consensus of current attitudes, issues, and policies involving tree and woody plant penetrations in dams, by state and federal officials, researchers, and practitioners active in dam safety. A follow-up practice manual is being developed by the workshop participants for engineers and owners to use in managing and problems associated with both plant and animal intrusions.

Attitudes Toward Woody Plant Growth on Dams

The Association of State Dam Safety Officials (ASDSO) sent out survey questionnaires to dam safety officials in all 50 states and to federal representatives to the Interagency Committee on Dam Safety (ICODS) to determine state and federal agency attitudes about the effects of trees and woody plant growth on dams (ASDSO, 1999).

In this survey the states and ICODS representatives were asked to respond, with comments, to the following seven questions:

1. Do you consider vegetative growth on earthen dams to be a problem for your organization?

2. Does your agency have a specific policy or operating procedures addressing the removal of trees/vegetation from earthen dams? Please provide a copy of your policy, and/or describe your operating procedures.

3. If your organization has no set policy or procedures, what do you recommend?

4. What legal, financial, environmental, or other constraints apply when your organization attempts to deal with problems caused by unwanted vegetation?

5. Do you have any documented evidence where vegetation has negatively affected the safe operation or has been linked to the failure of earthen dams? Give examples, if available.

6. Are you aware of current or past research or documented discussions regarding the effects of unwanted vegetation on dam safety? Please list or attach known references.

7. If tree removal from earthen dams is authorized by your organization, would you please provide available data for examples of procedures, costs, contract specifications, and photographs of rehabilitated dams?

Problems caused by trees and woody plants

Of the 48 states that responded to the above seven questions (Alabama and Delaware did not reply), all state dam safety officials indicated that they consider trees and plant growth on dams to be a safety problem. One eastern state dam safety engineer goes so far to say that trees are probably the major problem that he has to deal with. He notes further that most of the trouble occurs because owners (and some engineers) do not recognize trees as problems and become complacent as trees slowly grow into serious problems. Both state and federal officials agree that trees have no place on dams. Federal agencies like the Corps of Engineers, U. S. Bureau of Reclamation, and TVA, which own, operate and maintain their own dams, do not allow trees to grow on their structures.

The problem most commonly noted by state officials is that trees, woody vegetation, briars, and vines interfere with effective safety inspections. Figure 2 gives a breakdown of the percentage ranges of regulated dams where the 48 reporting state dam safety officials shown in Figure 1 estimate that trees and brush hinder safety inspections in their respective states (ASDSO, 1999). While half the states report having only 20 percent or fewer dams with significant trees and woody vegetation that hinder inspections, vegetation on an estimated 23,500 or nearly a third of the collective state-regulated dams, is reported to obstruct effective dam safety inspections.

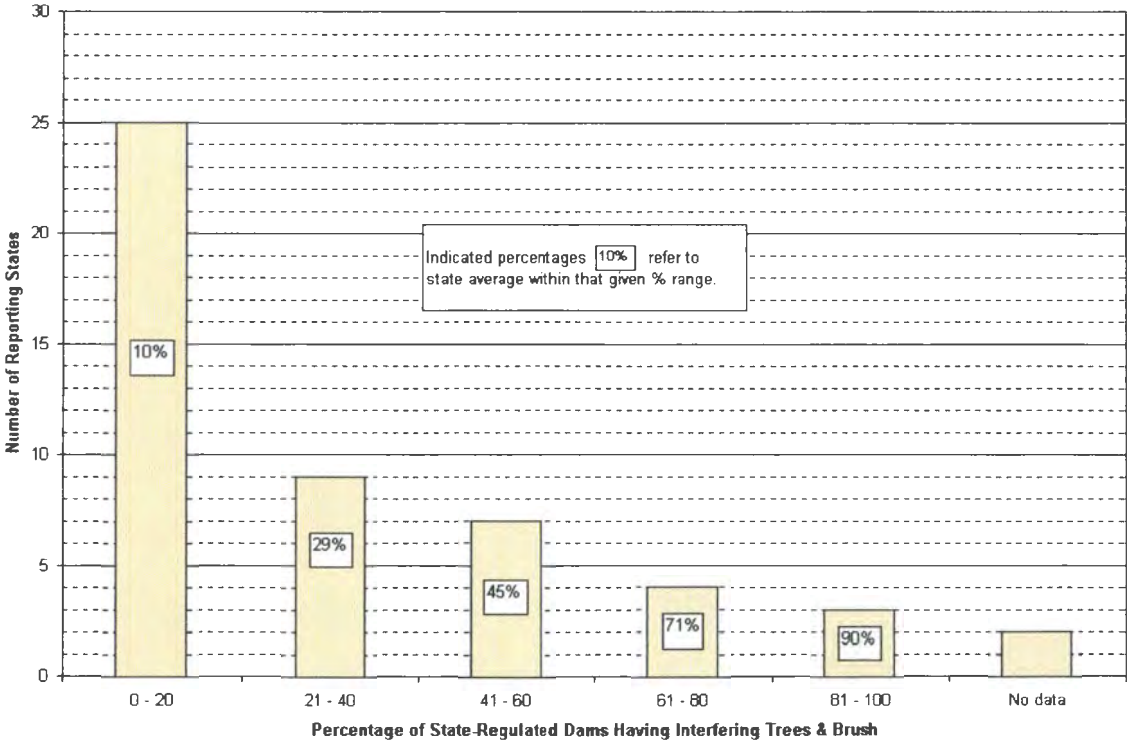

Figure 2. Estimated percentages of state-regulated dams where trees and brush are considered a deterrent to effective safety inspections.

Other dam safety problems caused by woody growth are:

- Overturning or uprooting trees causing large voids and reduced freeboard; and/or reduced x-section for maintaining stability
- Decaying roots of dead trees causing potential seepage paths and piping problems
- Interfering with effective dam safety monitoring, inspection and maintenance for seepage, cracking, sinkholes, slumping, settlement, deflection, and other signs of stress
- Hindering desirable vegetative cover and causing embankment erosion
- Obstructing emergency spillway capacity
- Falling trees causing possible damage to spillways and outlet facilities
- Clogging embankment underdrain systems
- Cracking, uplifting or displacing concrete structures and other facilities
- Inducing local turbulence and scouring around trees in emergency spillways and during overtopping
- Providing cover for burrowing animals
- Loosening compacted soil
- Allowing roots to wedge into open joints and cracks in foundation rock along abutment groins and toe of embankment, thus increasing piping and leakage potential.

Current Policies and Procedures

Twenty-four of the 48 responding states noted that they had formal policies and/or operating procedures for addressing tree and woody plant growth issues. These policies usually include one, or some combination, of the following:

- Trees are not allowed to grow on dams or near toe and abutment
- All trees and stumps must be removed, but roots may be left
- All trees, stumps, and roots must be removed
- All trees must be removed, but root systems of "small" trees may be left; root systems of "large" trees must be removed
- Dams are treated on a case-by-case basis -- usually under the direction of a qualified professional engineer.

For those states that choose to distinguish between "small" and "large" trees, the definition basis ranges from 2 to 8 inches in diameter; most use a size of 4 or 6 inches in carrying out their policies.

Of the remaining 24 states indicating that they have no formal policies or procedures, the range of recommended procedures to dam owners varies widely. Some states evaluate dams on a case-by-case basis, while other states require owners either to maintain their dams, to remove vegetation for inspection, or to use other means for dealing with plant problems such as requiring a qualified engineer to be retained, depending on the dam hazard classification.

In summary, states follow several schools of thought and considerations in dealing with trees and vegetation on existing and new dams:

EXISTING DAMS:

- Distinguish between "small" trees and "large" trees
- Remove all trees, stumps, and roots from dam embankment

- Cut trees to ground level, but leave stumps and roots
- Cut trees, remove stumps, but leave roots
- Consider case-by-case basis
- Breach, remove, or decommission dam
- Require retention of a qualified engineer by owner
- Do nothing.

NEW DAMS:

- Establish effective ground cover and hope for the best in continual maintenance
- Use vegetative barriers such as bio-barriers or use silvicides/herbicides/chemical treatment.

Constraints to Removing Trees and Plants

Constraints to removing and/or controlling unwanted trees and other vegetation were listed by several state and federal dam safety officials. Constraint categories explicitly cited by state dam safety officials (number of states in parentheses) are given below:

- Financial limitations by owners (13 states)
- Environmental regulations and/or permits (10 states)
- Legal issues (6 states)
- Esthetics (5 states)
- Threatened/endangered species issues (2 states)
- Media (1 state)
- Sentimental reasons (several).

States indicated that the greatest constraint to removing unwanted trees and plants and repairing a structure infested with roots is limited financial capability by the owner. States such as Kentucky try to work with the owner to minimize the financial burden without threatening public safety. Ohio has recently established two low-cost loan programs to assist qualified public and private dam owners in funding safety-related improvements to their dams, including repairs mandated by the state dam safety program.

Environmental constraints range from limitation of the use of certain herbicides or chemicals for controlling vegetation and for treating stumps and/or roots near water bodies; to prohibition of, or air quality concern for, burning cleared vegetation. Unless exempted, vegetation removal and maintenance around dams may conflict with wetland protection regulations. In Washington, environmental issues can pose a major hurdle to removing trees, but ultimately, public safety takes precedence over environmental concerns. In Arizona, problems with time-consuming environmental permit requirements for larger plant removal projects are sometimes encountered.

Some states have limited legal power to force owners to remove trees and vegetation from dams. This lack of authority may cause delays and expensive and time-consuming litigation to obtain an order. Other states, like Maine, do not have specific laws that force owners to remove vegetation from their dams, and removal orders have yet to be tested. One state, South Carolina, notes that if the owner will not voluntarily cut or remove unwanted vegetation, the only course is to start legal action against the owner. Because legal help is limited, such help is normally requested for the "most extreme

cases." This means that only a few owners can be forced to do something about their vegetation. In New Hampshire, legal assistance is sometimes necessary to perform enforcement functions. In Oregon, if there is a problem with a recalcitrant owner, a Proposed Order can be initiated by Dam Safety to correct the situation if it is determined to be an immediate threat to the integrity of the structure. However, this process can be rather lengthy and expensive when staff time, materials, and attorney fees are included in the costs of preparing for a contested case hearing. In the end, most dam owners have the right to contest state directives to remove trees and other plants through administrative and legal processes and judicial appeals.

In some states, concerns have arisen when dams are located in parks or environmentally sensitive areas, especially when endangered or threatened species habitat is involved, in turn creating legal constraints.

Esthetics and sentimental reasons are often used by dam owners and their neighbors to resist removing trees and undesirable vegetation. This is particularly true if owners have intentionally planted ornamental trees and shrubs on their dams to provide shade or fruit, or to improve looks. Some owners believe that the more woody vegetation on a structure, the better -- thus making it very difficult for state dam safety officials to request its removal.

The power of the press has had major influence on tree removal programs in some cases, especially where the target dam is owned by a poor or downtrodden citizen or insolvent municipality. Heated controversy between public safety interests and private owner rights was generated through various Wyoming newspaper stories and letters to the editor in 1990 over the removal of 500 mature cottonwood trees on two dams owned by an 85-year-old widowed rancher who at the time was suffering from cancer. The news stories, which cast the owner as being targeted because she was vulnerable, influenced the owner's neighbors to encourage her to take a stand against further removal of 500 remaining trees because they felt that enforcement of the state dam safety act "would cause more harm than good."

While these constraints affect many states' ability to enforce their regulations, some states, such as Arkansas, Georgia, Colorado, Iowa, Maryland, Montana, New Jersey, North Carolina, and Tennessee, report no major constraints to enforcement and consider the safety of the dam structure to be of primary importance.

Federal agencies appear to have fewer constraints than states do in maintaining their dams, but some noted that they need to comply with the national Environmental Policy Act and the Endangered Species Act prior to initiating tree and plant control and management. Isolated constraints at the National Park Service involving funding priorities, historic preservation, and disruption of visitor services may override safe operation and maintenance needs at some dams. Because local watershed project sponsors are responsible for operation and maintenance throughout the lives of USDA/NRCS-assisted dam projects, funding for maintenance at these sites can be a continual challenge.

Vegetation-caused problems or failures

Twenty-nine states indicated documented evidence where vegetation on dams has either caused dam failure or negatively affected their safe operation. Sixteen states had no documented evidence and five states had no response. Several states provided photos and information on tree-caused failures or dam safety problems. The most recent documented dam failure due to tree root penetration occurred in May 1999 at an unnamed Air Force Academy dam near Colorado Springs. Here, an approximately 13-ft. high dam with a pond capacity of less than 5 acre-feet of horse stable waste water failed, releasing its contents and injuring a horse in a stable located about 100 yards downstream. The failure occurred after more than 7 inches of rain had fallen in the previous 72 hours. The dam had several pine trees on its crest and faces, and the breach opening exposed an extensive, deep root system. Roots up to 4 inches in diameter were found in the breach area. Figure 3 shows an example of a large root exposed in the bottom of the channel at the breach. The dam had not overtopped, and the failure was attributed to internal erosion of the decomposed granite embankment material along the roots. A tree had been located directly over the breach.

Figure 3. Large pine root located in the channel of the breach opening of a failed Air Force Academy waste lagoon pond dam (David Eyre, Senior Civil Engineer, Air Force Academy, Colorado, 1999).

At the Federal level, USDA/NRCS referred to documented cases where dam failure has been determined to be caused solely by trees, and noted that trees have also masked other more serious seepage problems, which went undetected.

Past and current research

Other than a few references to the University of Tennessee Tree Growth Report (Tschantz, 1988), only 1 or 2 other citations for tree or woody plant-related research were identified by the state dam safety officials (USDA/SCS, 1981).

The surveyed Federal agencies had relatively little to offer in the way of references to current or past research regarding the effects of tree and plant growth on dam safety. The Corps of Engineers referred to geotechnical and other related program research conducted at the Waterways Experiment Station, published as a technical report series, Repair- Evaluation-Maintenance-Rehabilitation (REMR). One recent study for the St. Paul District showed that a hole formed by a blown-down tree in the downstream toe area can produce a potentially dangerous increase in hydraulic seepage gradient and internal erosion or piping problems in dikes (Duncan, 1999). The USDA/NRCS referred to the 1950's research work done at the ARS Hydraulics Laboratory in Stillwater, Oklahoma, on Flow in Vegetative Channels, which could have application to some emergency spillways.

A recent literature review, sponsored by ASDSO/FEMA and conducted for the Steering Committee on Plant and Animal Penetration of Earthen Dams, researched available material on the effects of woody plants on dam safety (Tschantz et al, 1999). All types of sources and searches were inventoried, including ASDSO conference and workshop proceedings, ASCE technical journals and articles, USCOLD, direct e-mail and telephone contacts of selected federal and state agency officials, universities, research laboratories and other data bases accessible through the National Technical Information Service (NTIS) and National Performance of Dams Program (NPDP). While only a few references were found on recent or current research of tree and plant effects on dam safety, several references on federal and state practices, policies, and procedures for dealing with trees and vegetation were cited in such topical areas as

- woody plant physiology
- documented examples of woody plant-caused dam failures, operation, and maintenance problems
- case histories related to tree-caused dam failures
- current and past federal, international, and other research activities
- federal, state, international, and other organizations' policies, procedures and practices for preventing and remediating woody plant problems, and
- federal, state or private cost documentation for removing or controlling trees and woody plants.

The reader is referred to this literature review document for further references.

Costs of removing trees and remedial actions

Limited cost information for removing trees and brush or for repairing damages caused by vegetation at dams was available from the states or federal agencies. Most state dam safety officials indicated either that they did not have the data or that the owner or his consultant would have that information. Virginia reported that, while costs can be nominal, in extensive tree growth situations where grubbing is required, $10,000 to $20,000 per dam is common and that at one dam, the tree-clearing cost was about $40,000. Missouri reported that such costs could range from $1,000 to $10,000 depending

on how badly the dam is overgrown with trees. A prominent North Carolina geotechnical engineering firm stated that 10 different contractors, who work in North Carolina, South Carolina, and Georgia, reported recent bid prices ranging from about $1500 to $3000 per acre for cutting trees at ground level, removing stumps and rootballs, and grubbing the area to remove perimeter roots. Contractors were advised that clearing and grubbing would be done on embankment slopes ranging from 1V:1.5H to 1V:4H, possible wet areas in the lower 1/3 to 1/2 of the downstream slopes, and for dam heights ranging from 25 to 50 feet. Table 1 compares cost experiences reported by state dam safety officials in different regions of the country for clearing and grubbing trees from dams.

Reporting State	Number of Dams	*Cost/acre	Comments
Georgia	More than 25	$1,000 - $5,000	Based on consultants' feedback; cost varies depending on dam face conditions such as slope steepness, degree of wetness and tree density.
Oklahoma	1 1	$900 $1,150	2 acres of d/s slope over 2-1/2 day period 3-1/2 acres, current proposal estimate.
South Dakota	Several	$100 - $200/tree	Usually 10 - 20 trees/dam
Nevada	1	$532	Based on 3 hourly laborers working for 2 weeks on 3.25 acres of willow & mesquite removal on d/s dam face (~1995)
Michigan	General DNR construction cost experience	$3,500 $6,000 $12,000	Light clear/grub (diam.<6") Medium clear/grub (diam.<12") Heavy clear/grub (diam<24")
Tennessee	7	$1,540 (Ave.) (apprx rnge = $1030 - $3290)	Total clearing, grubbing & reseeding cost for 7 dams = $16,705 @ ~1.5 acres per dam; jobs including range of tree sizes & heavy brush. (1995-98)
Texas	1	$5,500	Part of overall site clearing and grubbing contract for new dam in East Texas (1995)
Ohio	1	$10,000	Cost included clearing, grubbing, mulching and seeding. Heavily wooded; hundreds of trees removed from d/s slope (1999)
Minnesota	Current estimates from Minnesota consultant Small maintenance projects	$1350 $2800 $4475 $4225 $6775 $960	Clearing brush with brush saw - no grubbing Clearing brush by hand - no grubbing Clear and grub brush, incl. stumps Cut & chip up to 6" trees; grub/remve stumps Cut & chip up to 12" trees; grub/remove stumps 16 m-hrs @ $60/hr to clear and grub small trees (diam. < 6") for less than 1 acre projects

*Reported costs not indexed

Table 1. Cost comparison for clearing and grubbing trees on dams.

While the range of remedial costs varies widely, depending on several factors, it appears that about $1,000 - $5,000/acre may be a reasonable baseline to use for rough estimating purposes, with the lower figure applicable to small and low-density tree growth and the larger figure appropriate to mature, very dense tree stands.

A typical 25-ft. high x 750-ft. long dam, having 3H:1V face slopes, a 15-ft. wide crest, and a freeboard of 10 feet above normal pool, has almost 2 acres of exposed crest and face area for potential tree growth. Total cost of grubbing and clearing trees for such a dam would likely fall into the $2000 - $10,000 range depending on the local site conditions.

Several site-specific factors can influence tree removal costs. These include size and type of trees, growth density, total job size (number of acres), location of growth (crest and/or both faces?), embankment face steepness, slope condition (such as degree of wetness or surface texture), degree and type of required surface treatment (backfilling, use of herbicides or bio-barriers, mulching, seeding, fertilizing, etc.), and regional labor and construction indices.

The U. S. Bureau of Reclamation reported detailed cost data using three herbicidal application methods (aerial, cut-stump, and ground-based foliar-application) in its 1987-93 program to control saltcedar along waterways in seven states of the Upper Colorado Region. Application costs ranged from about $60/acre for aerial spraying to about $1000/acre for cut-stump and spray methods (Sisneros, 1994).

The National Park Service indicated that it has done tree removal with the assistance of the U. S. Bureau of Reclamation, but cost information is not readily available.

Summary

Trees appear to be a major dam safety issue for many states. Based on recent survey responses from 48 states, it is estimated that an average of half of the state-regulated dams have trees growing on them. The same reporting states estimate that an average of nearly a third of the dams that they regulate have sufficient trees, brush and other growth to hinder effective safety inspections.

Current state and federal policies, procedures, and practices relating to tree and woody plant removal, control, and management for dam safety are generally fragmented and inconsistent among state and federal dam safety agencies. However, all state and federal agency dam safety officials and experts agree that *trees have no place on dams and need to be managed and controlled on both existing and new dams* for at least three important reasons: (1) trees and dense vegetation hinder effective dam inspections; (2) tree roots can cause serious structural instability or hydraulic problems, which could lead to dam failure and possible loss of life; and (3) trees and brush attract burrowing animals, which can in turn cause serious structural or hydraulic problems.

The fragmentation among state and federal agencies applies only to procedures about *how* and *to what extent* the trees and their roots should be removed and resulting

cavities remediated to ensure a hydraulically and structurally safe dam. Other chapters in this section discuss acceptable methods and practices for controlling problem plants and for repairing damage caused by trees and other plants.

While limited information is available, a sampling of state dam safety officials and other experts report that the cost of removing trees and brush from the face of a dam can broadly range from about $1,000 to $10,000 per acre, depending on several factors. Typically, the cost of clearing and grubbing trees from dams falls into the $1,000 - $5,000 per acre range. The broad range of costs is not surprising as most dam safety engineers agree that tree removal costs are very much site specific. Controlling vegetation annually is relatively inexpensive, but removing trees on and repairing damage to neglected dams may cost owners several thousand dollars.

Most dam safety experts agree that research needs to be done on determining the relationship of plant and tree species to root penetration of artificial environments such as embankment dams; the interaction between root systems and the phreatic zone and surface; and development and understanding of various types of physical, biological, and chemical treatment and barriers for controlling root growth. Because many existing dams have extensive deep-penetrating root systems, engineering methods need to be developed for understanding, predicting, and stabilizing their effects to minimize internal erosion and failure. Dam safety experts also agree that both technical and non-technical pamphlets and brochures, practice manuals, web-based documents, workshops, and guidance materials need to be developed for educating dam owners about the problems caused by trees and vegetation and for guiding engineers, developers, dam safety inspectors, and field people about preventing or safely removing trees and other undesirable plants from dams.

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