Contents

SAFETY ISSUES

Safety Issues in Deactivation

Cary White
Workers' Compensation Board of British Columbia
1980 Wills Road
Nanaimo, BC, V9T 6C6
Tel: 250-751-8065 Fax: 250-751-8046

This abstract outlines several new and expanded provisions in the Workers' Compensation Board (WCB) Regulations, Part 26: Forestry Operations and makes some recommendations regarding the personal safety of operators.

Each operator should have a personal safety plan. All personnel must follow safe work procedures including the wearing of personal safety equipment, such as hard hats and safety boots. Safety equipment such as safety belts and guards must be installed, in proper order, and used appropriately. Operators should never do any work beyond their own personal ability or attempt to use a machine beyond its ability to safely perform. Personnel should come to work in condition to perform their duties. It is important to think ahead and plan necessary actions in case of emergency, including primary and secondary escape routes.

Replacing the previous standard that applied only to personnel working alone, a new Section 26.6 of the WCB Regulations requires that "The well-being of a worker working alone or in isolation in a forestry operation must be checked in accordance with the requirements of Part 4 (General Conditions)." This new section recognizes that groups working in isolation may together be exposed to a risk that prevents any of them from sounding an alarm or seeking assistance.

Section 26.17 requires that "When weather conditions create hazards to workers, additional precautions must be taken as necessary for the safe conduct of the work." This section is being expanded to provide *rainfall shutdown criteria based on a WCB report,* Operational Shutdown Guidelines for Vancouver Island and the Lower Mainland. *The new regulations will include procedures to determine the amount of water in the soil (the soil water balance). When the permissible soil water balance for the area is exceeded, work is to be shut down.*

In response to a Coroner's Inquest following a fatal landslide, the WCB rewrote Section 26.18. The new section requires that where there is a risk of avalanche or landslide, the risk must be assessed in an acceptable manner, written safe work procedures must be developed and workers must be educated in the procedures. Draft standards set out the acceptable assessment procedure using the Terrain Stability Analysis Guidebook *and the* Gully Management Guidebook *processes. Where Class 4 or 5 terrain is identified, procedures must be developed to reduce the risk. If the area is not mapped, engineers or geoscientists must assess slopes in excess of 60%.*

WCB is developing a handbook setting out hazard recognition information for forest workers. The handbook plus application of the rainfall shutdown criteria, as required by Section 26.17, will meet the requirement for safe, written, work procedures.

The effective date of the new and amended WCB Regulations is April 15, 1998. ▲

The Use of Explosives in Deactivation - McTavish Creek Watershed, Rivers Inlet

Eric L Kay
Forestry Training and Forest and Road Consultant
8712 Island Highway, Black Creek, BC, V9J 1K5
Tel: 250-337-5096 Fax: 250-337-5096

The deactivation of logging access roads has become a necessary component of responsible forestry practice. Typically, deactivation has involved the use of excavators. Some experts have used explosives successfully for the treatment of specific, small areas, however, costs tended to be very high in proportion to the size of the area treated and the amount of deactivation achieved. The high costs are associated with the mobilization and demobilization and equipment and with the purchase, transportation, storage and handling of explosives

A recent example of a more cost-effective use of blasting in deactivation took place in the McTavish Creek Watershed. Access for deactivation work using excavators in the McTavish Creek area was limited over approximately six km of abandoned logging road. A road failure had cut off access to a section of road three km long; two other sections would have required the construction of a 33 m and a 12 m bridge to bring in the excavators. The severely restricted access to the area meant that blasting was a preferred alternative to the use of excavators in deactivating this long section of road.

The hill slopes in the drainage system had experienced a number of failures over the years as a result of interruption of the natural drainage patterns, and of failed over-steepened road fill. This resulted in the degradation of water quality both for human consumption and for the fisheries resources of Rivers Inlet. Productive land for tree growth was also lost. The Ministry of Forests had previously identified as a priority the re-establishment of natural drainage patterns and the stabilization of over-steepened fill material to ensure slope stability in this area.

*The author prepared a plan to restore natural drainage by construction of cross-ditches and removal of metal culverts using explosives. A report prepared for the Ministry (*Proposal to Stabilize Road-Induced Slope Hazards with Explosives in McTavish Creek, *Milt Holter, P.Eng. and Eric L.Kay) prescribed the use of explosives to pull back (scatter) over-steepened road fill material directly above and threatening McTavish Creek.*

The explosive work was carried out in the summer of 1996 with the Oweekeno Nation. The author provided blaster and helper training along with supervision. A Robertson 44 helicopter provided access to the work sites for workers, tools and supplies (including explosives) at the rate of $450.00/hour.

There are some cost, operational and safety concerns in a deactivation explosive project. These should be identified and assessed:

- Large (500+ mm) puncheon or oversize shot rock in the roadbed.
- The cost of mobilization/demobilization of explosives material. (An existing powder magazine can greatly reduce costs)
- Stability of immediate work area and surrounding hill-slopes.
- Safety to other workers and the public from fly rock.

Both air checks and ground checks were carried out to monitor the areas that had been deactivated by excavator and by explosives during the following seasons. Although there was a severe rain on snow event in November 1996 that initiated landslides in adjacent valleys and there was an unusually wet spring/early summer in 1997, the deactivated areas demonstrated no sign of failure or erosion problems. It can be concluded, therefore, that deactivating by explosives, if properly planned and executed, is as effective as traditional deactivation using excavators. ▲

SOIL BIOENGINEERING

Soil Bioengineering Solutions to Forest Landslides

David. F Polster
Polster Environmental Services
5953 Deuchars Dr.
Duncan, BC, V9L 1L5
Tel: 250-746-8052 Fax: 250-746-5307

Soil bioengineering is the use of living plant materials to perform some engineering function. The simplest application, seeding an area with a grass and legume mix, provides a surface blanket and protects the soil from surface erosion. More complex structures such as wattle fences, live pole drains, and live gully breaks perform functions similar to traditional retaining walls, French drains, and drop structures respectively. This presentation describes the use of soil bioengineering for the restoration of forest landslides and unstable slopes.

Soil bioengineering is becoming increasingly popular in the Watershed Restoration Program as a means of treating forest landslides and other disturbed sites. There are two types of bioengineering systems, one for water management and one for slope stabilization and these are described in the paper "Soil Bioengineering Solutions to Forest Landslides." by David F. Polster (included in the Workshop proceedings). The bioengineering systems employed for water management include the following structures:

- live pole drains which replace the traditional French drains, to collect moisture from a moist site and conduct it quickly away
- live silt fences which reduce sediment movement on low gradient stream
- live bank protection which stabilizes unstable stream banks, roadside ditches, and culvert inlets and outfalls
- live gully breaks which control the initiation of torrents and the flow of water
- live staking which stabilizes slumping materials, "pins" sod to a slope or adds riparian cover along stream banks.

Bioengineering systems for steep slopes include the structures noted above and the following additional structures:

- modified brush layers which prevent rocks from rolling downslope and damaging vegetation and which also provide resistance to shallow soil movement after the plant roots become established
- wattle fences which produce a break in the slope and reduce the impact of rolling material on vegetation growing on the lower slope
- brush layers which provide initial slope strength as reinforced earth structures, then provide additional strength as the cuttings sprout.

During the past two seasons, thousands of linear meters of bioengineering structures have been installed throughout British Columbia. These structures include about 9,700 m of modified brush layer, each at two m long, 8,500 m of live pole drain and wattle fencing, 400 gully breaks, hundreds of m of live stream bank protection and tens of thousands of live stakes. Live silt fences and a variety of experimental techniques such as brush layers and contour fascines have been used in a few locations.

Bioengineering is gaining wide acceptance as a practical tool for revegetation following forest harvesting practices. It uses natural materials, requires minimal training for workers, and, since it is primarily hand work, it generates considerable local employment. ▲

The Oweekeno Drain Process

Dan Mechalchuk
Mechalchuk Contracting
Site 298, Compartment 15
RR # 2, Courtney, B.C., V9N 5M9
Tel: 250-339-4345

Many road failures have been observed in full pullback, especially where the slopes and pullback are steep and where seepage is occurring. The seepage water infiltrates the unconsolidated fill causing the soil to lose cohesion. This reduced soil strength plus the increased weight of the pulled back soil leads to slope failure.

The author developed the Oweekeno Drain while working in the Shotbolt, McTavish and Nicknaqueet Valleys near River's Inlet in 1996. The Oweekeno Drain is a coarse rock drain that is placed against steep slopes prior to placing pullback fill. The drain acts as a buttress to help strengthen the cut slope, a filter to prevent migration of fine grained cutslope soils, and as a drain to disperse the seepage without saturating and weakening the pulled back material.

The procedure takes advantage of natural sorting due to gravity, similar to the sorting evident on a talus slide. During road deactivation the excavator places the pullback material against the cut bank in front of the seepage area as high as possible so that it forms a triangular wedge. This is done by placing the material at the top of the cut bank using a spreading action, then allowing the larger materials to fall down the leading edge of the wedge.

As long as the angle of the cut bank is greater than the angle of repose of the pulled back soil, the material will sort. The finer soils will stay on the inside and top of the triangular wedge and the coarser material will fall to the outside and bottom of the wedge. The finer soils will filter the cutslope, allowing the seepage water into the wedge without transporting the fine soils from the cutslope. The larger material will allow the water to drain away under the cutslope in a dispersed manner, without being concentrated at any one point.

Before the top of the cut bank is out of reach of the excavator, the cutslope and fill is recontoured to the natural slope angle. The process is continued, bucketful after bucketful, until the seepage area has been treated.

This same sorting process can be used in other locations to produce extra rock armor for cross ditches. In some applications, the sorting process may be suitable in drains under roads to conduct water from ditches and disperse it downhill. The Oweekeno Drain uses only natural materials that will never deteriorate or fail, as can happen to filter cloth if not handled carefully. Most operators will require some training to learn this method. However, it is a relatively simple procedure and training time should be short. It is a cost-effective procedure and should be considered for use in forestry applications. ▲

Slope Stability Analysis of Biotechnical Works

Hardy Bartle, P.Eng.
Ministry of Forests
2100 Labiex Road, Nanaimo, BC, V9T 6E9
Tel: 250-751-7073 Fax: 250-751-7190

Slope stability analysis is a tool for assessing the risk of slope failure. Slope stability analysis can be used to assess appropriate uses of road deactivation and biotechnical works.

The five factors controlling slope stability are:

1. The frictional resistance to sliding of the slope material(s): In the language of geotechnical engineering, the frictional resistance to sliding of a material is referred to as its angle of internal friction. Forestry workers tend to use the term "angle of repose" when referring to the maximum frictional resistance of a material to sliding. A high frictional resistance to sliding, or larger angle of repose, is preferred to lower values.
2. The slope angle of the potential failure surface: A steep potential failure surface angle is bad.
3. The weight of material above the potential failure surface: In general, if a potential failure surface is:
   - less than the local soil's angle of internal friction, a large volume of material above the failure surface is good;
   - greater than the local soil's angle of internal friction, a large volume of material above the failure surface is bad;
   - approximately the same as the local soil's angle of internal friction, the amount of material above the failure surface makes little difference to slope stability.
4. The cohesion or "stickiness" of the material(s) within a slope: In stability analyses with forestry applications there are two common sources of "stickiness"within a hill slope; tree roots and soil cohesion. The effects of tree roots upon shallow slope stability are complex. For simplicity, tree roots are usually modeled as a thin veneer of extra "sticky" soil upon a hill slope. Strong, "sticky", tree roots are good. Hardpan (till) is an excellent example of a forest material with high soil cohesion. Hardpan is difficult to dig until the stickiness (cohesion) between adjacent chunks of soil is broken; once broken hardpan is easy to move. Soils (such as hardpan) with high cohesion are good**.** Total slope cohesion refers to the available soil cohesion plus the available tree root cohesion. High cohesion is good for slope stability.
5. The magnitude and direction of water pressures within a slope: The destabilizing effects (horizontal thrust forces) of water increase by the square of water depth; water is bad; deep water is terrible.

In 1989 the US Forest Service published "LISA" (Level 1 Stability Analysis, a computer program and associated documentation manual). LISA is a useful and concise guide to slope stability analysis of open slope failures.

Road fill failures frequently approximate finite slope failures. The core equations for numerical modeling of finite planar slope failures can be readily modified to incorporate tree load surcharging, tree root cohesion, and water pressures.

Slope stability analysis suggests:

- It is important to look for and correct water control problems on a slope. Physics (and most forestry workers' field experience) indicates that water control is an inexpensive and effective method of improving slope stability.
- Trees on steep (>60%, 16 m slope length or greater) and deep (>1 m) sidecast road fills do not assure slope stability. Tree roots must penetrate the original forest floor or the road fill will be"primed" for failure.
- Light pullback on steep and deep fill slopes contributes very little to slope stability.
- Poor water control in the short-term (typically a bad

cross ditch) can easily defeat moderate pullback, and may defeat heavy pullback upon a steep and deep fill slope.

- Moderate pullback combined with long-term reforestation may stabilize a steep and deep fill slope; however, long term stability of moderate pullback is highly dependent on the depth and strength of the tree roots on the residual fill slope. Deep and strong tree roots give moderate assurance of slope stability; shallow and/or weak roots contribute very little to slope stability.
- Heavy pullback and long term reforestation of a sidecast fill slope should ensure slope stability. Whenever the fill depth is reduced to a level where tree roots can reach below the original forest floor there is significant hope for long-term slope stability.
- Reforestation or biotechnical measures on steep slide tracks should significantly improve near surface slope stability. Any vegetation cover that delays the loss of native soil cohesion along a slide track, due to water erosion or frost jacking, is desirable.

Free copies of the LISA documentation manual are available from: Research Information Center, Intermountain Research Station, 324 25th Street, Ogden, UT 84401. LISA software is available upon the Internet at: <http://forest.moscowfsl.wsu.edu/4702/slope0.html>. ▲

RISK ASSESSMENT

Editor's Note: The following presentations made up a panel discussion about Risk Assessment.

Introduction : Risk Assessment

Frank Baumann, P.Eng.
Baumann Engineering
Box 1846, 1160 Hunter Drive
Squamish, BC, V0N 3G0
Tel: 604-892-2303 Fax: 604-898-2331

Risk assessment has long been used in a general way for managing forested terrain, roads, and geotechnical problems. However, used more specifically, it can be an even more useful tool: for example, it can determine if an action or policy is justifiable, whether a given situation represents an unacceptable risk to life or property, or assess the amount of time, effort and money that should be spent on a particular problem. Properly used, risk assessment is useful for determining the existence of large and small problems and strategies to manage them.

The following case histories illustrate a suggested methodology for applying risk assessment in the forest industry. ▲

Hillslope and Stream Restoration - The Habitat Protection Outlook on Risk

Alan Caverly
Ministry of Environment, Lands and Parks
370 South Dogwood St.,
Campbell River, B.C,, V9W 6Y7
Tel: 259-286-7630 Fax: 250- 286-9516

Proponents of Watershed Restoration Program (WRP) activities must be familiar with legislation affecting both the permit and approval processes and with the potential liabilities (risks) that apply to work that causes negative impacts to fish and/or fish habitat. Many fish stocks are already very low, due in part to habitat degradation, and in part, low marine survival.

Most proponents will have already encountered and probably questioned the process and legislative constraints that surround actual project approvals. While to some the process seems cumbersome, existing legislation and concern for protection of existing habitat values makes a precautionary approach essential. Inadequate planning or careless implementation have been demonstrated to cause habitat degradation. The sheer volume of WRP work in progress increases risk dramatically.

The following existing legislation provides considerable protection for fisheries and water resources on Crown Land:

Fisheries Act
Section 35(1) - No person shall carry on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat.

Section 36(3) No person shall deposit or permit the deposit of a deleterious substance of any type into water frequented into waters frequented by fish. (i.e. sediment, fuel oil)

Water Act
Section 9 and Regulation 241/95. Notification or approvals for work in and about a stream (Note: does not apply to roads and stream crossings on Crown Lands administered by the Ministry of Forests).

Waste Management Act
Regulation 375/96 - Contaminated Sites and Regulation 66/88 –Special Wastes (i.e. old logging camps/shops or rail logging fueling sites).

Forest Practices Code
Section 45 (1) No person shall carry out a forest practice that results in damage to the environment.

Section 45 (3) A person must not carry out a forest practice if he or she knows or should reasonably know that, due to weather conditions or site factors, the practice may result, directly or indirectly, in (a) slumping or sliding of land.

This legislation should deter the inexperienced or unprepared project team from becoming involved in hillslope or stream restoration activities.

Note that receiving "approvals" satisfies only the process side of the legislation and should follow adequate planning. The laws still apply. Planning and on-site team performance including operator experience and diligence throughout the project can avoid prosecution under the legislation noted above. Habitat staff is often pressured to allow deactivation work outside timing windows or asked to endorse instream activity that proponents claim will have "minimal" impact. Existing values are often poorly documented and may be very localized and fragile (i.e. small escapement of spawning sea-run cutthroat). MELP is often asked to allow wet season restoration activities to help proponents meet employment targets or other contract deadlines. While typical forest operations such as logging often have their own seasonal constraints, the MELP timing constraints are often criticized as too restrictive. Some flexibility exists, however, in the following areas:

- most proponents are familiar with the "All Weather Guidelines" from MELP Region 1 for work in and about a stream. Temporary bridges, low risk sites within rock control channels and coarse textured, stable upslope materials give some room to move, in less than ideal weather and season, on WRP activity.
- sediment control plans and on-site environmental monitors can play a key role in reducing risk. Involve monitors before planning is finalized.

Note that both Federal and Provincial enforcement staff are neither part of, nor bound by, the WRP approval process. They can and will take action in some situations involving environmental damage, including WRP projects. A proponent undertaking a project assumes certain risks, should there be an investigation of the project. These risks may include:

- Stop Work Order (Forest Practices Code-Sect 123(1)) - costly delays to the project, remediation, administrative penalties;
- legal investigation resulting in delays, lawyers, fines if convicted and remediation costs; and
- notoriety - the public has access to the information on firms/individuals convicted of violations of the aforementioned legislation.

Habitat and Enforcement staff enforce certain procedures to avoid risk and damage to the environment. The main focus is on prevention. To avoid risks:

- during wetter months focus on project planning and assessment, not project implementation
- have up-to-date information on fish presence at or near the work-sites; be aware of downstream fisheries resources and local soil hazards; consider timing windows in work plans
- apply well in advance for approvals from resource agencies; provide accurate information and maps
- use current "best management practices" to prevent downstream impacts
- use expert advice and experienced personnel on projects
- keep inexperienced workers out of high risk situations; encourage such workers to always have mentors or to work in an apprenticeship with experienced workers
- stabilize erodible banks and slopes with the best products and techniques; use these correctly

Further information on permits/approvals and legislation can be found in Streamline Vol. 2 No. 1 and on the websites of MELP (http://www.env.gov.bc.ca/), MOF (http://www.for.gov.bc.ca/), and DFO (http://www.ncr.dfo.ca).

Risk Management

Doug Erickson
District Engineering Officer
South Island Forest District, Ministry of Forests
4227 6th Avenue, Port Alberni, B.C. V9Y 4N1
Tel: 250 724-9205 Fax: 250 724 9261

Risk is defined as exposure to possible loss or injury (noun) or to expose to danger (verb). The Ministry of Forests policy is to define risk in terms of the probability of an event occurring, for example sediment reaching a stream, and the consequence, or resource impact of that event. The consequence of an event depends greatly on the magnitude of the event. For example compare the consequence of a two hectare landslide into a stream versus sediment generated from ditchline maintenance reaching the same stream.

Due to the various resource constraints, many organizations operate on a "risk management " basis, risk management being defined as a decision making process that helps direct resources to where they are most needed. Unfortunately, the term "risk management" can mean many things to many people. For example, a manager may be quite happy with accepting minor resource impact, as the monetary cost to reduce the impact to nil would be prohibitively expensive. On the other hand, staff of a government approving agency may insist on nothing less than total elimination of the impact.

Both positions have merit, but must be tempered by the actual requirements of the other party. In some cases, the government agency may be willing to accept some minor impact, providing there is a good reason for so doing and the rationale is explained. By the same token, industry personnel must realize that while total elimination of impact is probably not achievable, this does not give them free license to adjust their operational practices so that minor resource impacts become the standard of the day.

There has been some debate whether we should be maintaining the current level of activity of road deactivation. It is argued that we could accept some additional risk by leaving some roads open, even though there are identified problems. That issue, however has been decided, with the passage of the Forest Practices Code which requires the deactivation of unused roads so as to minimize risks. Under the Code, howver, there is the option of keeping the road open under permit, provide regular inspection and maintenance is carried out and the permittee assumes any associated risk.

To reduce environmental risks from road based activities, it is necessary to treat the obvious small issues before they become big issues. This can be done by increasing the frequency of inspection and maintenance activities. If the risk is not effectively managed it will slow down industrial operations, such as logging. If logging is curtailed then so is stumpage revenue. Consequently, funding can suffer for Crown agencies such as Forest Renewal BC and such activities as the Watershed Restoration Program. In the extreme, inattention to risk could adversely affect programs, such as the WRP, which are making a major contribution to environmental integrity.

If "risk management" is done poorly, and cost is the only justification for not doing the maximum, then someone will legislate the amount of risk allowed. The Forest Practices Code is a prime example where a risk management ceiling has been legislated. ▲

WRP PARTNERSHIP

Theodesia Watershed Restoration Project Partnership: "Work in Partnership"

Marion Blank[1], Tanis Douglas[2], Walter Cowland[3], Leonard Harry[4] and Scott Galligos[4]

[1]Ministry of Forests
7077 Duncan St.
Powell River, B.C. V8A 1W1
Tel: 604-485-0799 Fax: 604-485-0779

[2]Ministry of Environment, Lands and Parks
10470 152A St., Surrey B.C., V3R 0Y3
Tel: 604-582-5351 Fax: 604-930-7119

[3]MacMillan Bloedel
Stillwater Division
301-4400 Marine Ave., Powell River, B.C., V8A 2K1
Tel: 604-485-3100 FAX: 604-485-9829

[4]Sliammon First Nation
RR # 2, Sliammon Road
Powell River, B.C., V8A 4Z3
Tel: 604-483-9646 Fax: 604-483-9769

The Ministry of Forests (MOF), Ministry of Environment, Land and Parks (MELP),

MacMillan Bloedel and Sliammon First Nation have used the partnership provisions developed by Forest Renewal BC to accomplish their collective goals in the Theodosia Watershed. These goals are:

- To restore, protect and maintain fisheries, aquatic and forest resources adversely affected by forest harvesting practices that without intervention would require decades to recover naturally
- To bring areas harvested under previous standards up to Forest Practices Code standard
- To provide community-based employment, training and stewardship opportunities

The Theodosia Watershed, located 23 km north of Powell River in the Sunshine Coast Forest District, has been negatively affected by past forest harvesting activities. The Sliammon First Nation has long wanted to do restoration work in the Theodosia watershed because of its cultural and ecological significance and realized an opportunity to complete this restoration work through Forest Renewal BC's Watershed Restoration Program (WRP).

In March 1995, Sliammon and the Ministry of Environment developed and submitted an integrated watershed restoration proposal to Forest Renewal BC. The proposal was jointly reviewed in November 1995 by MOF and MELP.

The MELP instream portion of the proposal was easily implemented. However, the upslope work was more complex because of the land tenure issues and regulatory obligations. It was apparent that the goals could not be accomplished without the cooperation of a major licensee.

Realizing that the instream success depended on the up-slope restoration, MOF and MELP began discussion on how to restore the watershed using a cooperative approach. In December 1995 a joint meeting was held with MOF, MELP, Sliammon and MacMillan Bloedel (the major tenure holder in the watershed) to discuss options regarding partnership. As a result, MacMillan Bloedel, on behalf of the Theodosia Watershed Restoration Program, agreed to lead the upslope portion of the watershed restoration work and to form a partnership with Sliammon.

Funding was obtained from Forest Renewal BC by MOF and MELP to conduct assessments and initiate instream and upslope work programs through various partnership arrangements. Sliammon was identified as the lead proponent for instream works and MacMillan Bloedel agreed to lead the upslope works in partnership with the First Nation group.

Instream Program
These works began in 1995 with the training of five Sliammon Nation members and the work continues. Under the partnership agreement with MELP, the Sliammon undertook fish habitat and riparian assessments, while MELP had the responsibility to complete detailed channel assessment and provide general technical advice. The Water Quality Quantity Inventory process was integrated with the WRP project.

Upslope Program
These works began in December 1995 with a Level I Overview Assessment followed by a Level II Prescription phase completed in May 1996. Major work began in August 1996. To date, 96 km of roads have been deactivated and 50 ha have been seeded. The Sliammon Nation played a role during each phase of this process and have developed skills/joint ventures to ensure their success in securing future employment in the Watershed Restoration Program and beyond.

The Theodosia Restoration Program has been facilitated through partnership agreements and roundtable discussions with partners. These partnerships have allowed rehabilitation of a crucial watershed within the Sunshine Coast Forest District and Sliammon traditional territory. Through formalized training, new skills have provided employment for the Sliammon Nation and other local contractors. We have developed strong relationships, based on trust and understanding, through our partnership agreements that will ensure success with future watershed restoration projects in our community. ▲

ROADS

Reactivation of Previously Deactivated Roads

Dennis Clarke[1] and Mike Leslie[2]
[1]Consider It Done Watershed Restoration Services
Box 553, Lake Cowichan B.C., V0R 2G0
Tel: 250-749-4150 Fax: 250-749-4165

[2]Mike Leslie Consulting Ltd.
1128 Viewtop Road
Duncan, B.C., V9l 5S7
Tel: 250-748-1486 Fax: 250-748-5952

The intent of this abstract is to indicate to all involved with watershed restoration that road failures continue to occur on roads that were deactivated to formerly acceptable standards. It addresses the difficulties with, and possible solutions to, gaining access to these failed areas. We must also be concerned with the long-term effectiveness of deactivating to questionable standards as the cost of re-doing this work may exceed the initial cost by as much as six times.

Industry and government began road deactivation in the late 1980’s and early 1990’s because of severe environmental impacts to fish-bearing watercourses due to failures of abandoned forest roads. The resulting publicity and political pressure led to changes in road building practices. Initially, road deactivation efforts were conducted at industry expense and the lack of experience with road deactivation resulted in various standards being established and approaches being used. As a result, failures occurred off roads that were deactivated to standards that, at the time were acceptable. These standards have improved with the implementation of the Forest Practices Code and the Watershed Restoration Program and continue to improve as practitioners gain more experience. The question must be asked, however: “Are our current standards for road deactivation good enough?”

A risk assessment is required to determine whether to take action on roads previously deactivated is required. Such an assessment involves determining the risk of failure associated with these roads. Those with a low residual risk would be left as is; those with a high residual risk would be reactivated, the road opened, and full deactivation work to a new higher standard completed.

In such cases, reactivation prescriptions are required for re-opening the road, and deactivation prescriptions are necessary for deactivating and re-closing the road. One of the major problems is re-establishing equipment access. This requires that reactivation prescriptions be implemented from the bottom up, rather than the top down as with normal deactivation prescriptions. Important factors to consider in these prescriptions are the locations of endhaul spoil sites, environmental protection measures, and work timing for safety purposes. In many cases, single width tote roads are specified to prevent overloading fill slopes. If the road is to be used for endhaul, a higher standard is necessary. ▲

Building Roads with Deactivation in Mind

Glynnis Horel
2287 Horel Road
Saltspring Island, B.C., V8K 2A4
Tel: 250-653-4925 Fax: 250-4653-926

The Forest Practices Code has changed the way roads are regarded in the context of forest health. The code seeks to minimize erosion and sediment production from long term roads, and to minimize lost forest site by restoring short-term roads to plantable ground, to the extent practicable. With these changed expectations, deactivation costs have become a significant factor in the lifetime cost of forest roads.

Thorough planning is critical to controlling road costs. The intended use of the road must first be established. Roads that are to be active and maintained on a long-term basis will have on-going maintenance and inspections. Structures will typically have a long design life (50 to 100 years). Disassembly of structures is not normally a consideration in selecting types of structures. Mainlines are typically planned for long term wood flow. Construction costs can be amortized over long periods of time. Over long haul distances, wear and tear costs may be a factor, leading to higher standards of surfacing, flatter adverse grades, and more frequent surface maintenance. Active haul roads generate the most sediment; sediment control will be a specific objective near sensitive water bodies.

Other long-term roads may be intended for short periods of active use followed by extended periods of semi-permanent deactivation.During the periods of deactivation, some level of inspection will be carried out but it is desirable to minimize the frequency of inspections and maintenance activities required. Avoid structures where failure to maintain could lead to serious consequences.These roads still need to be designed for long term stability, and the larger drainage structures are likely to have the same design life as active mainlines. Access may or may not be retained during deactivation periods, or may be seasonal. Temporary bridges may be feasible. Steeper grades may be acceptable.

The cost of short-term roads usually needs to be offset against the immediate wood volume. Short-term roads may have a specific deactivation target in the logging plan, such as complete debuilding to achieve plantable site, or to mitigate hydrologic effects. The method of road construction must be selected that meets these targets. For example, if the silvicultural plan indicates that the road will be debuilt and planted, but the road location requires full-bench endhaul in high rock cuts, the construction methodology needed for the road will not result in the silvicultural target being met.

Higher hazard levels may be acceptable on short-term roads; some hazards might be, for example, the likelihood of cutslope instability, flooding, channel avulsion on fans, avalanches. More severe alignments and narrower road widths may be acceptable. Road designs can make use of temporary structures, including temporary bridges, retaining structures. For seasonal roads, it may be acceptable in some situations to forego ditches in order to minimize road width.

For short-term roads that are to be subsequently deactivated, bear in mind that construction crews and equipment are more readily available during construction than during deactivation. Plan to stockpile additional material, such as shot rock, if it will be needed for deactivation. If fords are planned to be constructed when crossings are deactivated, build the basic ford structure at the time of road construction. Where feasible, coordinate deactivation work with construction of other roads in the vicinity, in order to optimize the use of equipment.

On short-term roads, avoid using structures that are difficult to disassemble. Most material will need to be handled twice; plan to minimize the effort required for deconstruction, by keeping short fill slopes and shallow fill depths wherever possible. Avoid deep fills that will need major efforts to remove. There may be advantages to using heavy-wall steel pipe, such as decertified pipeline pipe, instead of corrugated pipe, because heavy-wall pipe can be removed and reused. As well, it needs less cover to support truck traffic.

Where retaining structures are needed, consider design options which would simplify removal, or which may not need to be removed. If a structure is meant to be sacrificial, consider the consequences of the structure remaining in place without access for maintenance.

In summary, when evaluating access and harvesting options, it is necessary to consider the total lifetime costs of the roads including cost of original construction, cost of special maintenance requirements, and cost to deactivate. Where a road is planned to be deactivated, consider construction methodologies that take into account both construction and deactivation costs. Ensure that the planned objectives can be met with the proposed road construction methods. And finally, don't put off work for deactivation that can be done during construction. ▲

Case Study of the Oyster River 300 Road

Jim Loftus, R.P.F.
MacMillan Bloedel Ltd.
Box 6000, Campbell River, B.C., V9W 5E1
Tel: 250-287-5020 Fax: 250-287-8387

Oyster River 300, located on private forest land on the East Coast of Vancouver Island, was built around 1970 with a cat bulldozer. Average side slopes were greater than 50 % - 60 % with areas of heavy rock. The road, showing signs of failure, was deactivated in 1996 and rebuilt in 1997. The following strategies are discussed:

- raising and moving the road profile into the slope;
- endhauling excessive roadfill;
- the use of French drains in ditches and cross ditches to eliminate the ditch line in order to keep the rebuilt road narrow;
- the use of gabion basket and rock retaining walls to retain fills;
- the use of an excavator-mounted rock hammer to break up bedrock outcrops and rock too large to handle;
- revegetation using grass seed, conifers and transplanting displaced conifers; and
- the use of old puncheons from old wooden culverts to armor cross ditch and fords. ▲

Opportunities for Instream Work at Deactivated Road Crossings

Randy Dolighan[1], Warren Warttig[2]
[1]Ministry of Forests
4227 6th Avenue
Port Alberni, B.C. V9Y 4N1
Tel: 250-724-9205 Fax: 250-724-9261

[2]International Forest Products Ltd.
630 Cambell Street, Tofino B.C., V0R 2Z0
Tel: 250-725-4444 Fax: 250-725-4474

This abstract describes the planning and delivery of a Watershed Restoration Program road deactivation project with the added feature of habitat restoration of fish-bearing streams at road crossings. This approach provides the highest possible benefit to the water resources. The project area, Kootowis Creek, encompasses 3,600 ha and drains into Grice Bay near Tofino. Swamp headwaters and a low gradient creek channel and flood plain characterize the area. Due to the favorable gradient and relatively stable channels, Kootowis Creek is a key salmonid production stream in the Tofino area.

Except for the lower two km reach of the creek located within the Pacific Rim Park, the entire watershed has been subject to clear-cut logging and a network of abandoned roads remains. Assessments revealed that the roads and failing culverts act as impermeable dykes, and in conjunction with instream debris resulting from cross-stream yarding and subsequent salvage logging, the hydraulic efficiency of the channels is dramatically reduced.

A coordinated Project Management team administers the project. MOF administers the road crossing work, including habitat restoration at the crossing sites. MELP administers all the remaining instream habitat work, including small woody debris removal and placement of large woody debris.

Standard deactivation prescriptions were developed for all road crossings in the watershed. A team consisting of the site supervisor and the biological monitor visited all crossing sites where fish were present. Based on limiting factors to salmonid production at each location, the team revised the deactivation prescriptions to take advantage of the opportunity for habitat enhancement at that location. The habitat design concentrated on pools, riffles, glides, scour and cover, the five basic elements of fish habitat. The revised prescriptions were submitted to the project management team for review and approval. A critical component was ensuring that the biological component of the prescription did not jeopardize the intent of the road prescriptions. Where conflicts arose, geotechnical objectives were paramount in the decision making process.

The field crew consisted of local displaced forest workers, a biological monitor and a site supervisor. Prior to starting work, all workers attended a four day Level 1 Streamkeepers course to provide a basic understanding and appreciation of the activities they would be undertaking.

The road deactivation component of the project has been ongoing during the 1996/97 and 1997/98 work seasons and there are already a number of immediate benefits. At the improved crossing locations, there is high utilization by various life stages of salmon and trout. This fostered a strong sense of accomplishment with the workers, as they could see the benefit of their extra efforts using this integrated approach. Workers were observed showing their friends the sites on weekends, checking the sites to see if they were being used and even fixing up structures that they were not completely satisfied with. ▲

SITE RECLAMATION

Barr Creek Logging Camp Dump Site Reclamation

Mark Desprez
Ministry of Forests
370 South Dogwood St.
Campbell River, B.C., V9W 6Y7
Tel: 250-287-9384 Fax: 250-286-9410

The Barr Creek watershed is located on the east side of Zeballos Inlet approximately eight km southwest of the village of Zeballos. Access to the lower reaches of the watershed, including the old Barr Creek camp location, is by boat from Zeballos or Tahsis. The mainline, accessed from Tahsis, is currently accessible only by four-wheel drive vehicle. This drainage was harvested under a forest license from the mid-1970's to the early 1990's. In 1996/97, the watershed was deactivated under the Watershed Restoration Program. The deactivation work involved all phases of upslope rehabilitation, including road deactivation, landslide heli-seeding, and gully restoration.

In 1995, in response to public concern that some sites had not been "left in a condition that is environmentally acceptable," the Vancouver Forest Region compiled a review of all expired special use permits. High-risk sites were identified by their potential for concern, based on past experience with permittees, on-site knowledge, and public comments. A representative sample of these sites was inspected to identify existing concerns and provide basic recommendations for follow-up. The review identified concerns for the Barr Creek site including an illegal landfill site with exposed fuel tanks, filters, batteries, tires and oil-stained soils. Campbell River Forest District management approved the reclamation of the site, to be conducted in conjunction with the upslope work.

The 1.7 ha Barr Creek site was environmentally ideal for a first attempt at such a project because:

- the camp was located well away from drainage into Barr Creek;
- existing water management measures intercepted the upslope drainage and directed it away from the project area;
- the natural downslope seepage areas did not affect fish bearing streams or the foreshore habitat; and
- the remains of the shop floor, including the containment wall, provided an environmentally stable working area for the handling and storage of potentially hazardous materials.

Key phases of the project were plan approval, site preparation and site work.

Plan approval entailed:

- approvals from the Waste Management Branch of the overall plan, the project supervisors and a contingency plan for containment of spills, and
- referrals to the Ministry of Environment, Lands and Parks and the Department of Fisheries and Oceans.

Site preparation included:

- clearing of the brush and alder from the site, and
- construction of collection sumps at all downslope seepage sites.

Site work entailed:

- electromagnetic induction mapping of the site to locate metal concentrations,
- careful dissection of the landfill,
- handling, storage and disposal of environmentally harmful materials such as hydrocarbons,
- regular soil sampling,
- the treatment of tainted soils on site with a "Biocell", and
- salvage of recyclable materials such as metals, tires, etc.

The works were conducted with equipment rented on an hourly basis. Equipment included two excavators, two dump trucks, and barges for mobilization, demobilization, and scrap removal. Labour included one supervisor, equipment operators and up to five swampers. The swampers received some training on the heavy equipment through additional funding provided by a Forest Renewal BC training contract. Professional services included the supervisor with experience in environmental sciences, a geophysical team to do the mapping, and engineering consultants for "Biocell" construction.

The "Biocell" process will take up to one year to complete and will restore the site to an environmental standard suitable for urban park use. ▲

WATERSHED RESTORATION

Slesse Creek Rehabilitation Project

David Sahlstrom, B.Sc., MBA
Terrasol Environmental Consulting
3-33557 Maclure Road
Abbotsford, B.C., V2S 4N3
Tel: 604-852-3782 Fax: 604-852-9376

Slesse Creek, a tributary of the Chilliwack River, provides valuable habitat for resident trout and steelhead as well as for the Chilliwack salmon run.

The BC Ministry of Environment, Lands, and Parks, therefore, has placed a high priority on protecting the watershed, once heavily logged. An extensive road network developed over the last 30 years has increased the potential for greater peak flows and sediment production. The valley has a significant recreational use, including a picturesque hiking trail to Slesse Mountain in the headwaters. Due to the high environmental value and extensive development that has occurred in the watershed, restoration of the watershed was a priority for the BC Ministry of Forest under the Watershed Restoration Program.

In August 1996, a WRP project began to rehabilitate the upper eastern portion of Slesse Creek. The project involved deactivating 6.4 km of road and rehabilitating nine landslides. The two gullies in the study areas did not require any work. Access to the Slesse Mountain hiking trail was maintained by deactivating the lower section of road to “semi-permanent” with four wheel drive vehicle access and the upper section to “permanent”with walking trail access. Deactivation activities focused on managing water, and removing road materials that were unstable or posed a risk of future failure. Special prescriptions were required for several sites. These included bridges to be removed and approaches to be resloped. Other special prescriptions were a stabilized, narrow road with a vertical rock cut that restricted equipment movement, a narrow road built on unstable fill that presented a safety hazard for deactivation equipment and personnel, and a narrow road with eroded fill that restricted equipment operations.

Revegetation prescriptions focussed on controlling erosion and developing a sustainable vegetation cover through a phased plan that included seeding the deactivated roads and landslides with a grass and legume mixtures. Biotechnical revegetation systems were prescribed for selected steep slopes. Follow-up work included planting with conifers and alders. Refertilization and maintenance of the vegetation were recommended.

Site work commenced in October 1996 and continued until snowfall. Two excavators, a bulldozer and two articulated dumps were employed to deactivate the roads. Deactivation was completed in the spring of 1997. Permanently deactivated roads were seeded and fertilized as the site work proceeded. In less than one year this project was assessed, prescribed and roads deactivated. Additional revegetation activities are planned for 1998. ▲

Watershed Restoration Program: Summary of Instream Work in Region 1

Marc Gaboury
Ministry of Environment, Lands and Parks
2080 Labieux Road
Nanaimo, B.C., V9T 6E9
Tel: 250-751-3152 Fax: 250-751-3103

British Columbia’s Watershed Restoration Program was initiated in 1994 under the auspices of Forest Renewal BC to restore, protect and maintain fisheries, aquatic and forest resources adversely affected by past forest harvesting practices. Prior to fish habitat restoration work in a watershed, assessments were made of upslope and stream conditions to determine the extent of hydrologic and sediment regime perturbations, channel instability, and fish habitat impairment. Stream assessments in Region 1 have been undertaken in 37 watersheds between 1995 and 1997. Typically, these hydrological and fish habitat assessments followed a standardized procedure, which included a review of existing information, field surveys, and the identification of the needs and opportunities for watershed restoration.

After evaluating the various instream restoration opportunities for the watershed, the higher priority restoration options were planned and designed following a routine survey and design procedure by a team that consisted of a fisheries biologist and river engineer or geomorphologist. Instream restoration projects were implemented in 1996 and/or 1997 in a total of 17 watersheds, including 13 mainstems and 18 tributaries. Various restoration techniques were applied in the watershed projects. Procedures describing these techniques can be found in the recent WRP Technical Circular No. 9 Fish Habitat Rehabilitation Procedures. *Examples of the application of these techniques were shown for the various project locations, including:*

- Keogh River, 5-Mile Creek (San Juan River) and Montague Creek (Eve River): using boulders and large woody debris (LWD) to rehabilitate juvenile salmonid habitat.
- Clemens Creek (Henderson): constructing off-channel habitat with a river intake for spawning and rearing.
- Malksope and Keogh rivers: constructing groundwater ponds or channels.
- Malksope River and Mercantile Creek: re-establishing historical drainage networks.
- Mahatta River: using LWD spurs to stabilize eroding streambanks.
- Lukwa Creek and Malksope River: restoring fish access using fishways.
- Kootowis and Lukwa creeks: removing high densities of logging slash to improve bed scour and reduce flooding of riparian vegetation.

A preliminary operational monitoring protocol has been developed by WRP. Its two parts are routine monitoring and project effectiveness monitoring. Routine monitoring is a low intensity and subjective field assessment of all restoration structures. Project effectiveness monitoring is conducted at a higher intensity on a subset of projects, and in order to quantify the biological and hydraulic performance of the restoration structure or technique. Routine monitoring in 7 out of 9 watersheds where work was undertaken in 1996 provided qualitative assessments on the biological and physical performance of the structures, and allowed for adjustments in the design of the 1997 restoration works prior to construction. Project effectiveness monitoring, which began on four of the projects in 1997, will provide the data to improve structure design and cost-effectiveness, and achieve biological, hydrological and hydraulic restoration objectives. ▲

Restoration Strategies for Aggraded River Reaches: Problem Identification and Preliminary Recommendations

Mike Miles
645 Island Road
Victoria, B.C., V8S 2T7
Tel: 250-0653 Fax: 250-595-7367

Alluvial stream channel morphology is a function of discharge, sediment supply, bed and bank material size, and riparian vegetation characteristics. Alluvial stream channels are in equilibrium with these properties and a change in one or more of these parameters will produce changes in channel morphology. Valleys with wide floodplains, in which sediment can be stored and channel banks can erode or prograde, best exhibit such changes.

Recent channel investigations using the Coastal Watershed Assessment Procedure have identified numerous channel reaches where the unvegetated channel width has dramatically increased, the riverbed has aggraded, and the channel has become increasingly laterally unstable. Review of air photos indicates that these changes are generally associated with riparian clearing and mass wasting into the stream channel. Other factors that may have contributed to these changes include post-1945 increases in annual precipitation totals, elevated equivalent clear-cut values, and recent sizable flood events.

Many Interior streams show similar morphologic changes. However, the principal cause is typically riparian agricultural clearing and grazing. Fire and mass wasting are locally important and the factors listed above may contribute.

The restoration of these aggraded river reaches is difficult, as the pattern of channel instability tends to move downstream both within an alluvial reach and from one alluvial reach to the next. Restoration activities must therefore be based on understanding the factor(s) that initiated the morphologic change and how the pattern of instability is being carried downstream.

Restoration must focus on treating the initial causes of the morphologic change. On the coast, this requires treating unstable slopes, deactivating problematic roads, and re-establishing disturbed riparian vegetation. Although the role of elevated equivalent clear-cut areas in enhancing flood peaks is debatable, reducing values to a sustainable value is probably justified. In the interior, the most important objective is generally to re-establish a riparian corridor through which the channel can freely migrate. This requires fencing to keep cattle out and the re-vegetation of the enclosed area. However, this is frequently difficult to implement when riparian areas are private property and the landowners are unwilling to give up the required riparian width. Air photo analysis indicates that a riparian fringe of half a channel width substantially reduces bank erosion. Research suggests that a riparian corridor should be approximately seven channel widths wide to provide a channel with room to develop an unconfined channel pattern.

This prescription will eventually result in a “restored” river channel and provide a diversity of fisheries habitat. A possible exception is that off-channel areas may require a riparian corridor of more than seven channel widths in which to reform. The rate of vegetation growth and the speed with which aggraded sediment can be removed from the system dictates the time scale for this to occur. Air photo studies indicate that substantial improvements can be seen for small streams (width< 10 m) in 20 to 30 years. On larger streams, little improvement can be seen over periods of 50 years, suggesting that recovery could easily take 100 to 200 years.

Expediting stream channel recovery should focus on stabilizing excessive amounts of stored sediment to prevent its movement downstream. Field trials are needed to determine the best methods of doing this. Observations indicate that large woody debris accumulations can stabilize higher elevation bars and allow primary colonizing plant species to become established. There are also a variety of bioengineering approaches that can be tried, such as using buried whips and wattles, possibly in conjunction with woody debris placement.

Another consideration is to allow the river to increase its channel length. This restores gradient and provides room to store the entrained sediment. This requires “re-naturalizing” channelized sections of river, removing unneeded rip rap, pulling out unused bridge abutments, etc. It also implies that further efforts to laterally constrain an aggraded section of river should be avoided if possible.

The task of re-establishing stream process is formidable, given the large areas which need to be treated. Such work requires competent technical expertise (including hydrology, fluvial geomorphology, civil engineering, and fisheries biology), landowner cooperation and political will. Without such effort, many restoration projects are doomed to failure and riparian property damage will increase as stored sediments move downstream into more populated areas. ▲

Feasibility Study for Watershed Restoration, Northwest Centre Creek, Chilliwack

Benko Boris[1] and Carolyn Lawby[1], David Sahlstrom[2]

[1] P. Machibroda Engineering Ltd.
44325 Yale Road East
Chilliwack, B.C/, V2P 6H7
Tel: 604-793-8401 Fax: 604-793-8402

[2]Terrasol Environmental Consulting
3-3357 Maclure Road
Abbotsford, B.C., V2S 4N3
Tel: 604-852-3782 Fax: 604-852-9376

A feasibility study for watershed restoration was undertaken in the northwest portion of the Centre Creek watershed, a sub-basin of the Chilliwack River Valley. The area drains into both Chilliwack River to the north and Centre Creek to the east. The area of investigation covered approximately 1200 ha with moderately steep to steep slopes and a local relief of 1400 m. Slopes typically consisted of moraine, colluvial and residual soils overlying bedrock and exposed bedrock. Numerous gullies dissected the slopes.

The logging in the area ranged from pre-1950 to approximately 1980. Numerous slope instability problems such as natural, road and/or harvest-related problems affected the area. The region has been subjected to various types of landslides and other slope-related hazards including channelized debris flows, debris avalanches, debris slides, dry ravel (a downslope movement of loose, cohesionless soil, debris and rock particles under the influence of gravity), rockslides, floods and snow avalanches. Road-related hazards included unstable, oversteepened cut and fill slopes, stump- and log-supported road sections and altered slope hydrology.

The main objectives of the study were to assess the nature, extent and severity of existing and potential slope-related hazards, to determine the risk to the environment and socio-economic values, to provide possible restoration strategies and associated costs, and to provide recommendations for the development of an integrated restoration plan. The aim was to reduce the possibility of future landslides, to revegetate and/or stabilize areas that have failed, or were likely to fail, to reduce erosion and sediment production from existing failures, and to accelerate the natural rehabilitation process.

The investigations revealed a total of 20.7 km of roads, 34 landslides at various stages of activity and 42 gullies. The highest environmental consequence was related to water quality and sediment transport since a spawning channel was recently constructed immediately downstream of the confluence of Centre Creek and Chilliwack River.

The benefits of the following three approaches to restoration were assessed in detail:

1. Complete restoration of the area, an approach that would include complete road deactivation, detailed assessments and rehabilitation of all landslides and gullies. Due to the extent of some of the failures, the roads would not only have to be re-opened for equipment access but, in some areas, the roads would have to be completely re-built to provide equipment access for the restoration works. The approach would also require the re-opening of road sections that had no apparent stability concerns.
2. Restoration of high priority areas, an approach that would concentrate on areas that present a very high risk to the environment and socio-economic values. The strategy would require either the re-opening and re-building of specific road sections, or flying in the necessary equipment and personnel to undertake works in areas with no road access.
3. No restoration, a third alternative that would involve only passive mitigation works such as the posting of warning signs.

Based on the assessment of the area, complete road deactivation was not recommended since it would require road reconstruction under difficult conditions in order to access areas requiring remediation. The construction works associated with road re-opening would unnecessarily increase slope erosion and disturb areas that were revegetating and stabilizing naturally. The “no restoration” option was not recommended due to the high probability of future slope-related hazards and ongoing erosion and sediment production from existing failures. Therefore, it was recommended that restoration of only the high priority areas be undertaken. This would involve a combination of handwork and machinery. ▲