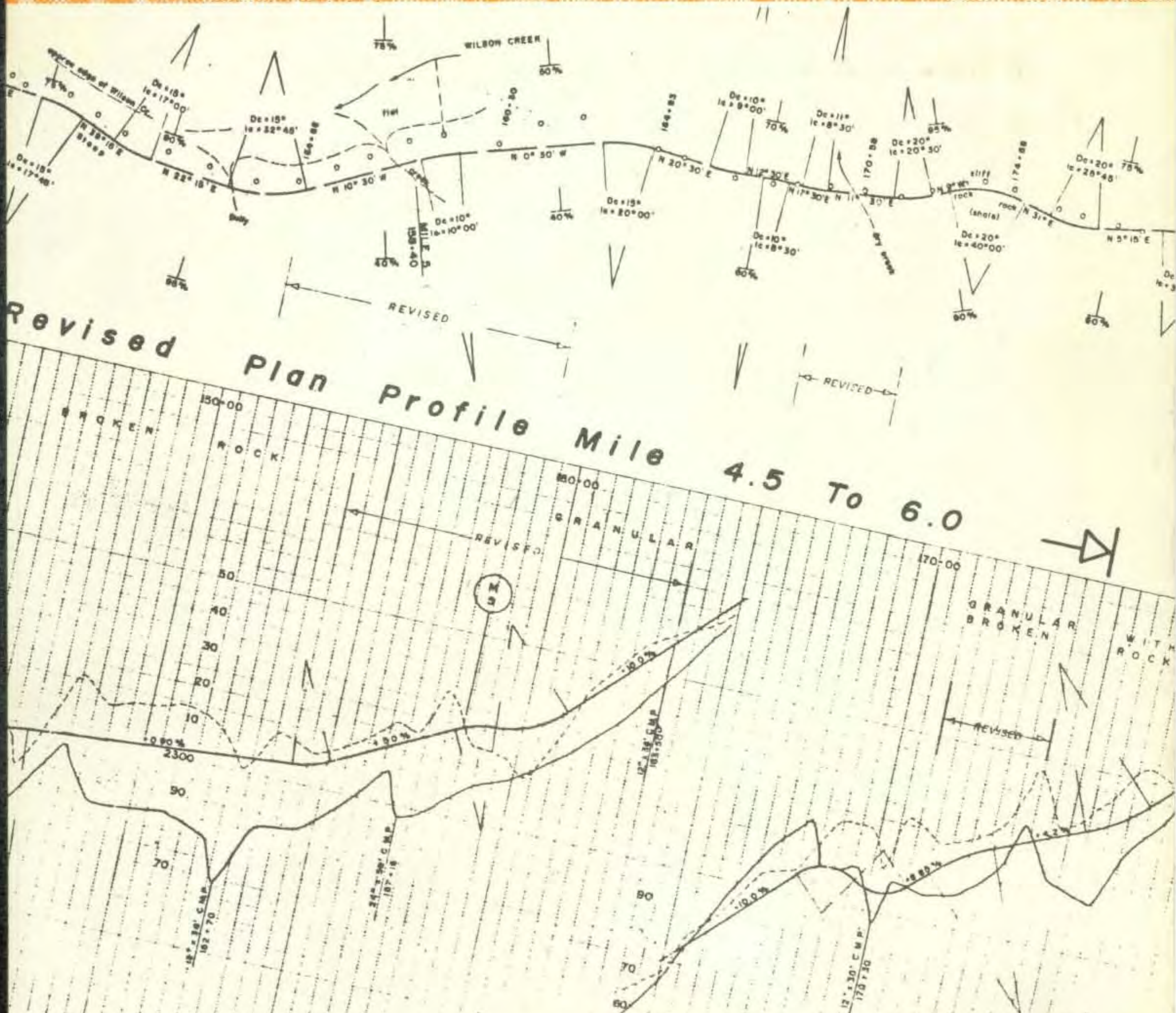
ENVIRONMENTAL COSTS IN LOGGING ROAD DESIGN AND CONSTRUCTION

J. OTTENS



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Environmental Costs in Logging Road Design and Construction

by

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Preface

Public and private timber harvesting policies and procedures are periodically revised to prevent deterioration of forest land values. Recently, stricter constraints have been imposed on logging road design and construction practices. It is possible to vary road design and construction practices to a large degree to achieve a desired standard of environmental protection. It is difficult to quantify the values which are being conserved, let alone the costs which are unknown until after the constraints have been applied or until the road has been built. This report uses a case study to examine the recording, magnitude and distribution among design and construction tasks of the costs incurred to comply with a set of environmental road-building constraints.

In cooperation with the B.C. Forest Service Engineering Division, a 5.8-mile section of the Wilson Creek Forest Road, which was being built in the Slocan Public Sustained Yield Unit, was chosen as a case study. This road was built by Triangle-Pacific Forest Products Ltd. during 1973 and 1974 with T.M. Thomson and Associates Ltd. in charge of surveying, designing and supervising construction. The Canadian Forestry Service also contracted T.M. Thomson and Associates Ltd. to help develop an environmental accounting system and to collect cost data for the road project. The consultant's submission forms the basis for this report. Members of the Pacific Forest Research Centre, Forestry and Environmental Services Group, provided a physical assessment of the site to determine, for the purposes of this study, the values being protected, potential problems, and whether further constraints could be meaningfully imposed on the project.

This report is intended to be helpful to public and private forest managers as a basis for collecting environmental costs data, both as a guide in future projects and to maintain cost control on current forest road projects.

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Abstract

The Wilson Creek Forest Road project in the Nelson Forest District was used from 1972 to 1974 as a case study to develop and verify a cost accounting system to determine the cost of imposing environmental and aesthetic constraints on logging road design and construction. The existing cost accounting system of the B.C. Forest Service Engineering Division was modified and expanded to compile the damage-prevention cost. Environmental protection accounted for 18.6% of the total construction cost.

Résumé

Entre 1972 et 1974, la construction d'un chemin forestier dans le bassin du ruisseau Wilson, situé dans le District forestier de Nelson, fut utilisée à titre d'exemple pour développer et vérifier une comptabilité par nature de frais. Le but de ce projet est de déterminer les frais d'imposer des restrictions reliées aux considérations du milieu et de l'esthétique sur le design et la construction des chemins forestiers. La comptabilité par nature de frais utilisée par la Division du génie du Service des forêts de la Colombie-Britannique fut modifiée et développée pour compiler les frais de prévention des dommages. La protection de l'environnement compta pour 18,6% des frais globaux de construction.

INTRODUCTION

In British Columbia, the B.C. Forest Service is imposing stricter regulations on logging operations in the coastal (B.C. Forest Service, 1972) and, more recently, in the interior forest regions (B.C. Forest Service, 1973) in response to public demand for the maintenance of their forests to acceptable aesthetic and environmental standards.

The increase in logging costs resulting from environmental constraints does not accrue to industry alone, but to British Columbia taxpayers and to forest products consumers. Therefore, it should be of interest to know the resulting cost from these constraints, which phases of the operation are most costly to modify, and how the cost increases can be established.

It has been estimated that the coastal forest logging guidelines result in about a 16% increase in logging costs, most of which is reflected in higher road costs (Council of Forest Industries of B.C., 1972). Forest road construction and maintenance, and log hauling generally account for the largest proportion of stream sedimentation resulting from timber harvesting activity (Anderson, 1971). The scope of this study was confined to an examination of the cost of imposing environmental and aesthetic constraints on the design and construction of a 5.8-mile section of the Wilson Creek Forest Road in the Nelson Forest District (Figure 1).

The conceptualization of waste-disposal costs (Dales, 1968; U.S. Environmental Protection Agency, 1972; U.S. Council on Environmental Quality, 1972; Environment Canada, 1974) can serve as a guide to understanding the types of costs involved in the amelioration of impacts of timber harvesting on the forest environment. The total cost to society of imposing a certain standard of environmental quality is the sum of: the cost of preventing damage, the cost of rehabilitating the previously damaged environment, and the damage suffered despite prevention and rehabilitation measures. The distribution of the total cost between groups causing and suffering damage is usually referred to as private and public, or social, costs. An economically optimum standard is one in which the cost to society is minimized. In the case of the Wilson Creek Forest Road project, the B.C. Forest Service set certain standards to maintain aesthetic and sports fishing values. These standards had to be met by preventing damage to the environment surrounding the road through preventive design and construction practices rather than by repairing damage resulting from the project.

The object of this report is to establish an accounting system to estimate the damage-prevention cost, and its distribution among construction tasks, incurred by the adoption of constraints imposed on the Wilson Creek Forest Road project.

Although it might have been preferable to have studied an entire road system, it was possible only to study a 5.8-mile section of new main haul road. However, this approach facilitated the collection of actual costs for an ongoing road project. In addition, available time and resources allowed for a sufficiently detailed study to isolate the relative importance of the effects of stricter environmental and aesthetic constraints on the

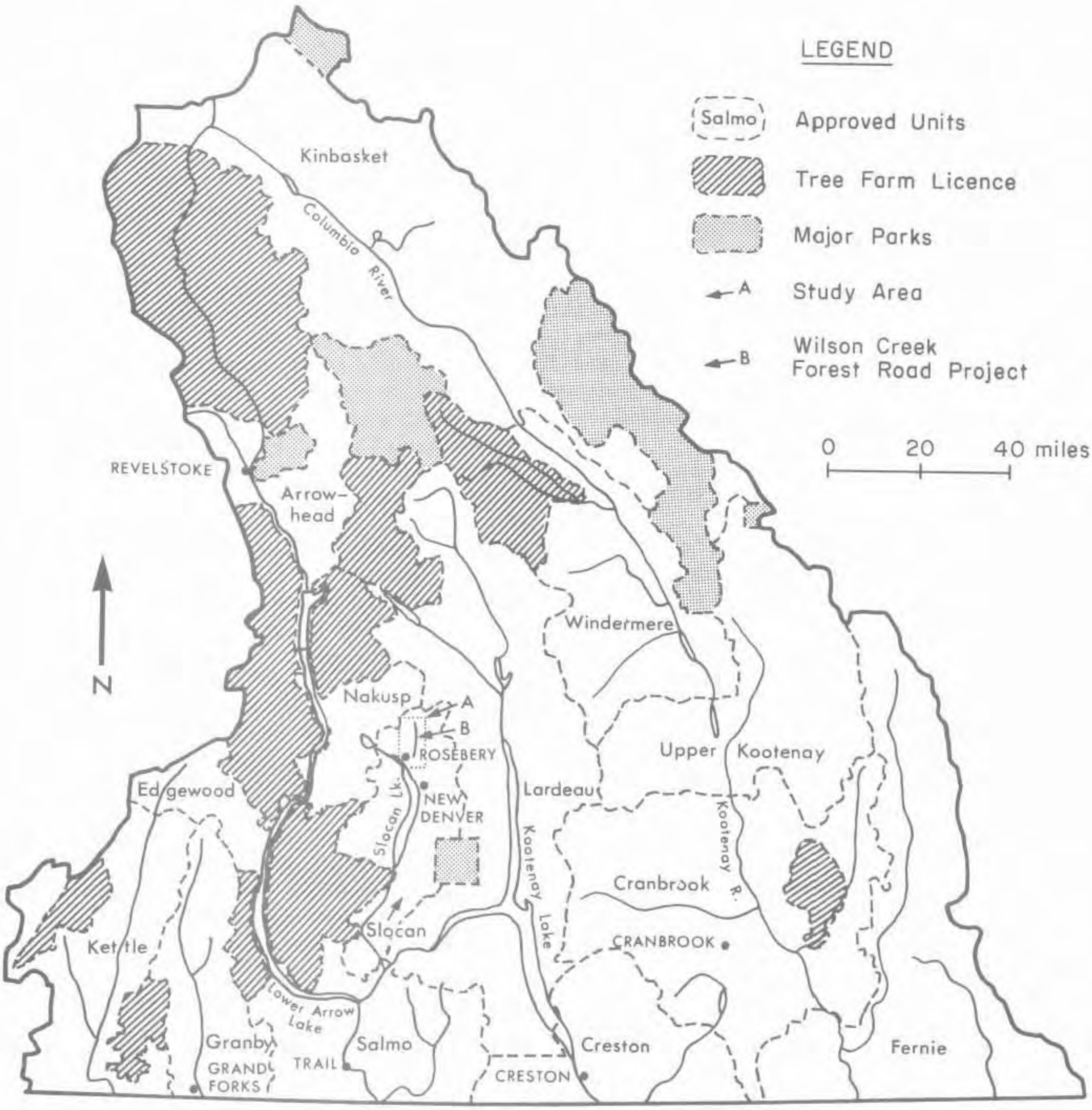

Figure 1 The Wilson Creek Forest Road in relation to the Nelson Forest District.

costs of individual logging road design and construction tasks. It would be more appropriate to study an entire road system if the effects of additional constraints on logging systems, such as tractor skidding as opposed to cable yarding, were being examined.

The Wilson Creek Forest Road Project

Route Selection

The new section of the Wilson Creek Forest Road was built primarily to improve the main haul road from a Timber Sale Harvesting Licence (TSHL) located in the Wilson Creek, Bremnar Creek and Kuskanax Creek drainages to a log sort and dump yard on Slocan Lake near Rosebery (Figure 1). The TSHL, which is held by Triangle Pacific Forest Products Ltd., has an allowable annual cut of 4,000,000 cubic feet. Upgrading the main road to B.C. Forest Service Road Class 4[1/] in most places permitted the average hauling speed to be increased from 15 to 30 miles per hour. For several reasons, a new section of road was built along the east side of the creek instead of reconstructing the existing road along the west side. To upgrade the existing road would have required virtually building a new road parallel to the old one. Relocating the road to the east side of the valley shortened the haul distance by 0.9 mile, virtually provided off-highway access directly to the log dump and required replacement of one instead of two bridges. These considerations prompted the B.C. Forest Service and the company to favor the relocation.

The proposal to relocate the road, submitted in September 1972, met with significant opposition from residents of the Slocan Valley, who felt that further road construction was unnecessary in the Wilson Creek valley, and that the resulting sedimentation of the creek would spoil the sports fishery. As a result, the feasibility of yet another route, which was 400 feet in elevation above the proposed route and thus farther from the creek, was investigated. However, this alternative route had a long section of adverse grade[2/] and was more winding and, therefore, slower and less safer than the initially proposed route, although the construction costs would have been similar. Furthermore, since the alternative route was higher on the slope and intercepted more tributary streams and gulls than the initial route, more washouts and thus a higher risk of sedimentation might have resulted from its construction.

After reviewing the three possible routes and keeping in mind the need to maintain environmental quality of the valley, the B.C. Forest Service issued a construction permit in September 1973, to relocate the road along the east bank of Wilson Creek at the lower elevation. The conditions of this permit differed markedly from those of previously issued permits. Prior to 1973, permits stated only the engineering specifications to which the road had to be built and required prelogging of the right-of-way, disposal of all slash within the right-of-way by burning or burying, and excavation of reasonably stable cutbanks. Since the construction practices actually followed were not specified and the degree of supervision of projects was often inadequate the resulting roads and their environmental and aesthetic consequences often left much to be desired (Adamovich, 1971).

1/ B.C. Forest Service Road Class 4 requires a roadway 20-feet wide, ditches 1½-feet deep, and a right-of-way clearing 60-feet wide.

2/ A road grade on which loaded trucks must haul uphill is referred to as an adverse grade.

Environmental and Aesthetic Constraints

In contrast to previous permits, the permit for the Wilson Creek Forest Road stipulated how the engineering specifications were to be achieved. These special conditions are summarized below.

1) Cut and fill slopes were to be cleared of debris and left in a smooth condition to facilitate seeding with grass.

2) Prior to right-of-way clearing of designated critical sections of the road (miles 4 to 6) and subgrade construction on all parts of the road, detailed engineering road plans and profiles with mass diagrams, quantity estimates and schedules of material movements were required. These plans were to be adhered to, once approved.

3) A professional engineer was required to be in charge of the construction and act as the company's agent in dealing with the B.C. Forest Service. In addition, a survey crew was required to provide survey control; i.e., grade staking and alignment surveys, in addition to center-line and right-of-way marking.

4) If construction debris did enter the creek, all work was to stop on the road until the debris was cleared from the creek and until steps were taken to ensure no recurrence.

5) Work could be stopped at any time if the B.C. Forest Service or Fish and Wildlife Branch representatives felt that further construction would result in increased sedimentation of the creek or other environmental damage. The B.C. Forest Service assigned one of its forest engineers to the site on a full-time basis. He had authority to enforce the conditions of the permit, as well as to order alterations to the construction plan and additional works if deemed necessary for environmental protection.

Soils and Landforms

The soils and terrain over most of the route (Wittneben, 1973) were conducive to good road building and posed few drainage, slope stability or erosion problems. In general, soil materials were either well-drained deep colluvial or glacio-fluvial, or fairly shallow soils. The shallow soils contained a large proportion of fragmented and unweathered rock. The underlying bedrock consisted of shale and shale-like material in various states of weathering. Excavated material contained only a small proportion of fines which might contribute to stream sedimentation.

Kame terraces were common along the route (Figures 2a, 2b). These terraces formed benches on which much of the road was built, and barriers to prevent sidecast materials from entering the creek. However, problems with slope stability were encountered in sections of the road between miles 4 and 6. The slopes were over 75% and often unbroken to the creek. The end-hauling operation required in this section will be discussed separately in this report.

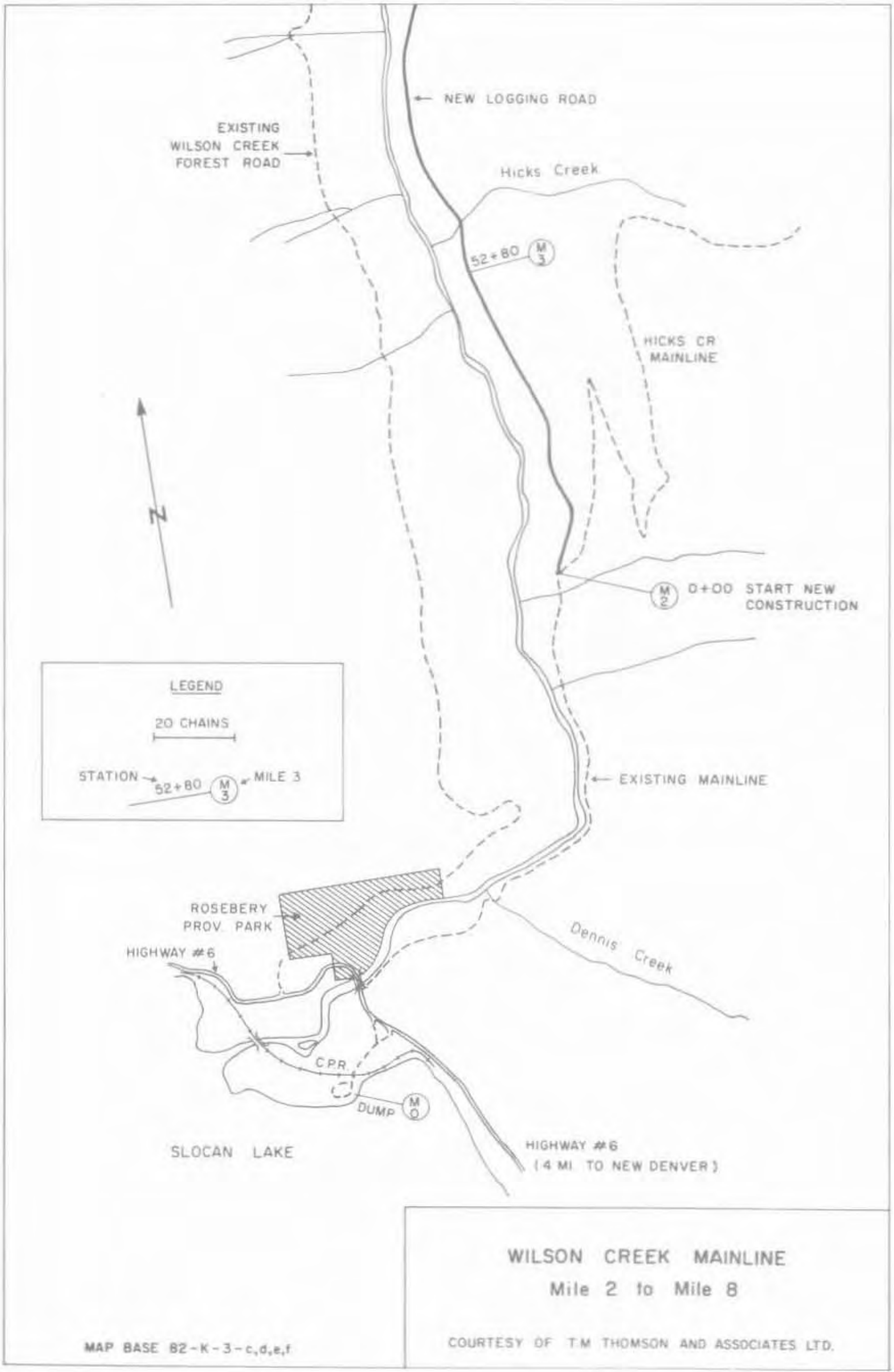

Figure 2a The Wilson Creek Forest Road project, southern half.

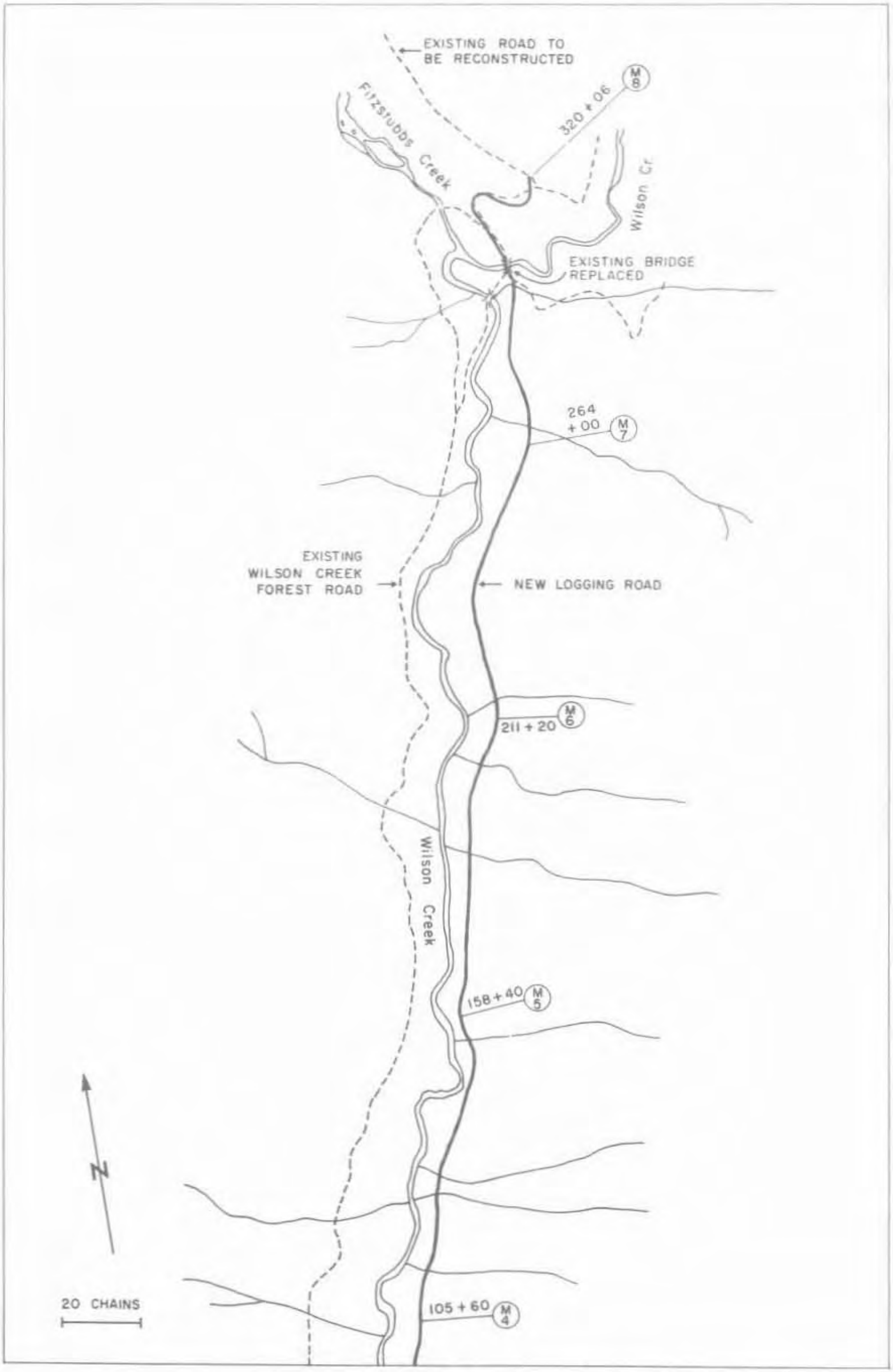

Figure 2b The Wilson Creek Forest Road project, northern half.

The road intercepted two larger streams and a few smaller streams. The log stringer bridge across Wilson Creek near mile 7½ was replaced with a 100-foot-long "glu-lum" bridge (Figure 3). Hicks Creek was crossed, using a 96-inch-diameter steel culvert. The installation of this culvert will be discussed separately in this report. Although seepage water occurred throughout the route, it was most prominent at the northern end of the road project, as well as at calcareous tufa deposits near mile 5. Water from seepage and minor streams was contained by adequate ditches and culverts. There was little danger of erosion of ditches since they were constructed in either stable soils or bedrock. Furthermore, erosion and cut bank stability were not serious problems in the northern end of the road despite the prominence of seepages because the terrain was not steep.

Figure 3 A Glu-Lam bridge replaced the old log stringer bridge across Wilson Creek near Mile 7½.

Design and Construction Problems.

Hicks Creek, a steep tributary of Wilson Creek, flows in a deep gully and has an average gradient of 15 to 20%. The north wall of the gully is composed of gravelly to stoney glacio-fluvial outwash and kame deposits. The south wall is composed of fractured shale-like bedrock. A 96-inch, instead of an 84-inch-diameter, steel culvert was used to provide a greater margin of safety against a washout. The 84-inch-diameter culvert should be able to withstand a 25-year flood and the 96-inch-diameter culvert, a 50-year flood[3]. In addition, measures were taken to prevent the culvert from shifting or washing out. Before the culvert was installed, the level of the creek bed was raised with a rock fill to prevent excessive ponding at the culvert intake. Also, the channel of the creek above the intake was straightened with dikes. The fill and diking material contained only a small proportion of fines so that relatively little sediment entered Wilson Creek.

3/ Logging guidelines in British Columbia require that culverts be designed to handle the 25-year storm (Hetherington, 1974).

The outflow was intercepted by a rocky embankment (Figure 4).

Figure 4 Outlet of the culvert at Hicks Creek.

For several reasons, the culvert was used instead of a bridge to cross Hicks Creek. Firstly, Hicks Creek does not support fish and interruption of its stream bed and flow caused by the culvert is not an important consideration.

Secondly, a bridge would have been more than twice as costly as the culvert crossing. To maintain the same alignment as achieved with the culvert, the bridge would have to be at least 80 feet long and supported by 30-foot trestles. A structure of this type would cost about $55,000 compared to $22,000 for the culvert crossing.

The section of road between miles 4 and 6 contains the most difficult construction conditions of the project, other than, perhaps, the Hicks Creek crossing. This section not only required much costly excavation through rock, but also special design and construction practices in three segments to prevent excavated material from entering Wilson Creek. The road standard through this section was reduced from B.C. Forest Service Road Class 4 to 5[4/] in order to lessen the volume of earth moved. These critical segments occurred between stations 145 and 150, 167 and 175, and 179 and 181[5/].

Between stations 167 and 175, the road passes within about 200 feet from Wilson Creek and was built by excavating through a rock outcrop on a side slope of about 80%. To prevent this material from entering the creek,

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4/ B.C. Forest Service Road Class 5 requires a roadway 16-feet wide, ditches 1-foot deep, and a right-of-way clearing 50-feet wide.

5/ A station is a 100-foot segment along the center-line of a road traverse.

the B.C. Forest Service required that it be end-hauled instead of sidecast. The road between stations 161 and 167 was designed to provide a place to deposit the end-hauled material as economically as possible and to prevent excessive spoilage of material. Had side-casting been permitted between stations 167 and 175, this portion of the road could have been built less expensively by raising the elevation of the center-line between stations 145 and 167 so that a relatively large fill would not have been necessary.

End-hauling is often conducted with shovels or front-end loaders simultaneously excavating and loading cut material into trucks which haul the material to a fill or spoil area. This method is very expensive and is usually used in extremely sensitive areas if the fill or spoil area is relatively far away, or if a large volume of soil must be moved. Otherwise, end-hauling can be achieved at a more reasonable cost with bulldozers, as was done on the Wilson Creek Forest Road project. This technique is commonly used to secure a fill embankment on a steep slope.

On this project, special care was taken to minimize spilling soil down the slope. Firstly, a narrow pioneer road or terrace was built below the center-line of the road. Ideally, a small crawler front-end loader should have been used if spillage down the bank was to be minimized; however, this would have been slow and expensive. On this project, excessive rock prevented the use of a D-6 sized bulldozer to build a terrace. A D-8 sized bulldozer was used, taking care not to make the terrace any wider than necessary for the machine to work safely on the sideslope. Secondly, this bulldozer was used to build a dike onto the terrace to form a trough through which cut material could be pushed along the center-line with a D-9 sized bulldozer equipped with a U-blade without spilling soil over the bank. Excavated material was transported to the fill areas with a rubber-tired front-end loader and a D-9 sized bulldozer. The remaining dike was then removed with the front-end loader and the subgrade finished.

Between stations 145 and 150, and 179 and 181, similar care was taken to prevent spilling soil into the creek. Ledges below these road sections were wide enough to intercept a significant amount of sidecast material. Soil was prevented from entering the creek by bulldozing some of the excavated material to either end of the road sections rather than sidecasting. In this way, the more expensive alternative of having to design large fills was avoided.

Two other problems, perhaps less serious, occurred in the section of road between miles 4 and 6. Firstly, there was insufficient fine fill in this rocky road section to bury right-of-way debris (Figure 5). Where this problem occurred, debris was pushed to the edge of right-of-way clearing. Not only was it too costly to obtain additional suitable fill to cover the debris, but to do so would have greatly widened the road surface so that the edge of the road would have been right up against the edge of the right-of-way clearing. If additional fill had been obtained by increasing the excavation into the sidehill, not only would the road have been widened on both sides, but more debris would have been created by the additionally necessary right-of-way clearing. Therefore, only debris left after the removal of right-of-way log decks was required to be piled and burned. The rest of the debris was left to be overtopped in a few years by roadside brush.

Figure 5 Insufficient fine soil to bury right-of-way debris.

Secondly, the B.C. Forest Service required that rock projections in cutbanks, left after initial excavation in six spots, had to be trimmed. This extra rock excavation was required for aesthetic purposes and was beyond that necessary to provide safe sight distance and adequate road width.

An Environmental Cost Accounting System

To develop a suitable cost accounting system to estimate the damage-prevention cost, it was necessary to: (1) formulate criteria for separating prevention costs from total construction costs, and (2) determine the nature of the cost items which were to be measured. The cost of all works and measures carried out on the project which were not standard in logging road design and construction in the Nelson Forest District prior to October 1973, or specifically ordered by the B.C. Forest Service representative to maintain or enhance environmental or aesthetic values, were included in the damage-prevention cost. It was possible to estimate the costs of adopting deviations from previously routine practice by modifying and expanding the cost accounting system used by the B.C. Forest Service Engineering Division (Appendix I) and by drawing on available appraisal experience and records.

Not all of the damage-prevention costs could be compiled directly from time sheets and invoices. In some cases, only portions of expenditures for certain tasks and materials were part of the prevention costs. In other instances, prevention costs were the difference between actual expenditures incurred and estimated expenditures required to pursue an alternative practice. The B.C. Forest Service accounting system was modified and expanded to yield codes which were as detailed as necessary to identify the additional expenditures resulting from the environmental constraints without being impractical for a road foreman to regularly code and record expenditures from time sheets and invoices. On the Wilson Creek Forest Road project, the resident engineer initially kept cost records by means of detailed diary entries. After the first month of the project, a tabular record system was adopted. Daily expenditures were recorded by cost codes and stations on separate pages for each machine-labor unit and typesof materials used.

The total design and construction cost of the 5.8-mile road project, excluding the bridge across Wilson Creek, was $68,159 per mile (Appendix II). The damage-prevention cost totalled $12,686 per mile or 18.6% of the total road cost (Table 1). The distribution of the damage-prevention cost between design and construction categories is shown in Figure 6.

Expenditures were classified by B.C. Forest Service Engineering Division categories and assigned numerical codes. The level of aggregation of expenditures is indicated by the number of non-zero digits in each expenditure code. Highly aggregated categories of expenditures are assigned codes having one or two digits. These first- and second-order categories contain more detailed or higher-order categories which are assigned codes having more than two digits. For example, first-order categories include "Construction" (Code 100), "Mobilization and Demobilization" (Code 200), "Freight and Haulage" (Code 300), "Overhead" (Code 400), "Camp Expenses" (Code 500) and "Incidentals" (Code 600). "Site Preparation" (Code 110) and "Excavation" (Code 120) are two of the second-order categories under "Construction". This coding system allows expenditures to be summarized at any level of aggregation. Furthermore, the system can easily be expanded to include additional detail by either expanding existing codes to higher-order classifications or inserting new codes of the same order of detail as existing codes.

The procedure for expanding the accounting system to include damage-prevention costs depends on the type of deviation from previous practice, as well as on the existing codes. For the purposes of environmental cost accounting, the Forest Service constraints resulted in three, although not perfectly distinct, types of deviations from previous practice on logging road projects:

(1) the design of some sections of the road was altered,
(2) the effort expended on certain tasks was increased, and
(3) some additional tasks were performed.

Two previous logging road design practices were modified. A 96-inch, instead of a 84-inch-diameter culvert was installed at Hicks Creek. A fill was engineered and constructed to permit end-hauling. Compilation of the costs of these modifications required detailed cost estimates of the best alternative design which might previously have been adopted. The extra cost of installing a larger culvert than normal was accounted for by the cost difference between the two sizes of culvert pipes and fittings. This cost was recorded by expanding "Culverts Larger Than 60 inches" (Code 181) to "Calculated Culvert Design" (Code 181.1) and "Environmental Margin in Culvert Design" (Code 181.2). The extra cost of end-hauling was accounted for by use of a front-end loader to transport cut material to the fill and by the extra design work required of the survey crew. Expenditures for the front-end loader were recorded under "End-Haul" (Code 127), a new category inserted under "Excavation" (Code 120). Expenditures for the survey crew employed between stations 161 and 175 were recorded under "Design" (Code 434),

Table 1. Summary of the Damage-Prevention Costs for the Wilson Creek Forest Road[1]

Code	Description	Damage-Prevention Cost per Mile	Percentage of Damage-Prevention Cost of Total Road Cost
119	R/W Clean Up	$ 856	1.3
124	Trim Cutbanks	440	0.6
127	End-Haul	1596	2.3
181.2	Environmental Margin in Culvert Design	176	0.3
411.12	Environmental Supervision	3341	4.9
411.22	Environmental Liaison	748	1.1
431.2	Alternative Route(s)	1167	1.7
434	Design	337	0.5
435	Grade Staking and Construction Control	2307	3.4
452	Expenses, Transportation, Supplies for Environmental Duties	1718	2.5
Totals		$12686	18.6

Note:

1. See Appendix II

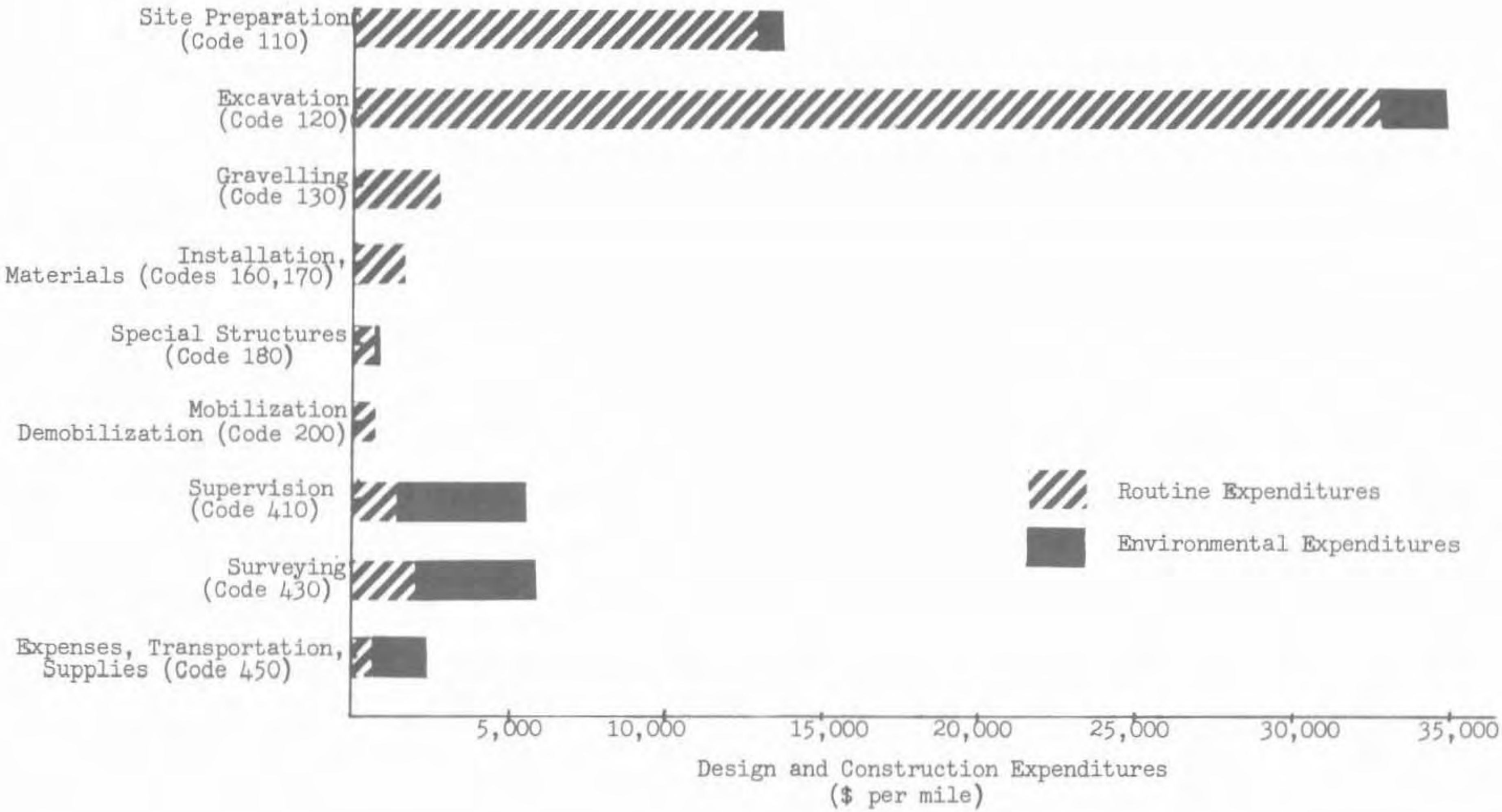

Figure 6. Summary of Routine and Environmental Expenditures for the Wilson Creek Forest Road (See Appendix II)

a new category inserted under "Surveying" (Code 430).

The Wilson Creek Forest Road project was more heavily supervised than previously. The project was supervised by a resident consultant engineer, a B.C. Forest Service engineer and, intermittently, by personnel from other government agencies. It was not possible to compile costs incurred by government agencies for research, development, planning, monitoring and enforcement needed to achieve desired environmental standards. This portion of the damage-prevention cost is termed as a "transaction cost" by the U.S. Council on Environmental Quality (1973).

The duties of the resident engineer were to supervise construction and to provide liaison between the forest company and the B.C. Forest Service, and other interested government agencies. The resident engineer's fees were recorded separately for these two duties, but not by "routine" and "environmental" categories. Therefore it was necessary to judge what portion of the total supervision and liaison expenditures might have been adequate under previous construction permits. No more than 25% of these expenditures were considered to be necessary if the constraints had not been imposed. The third-order category "Engineer" (Code 411) was first expanded to "Construction Supervision" (Code 411.1) and "Meetings, Liaison" (Code 411.2). These were further expanded to fifth-order categories to record "Routine" and "Environmental" supervision and liaison expenditures.

Additional effort was also expended by the survey crew in "Route Surveys and Plans" (Code 431) to investigate and report the feasibility of alternative routes. Therefore, Code 431 was expanded to "Initial Route(s)" (Code 431.1) and "Alternative Routes" (Code 431.2).

Two construction and one surveying tasks were not previously common practice on logging road projects. The costs for these were compiled directly from expenditure records. Since these are not part of other third-order tasks, they were assigned new third-order codes. Cleaning debris from the right-of-way after initial grubbing and subgrade construction was designated by "R/W Clean Up" (Code 119) under "Site Preparation" (Code 110). Shaping cutbanks after initial excavation to prevent overhangs and to improve alignment was designated by "Trim Cutbanks" (Code 124) under "Excavation" (Code 120). Grade staking and construction control surveying was designated by "Grade Staking and Construction Control" (Code 435) under "Survey" (Code 430).

Expenses for room and board, transportation and supplies incurred by the resident engineer and the survey crew, were not recorded by separate duties after September 1973. After that date, these expenses were recorded by "Expenses, Transportation, Supplies" (Code 450). Code 450 was expanded to "Expenses, Transportation, Supplies for Routine Duties" (Code 451) and "Expenses, Transportation, Supplies for Environmental Duties" (Code 452). The "routine" and "environmental" portions of these expenses were derived by apportioning total expenses (Code 450) to "Supervision" (Code 411) and "Surveying" (Code 430) expenditures which were incurred during September 1973 to August 1974. A rate of $0.26 expenses (Code 452) for each $1.00 of "Supervision" and "Surveying" was adopted.

CONCLUSIONS AND RECOMMENDATIONS

The damage-prevention cost incurred as a result of imposing environmental and aesthetic constraints on logging road design and construction can be compiled by using a modified and expanded form of the B.C. Forest Service Engineering Division cost accounting system and by drawing on local cost appraisal experience and records.

Many portions of the damage-prevention cost can be compiled directly from expenditures recorded by codes and stations from time slips and invoices. To this end, it is necessary to stipulate which tasks and materials are not normally required, and to assign appropriate codes to these. Entirely new code numbers can be added to the accounting system, or existing designations can be expanded to correspond to the extra phases of a particular task. By using this approach, there is no need to make judgments about what percentage or amount of the actual expenditure is in excess of "normal" costs incurred. Furthermore, current recording of expenditures normally incurred as well as those incurred due to constraints are useful to provide cost control information.

It may not be possible to expand existing cost codes in this manner for certain tasks which are affected by environmental constraints. In such cases, the only recourse is to make an estimate of the damage-prevention cost portion of actual expenditures for such tasks based on local cost appraisal experience and records. If estimates of the costs of such tasks without constraints can be made near the start of the project or affected road sections, these estimates can be treated as allowances for normal practice. Expenditures in excess of these allowances could be recorded separately. In this way, it is possible to maintain more complete current cost control information. The allowances can be adjusted as better information becomes available.

The cost codes should be as detailed as is necessary to identify the additional expenditures resulting from constraints and still be practical for the road foreman to code and record, quickly and regularly, expenditures from time sheets and invoices. The coding and recording procedures adopted depend on the circumstances peculiar to each project.

Information generated by this type of accounting system can be useful to guide design and construction of logging roads under environmental constraints before, during and after the project.

The Wilson Creek Forest Road project was unique in several respects. (1) The project was one of the first in the Nelson Forest District to be conducted under very strict environmental and aesthetic constraints. (2) Design and construction conditions were unique, as they are in most logging road projects. The amount of the damage-prevention cost and its distribution among tasks will undoubtedly differ for other road projects. However, aside from demonstrating that most of the damage-prevention cost can be estimated by means of a cost-accounting system, this case study also provides information which may be helpful in planning future road projects.

Seventy-five percent of the damage-protection cost was accounted for by the requirements for a resident engineer and for detailed design and surveying. There were several reasons for this. One is that the soils and terrain along the route were conducive to sound road construction with relatively little potential for environmental damage; therefore, only a few changes from normal construction practice had to be adopted. Another reason was that construction progressed quite slowly because excessive bedrock had to be excavated. Construction progress was also slowed by delays in starting work in 1973. Right-of-way clearing, grubbing and excavation which was allowed to commence in October 1973 was forced to stop by snow in December. As a result, insufficient right-of-way had been cleared to permit efficient scheduling of work for roadbuilding equipment when construction commenced in the spring of 1974. Because of the slow progress, the resident engineer was required for an extended time. It may have been possible to realize a cost saving in supervision if a grade foreman had been placed in charge of the project on a full-time basis. The engineer could then have been better employed in overseeing several projects and in personally supervising construction through critical sections of road and special structures.

Most of the surveying component of the damage-prevention cost was for grade staking and construction control surveys. This portion of the cost could have been reduced if grade staking and control surveys had been confined to critical road sections and to sections requiring large rock cuts.

In future logging road projects, it is unlikely that the proportion of the damage-prevention cost accounted for by supervision and surveying will be as high as in this case study. The Wilson Creek Forest Road project was one of the first in which strict environmental and aesthetic constraints were imposed. Experience gained through practice and cost records will aid in determining an efficient means of achieving desired environmental and aesthetic standards in logging road design and construction.

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Appendix I

Environmental Cost Accounting System
Adapted from the B.C. Forest Service Engineering Division Cost Accounting System

Code	Description
100	Construction
110	Site Preparation
111	Falling and bucking of non-merchantable material
112	Falling and bucking of merchantable material
113	Piling and burning by hand
114	Piling and burning by machine
115	Machine clearing of non-merchantable material
116	Grubbing (Removing the vegetation and organic layers to expose the mineral soil for subgrade construction)
117	Terracing (In silt and clay soils a terrace is constructed with in-place soil on which more suitable fill material can be deposited. Terracing provides a more stable surface to secure the fill than if the fill is placed on a sloping surface of silt or clay.)
118	Tote road construction (Tote roads are rudimentary roads built to permit initial access for construction equipment used to build the final subgrade.)
119*	Right-of-way (R/W) cleanup after initial subgrade construction
120	Excavation
121	Solid rock (Blasting and bulldozing solid rock)
122	Other material (Bulldozing loose soil)
123	Stripping unsuitable material (In shallow swamps, the swampy material is often removed to obtain a firmer base on which to place a fill.)
124*	Excavation to improve stability of cutbanks (conducted after initial subgrade construction)
126	Overhaul on excavation (Transporting excavated material, usually with trucks and scrapers, over the excavation to fill or spoil areas.)
127*	End-haul of excavation for environmental protection (Excavated material is transported from either end of the excavation but not over the excavation as in Code 126)
130	Gravelling
131	Loading, including breaking up or loosing material

Appendix I (Cont'd)

Code	Description
132	Preparation and stock pile specified material such as crushed rock
133	Hauling gravel or surfacing material
134	Spreading, grading gravel or surfacing material
140	Compaction
141	Compaction of subgrade material
142	Compaction of surfacing material
150	Watering
151	Watering subgrade material
152	Watering surface material
160	Installation
161	Installation of culverts of 60 inches and smaller in diameter (Culverts larger than 60 inches in diameter or designated as "Special Structures", Code 180).
162	Headwalls and other protective measures including flumes rip-rap for drainage installations.
163	Fences, gates
164	Cattle guards
165	Corduroy for special cases not covered in "Site Preparation", Code 110.
170	Materials
171	Culvert material
180	Special structures
181	Culverts larger than 60 inches in diameter and pipe arches
181.1	Calculated culvert design (Culvert size designed to be adequate under normal construction standards)
181.2*	Environmental margin in culvert design (Additional costs incurred as the result of increasing the culvert size as designed under normal construction conditions for environmental reasons)
182	Temporary bridges (expected to last 10 years or less), log stringer bridges
183	Permanent bridges (expected to last more than 10 years), "glu-lam" and sawn timber bridges.
200	Mobilization and demobilization
210	Moving camp and equipment

Appendix I (Cont'd)

Code	Description
220	Setting up camp
230	Dismantling camp
300	Freight and haulage
310	Freight and haulage of culvert and bridge material
320	Transport of crew from camp to work site
330	Freight and haulage of camp and cookhouse supplies
400	Overhead
410	Supervision
411	Engineer
411.1	Construction Supervision
411.11	Routine supervision (Portion of "Construction Supervision" required under normal construction conditions)
411.12*	Environmental supervision (Portion of "Construction Supervision" required to fulfill construction permit conditions for environmental protection)
411.2	Meetings and liaison
411.21	Routine liaison (See Code 411.11)
411.22*	Environmental Liaison (See Code 411.12)
412	Grade foreman
420	Office and first aid
430	Surveying
431	Route surveys and plans
431.1	Initial route(s)
431.2*	Alternative route(s) (Surveys and plans to investigate alternative routes when environmental conflicts are encountered with initially proposed routes)
432	Access survey (Surveys to provide control for acquisition of right-of-way through private lots)
433	Right-of-way marking
434*	Design
435*	Grade staking and construction control
440	Others (eg. sick leave, holiday pay)

Appendix I (Cont'd)

Code	Description
450	Expenses, transportation, supplies (For engineering, supervision and surveying staff)
451	Expenses, transportation, supplies for routine duties
452*	Expenses, transportation, supplies for environmental duties
500	Camp expenses
510	Camp, rentals, maintenance
520	Cookhouse
600	Incidentals (Items not covered by any other designation)

* Environmental (damage-prevention) cost codes are denoted by asterisks.

Appendix II

Design and Construction Expenditures for the Wilson Creek Forest Road by Cost Accounting Codes Incurred During 1972-1974[1/]

Code	Description	Routine Expenditures	Environmental Expenditures	Total Expenditures
100	Construction	$298,163	$17,791	$315,954
110	Site Preparation	75,146	4,965	80,111
111,114 115	R/W Clearing[2]	18,333		18,333
112	R/W Logging[3]	25,777		25,777
116	Grubbing	18,385		18,385
118	Tote Road	12,654		12,654
119	R/W Clean Up		4,965	4,965
120	Excavation	190,614	11,806	202,420
121	Solid Rock	150,965		150,965
122	Other Material	39,649		39,649
124	Trim Cutbanks		2,550	2,550
127	End-Haul		9,256	9,256
130	Gravelling	16,043		16,043
160,170	Installation, Materials[3]	9,289		9,289
180	Special Structures	3,513	1,020	4,533
181	Culverts >60"[5]	3,513	1,020	4,533
181.1	Calculated Culvert Design[5]	3,513		3,513
181.2	Environmental Margin in Culvert Design[4]		1,020	1,020

Appendix II (Cont'd)

Code	Description	Routine Expenditures	Environmental Expenditures	Total Expenditures
200	Mobilization and Demobilization	3,558		3,558
210	Moving Camp and Equipment[6]	3,558		3,558
400	Overhead	23,577	55,789	79,366
410	Supervision[7]	7,907	23,718	31,625
411	Engineer	7,907	23,718	31,625
411.1	Construction Supervision	6,461	19,382	25,843
411.11	Routine Supervision	6,461		6,461
411.12	Environmental Supervision		19,383	19,383
411.2	Meetings, Liaison	1,446	4,336	5,782
411.21	Routine Liaison	1,446		1,446
411.22	Environmental Liaison		4,336	4,336
430	Surveying	12,090	22,106	34,196
431	Route Surveys and Plans	6,000	6,771	12,771
431.1	Initial Route(s)	6,000		6,000
431.2	Alternative Route(s)		6,771	6,771
432	Access Survey	2,518		2,518
433	R/W Marking	3,572		3,572
434	Design		1,954	1,954

Appendix II (Cont'd)

Code	Description	Routine Expenditures	Environmental Expenditures	Total Expenditures
435	Grade Staking and Construction Control		13,381	13,381
450	Expenses, Transportation, Supplies[8]	3,580	9,965	13,545
451	Expenses, Transportation, Supplies for Operational Duties	3,580		3,580
452	Expenses, Transportation, Supplies for Environmental Duties		9,965	9,965
Total Expenditures Excluding Wilson Creek Bridge		$ 321,740	$ 73,580	$ 395,320
Total Expenditures Excluding Wilson Creek Bridge per Mile		$ 55,472	$ 12,686	$ 68,159
Percent of Total Expenditures		81.4%	18.6%	100%

Notes:

1. Expenditures are compiled by "routine", "environmental" and "total" designations for all cost codes used in the case study. First order codes, such as 100, 200, etc., denote general categories of cost items. Second order codes, such as 110, 230, etc., denote subdivisions of first order cost items. Higher order codes denote further details of lower or general categories. Detailed expenditures are summed to derive lower order totals which, in turn, are summed to yield even lower order totals.

2. Includes falling and bucking of non-merchantable material, piling and burning by machine, and machine clearing of non-merchantable material from the right-of-way (R/W).

3. Includes falling and bucking of merchantable material.

4. Includes the installation and material costs of culverts of up to and including 60 inches diameter.

5. The installation and material costs of culverts of over 60 inches diameter. This entry refers to the Hicks Creek culvert. Calculations indicated that an 84-inch-diameter culvert was required for a 25-year flood runoff event. For environmental reasons, a 96-inch-diameter culvert was installed.

6. It was not possible to apportion the cost of transporting construction equipment to specific tasks.

7. Of the total supervision expenditures, 25% were assigned to Routine Expenditures and 75% to Environmental Expenditures.

8. Expenses, Transportation, (and) Supplies expenditures incurred during July 1972 to August 1973 are included in the varied Overhead entries. Expenses, Transportation, (and) Supplies entries include expenditures incurred during September 1973 to August 1974. The Routine and Environmental portions of this designation were derived by apportioning total Expenses, Transportation, (and) Supplies to the Supervision and Surveying expenditures, incurred during September 1973 to August 1974. A rate of $.26 of Expenses, Transportation, (and) Supplies expenditures to each $1.00 of Supervision and Surveying expenditures was used.