LANDSLIDE REFORESTATION AND EROSION CONTROL IN THE QUEEN CHARLOTTE ISLANDS, B.C.

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Abstract

Control of sedimentation in anadromous fish bearing waters from surface erosion of landslides, and reforestation of large debris slide tracks, are two major concerns of land managers in the mountainous, high rainfall forest lands of the Queen Charlotte Islands. Results of the initial phases of a project designed to test several methods of landslide rehabilitation are presented. Helicopter hydroseeding of grasses, legumes and fertilizer, followed by planting of several native shrub species and container-grown tree seedlings in several combinations and planting designs, are being tested as methods for controlling surface erosion and establishing a forest crop. Linear versus grid shrub planting designs, and development of stabilizing root networks by various species, are being tested with regard to their effect upon tree growth. Trials will be monitored for five years. Previous erosion control activities in the Queen Charlottes are also reviewed.

INTRODUCTION

Forest harvesting and roadbuilding activities in steep, mountainous terrain can cause an increase in soil mass movements, particularly in high rainfall areas of coastal British Columbia. Large debris slides or avalanches on productive forest land are of concern for at least two reasons: 1) soil loss through erosion and subsequent sedimentation in streams, and 2) temporary or permanent loss of sites from the productive forest land base. Studies have also quantified a decline in productivity compared to logged sites of the same age due to loss of soil material (Miles et al. 1984, Smith et al. 1984).

This project investigates the use of bioengineering techniques for artificially accelerating natural succession on landslides. Hydroseeding -- applying seed in a water slurry that usually contains fertilizer and a tactifier or mulching agent -- is an effective way to check surface erosion on steep slopes. Combining shrubs with grass-legume cover will provide a better stabilizing root network than grass-legume cover alone. The value of shrubs in slope stabilization methods is well-documented (Schiechtl 1980). Questions as to the positive or negative effects (e.g., shading, competition) of shrub plantings on conifer establishment, and whether planting designs or shrub species differ in these effects remain to be answered.

OBJECTIVES

The objective of this project is to evaluate methods for early reestablishment of conifers on debris slide tracks. Specifically,

- to compare conifer plantation success when combined with hydroseeding alone versus hydroseeding plus shrub planting;
- to evaluate the effect of shrub planting design (row vs. grid) on conifer establishment;
- to test the suitability of several shrub species for mixed conifer/shrub plantings.

In addition, further testing of an aerial hydroseeding technique designed for revegetating steep landslides that are inaccessible to conventional truck-mounted hydroseeders will be done.

METHODS

Study Area

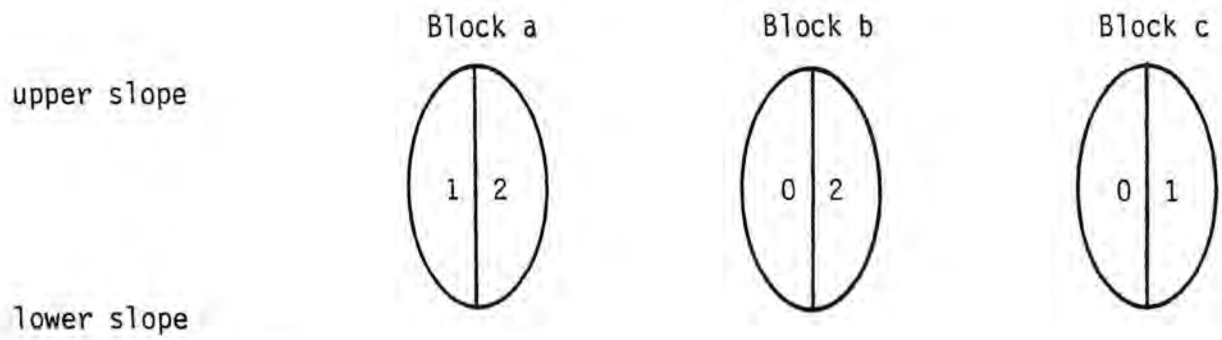
The Queen Charlotte Islands lie off the north coast of the B.C. mainland. The study area is a 2 ha slide near Sue Lake, about 20 km north of Queen Charlotte City. The slide occurred 10 years ago as a road-induced failure resulting from an overloaded fill slope. Since the initial slide, its size has increased and only small islands of vegetation have become established. There is over a meter of glacial till on most of the slide. Some portions have a surface layer of angular, gravel-sized rock fragments (colluvium) over the till.

Experimental Design

I set up the project as two separate trials: planting design and shrub species performance. The planting design trial tests conifer plantation success with grid versus row plantings of the same shrub species. I used a randomized incomplete block design, in which two replicates each of the two treatments and a control (no shrubs) were allocated randomly to three portions of the slide (blocks) that were divided vertically in half (Figure 1). Two year old sitka alder (*Alnus sinuata*), grown as plugs and transplanted, were planted either in a 1 x 1 m grid spacing or in rows 4 m apart with plants every 25 cm within rows. Both planting patterns give the same density.

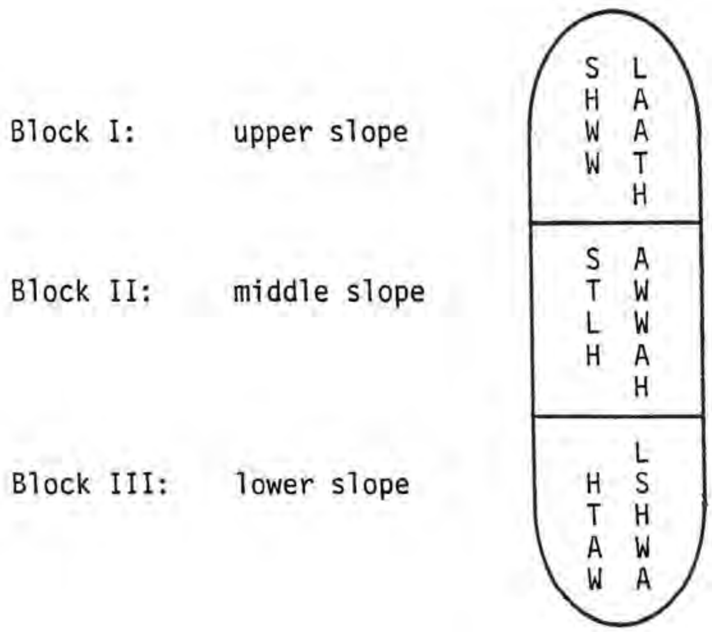
The shrub species performance trial tests the suitability of six native shrub species for mixed plantings with conifers. I used a randomized complete block design, in which two replicates of 50 plants of each species were allocated randomly within each of three portions of the slide (blocks) representing the upper, middle and lower slope positions (Figure 2). The shrub species being tested are: sitka alder, willow (*Salix* spp.), hardhack (*Spirea douglasii*), thimbleberry (*Rubus parviflorus*), salmonberry (*Rubus spectabilis*) and honeysuckle (*Lonicera involucrata*). As part of this trial, 40-60 shrubs of each species were planted on a roadcut near the slide. Ten plants of each species will be excavated each fall to observe and measure root system development.

Figure 1. Experimental layout for planting design.



0 = control - hydroseeding only
1 = treatment 1 - hydroseeding plus shrubs in grid
2 = treatment 2 - hydroseeding plus shrubs in rows

Figure 2. Experimental layout for shrub performance.



Shrub species:
A - alder
H - Hardhack
L - Honeysuckle
S - Salmonberry
T - Thimbleberry
W - Willow

Each letter in the diagram represents 50 plants in a 5 x 10 m plot.

Both the planting design and shrub species performance trials were hydroseeded with a grass-legume mixture and planted with sitka spruce (Picea sitchensis) 1+0 PSB 211 stock at 2 x 2 m spacing (2500/ha). A higher density than normally used in reforestation was chosen to allow for anticipated seedling mortality.

Sampling Procedures

The trials will be monitored annually for five years. Success will be measured in terms of seedling growth and survival on permanent sample plots. Twenty 1 m^2 plots will be established within each treatment unit to measure percent coverage and survival of the grasses and legumes, and percent bare mineral soil. A total of 150 trees will be measured for each treatment in both trials, 25 trees in each of the two replicates (5 rows of 5 trees) in the upper, middle and lower segments of the slope. Percent survival, height growth (cm), vigor, deer browse evidence and shrub competition will be observed. Shrubs will be measured using the same system as the conifers. For the 10 plants of each species examined annually, rooting depth and root zone diameter will be measured (as far as possible) along with average foliage crown diameter. Five root systems of each species will be collected, washed, oven dried and weighed at year 1, 3 and 5 of the sampling period as a comparison of root biomass.

Erosion Measurement

Twelve erosion measurement stations were established on the Sue Lake slide to monitor surface erosion over the first 5 years of vegetation establishment. The erosion bridge technique (Ranger and Frank 1978, Blaney and Warrington 1983) was used. This simple procedure consists of driving three lengths of steel reinforcement bar approximately 1.2 m apart in a line perpendicular to the slope, levelling the tops of the three bars, and measuring the distance between the ground surface and a modified masonry level placed on the bars. One station was installed in the upper, middle and lower portions of the slide in each of the three shrub/hydroseeding treatment areas. An additional three stations were placed in an unseeded portion of the slide as a control.

Data Analysis

Analysis of variance will be performed to determine if there are significant differences between the means for percent survival, height growth, browse, surface erosion, shrub competition, and percent of seedlings affected by slope disturbance for the various combinations of treatments. Subsequent to analysis of variance, students t-tests will be performed on the means.

REVIEW OF PREVIOUS WORK

This project is an extension of work begun in the Queen Charlotte Islands in 1980 by Carr and Marchant and reported at the Canadian Land Reclamation Association (CLRA) Annual Meeting in 1981 at Cranbrook, B.C. Several landslides were hydroseeded with grasses and legumes, and planted with several native shrub species. This work concentrated on erosion control and soil stabilization without specific regard to conifer establishment on landslides. It also focused on propagation techniques for numerous shrub species. I visited these earlier trials with Bill Carr in the Fall of 1983 to evaluate their performance. We also reviewed several roadside hydroseeding applications.

Roadside Hydroseeding in the Queen Charlotte Islands

The first hydroseeding on logging roads in the Queen Charlottes began in 1979. Two of the major forest companies with land tenures on the islands, MacMillan Bloedel Limited and Crown Forest Industries, contracted with Terrasol Revegetation and Erosion Control Services Ltd. to do 7 hectares of roadside seeding. The following year both forest companies converted existing fire tankers to hydroseeders. The third major forest licencee, Western Forest Products, purchased a hydroseeder developed by the B.C. Ministry of Forests (W.W. Carr) and Conair Aviation Ltd. From 1980 through 1983, 66 hectares of roadside seeding was completed. Labor and material costs using company equipment and personnel ranged from $500 to $850 per hectare. Costs for recent hydroseeding by MacMillan Bloedel on Vancouver Island were $620 per hectare ($420 materials, $200 labor). The length of roadside yielding 1 hectare varied from 1 to 2.5 km, depending upon the exposed surface of cut and fill slopes.

Seed Coverage and Mixes

The seed mixes used by MB and others from 1979 through 1983 are given in Table 1, along with the mix for the current project. All mixes have been similar, with a grass/legume ratio of about 70:30 (by weight). The proportion of legumes in the mixture of the current project was increased to 40% (by weight) to provide additional N-fixation benefits to the seedlings.

All of the roadside areas that we viewed in September of 1983 had good coverage of grass and clover. They were dominated by Redtop, Creeping Red Fescue and Perrenial Ryegrass. White and Alsike clover also maintained

Table 1. Seed mixes used by forest licencees in the Queen Charlottes for hydroseeding.

SPECIES	% (Wt.) of Mix by Year				
	MB 79/80	WFP 80	MB 81/82	CF 82/83	MB 84 (Sue L.)
Grasses					
Perennial Rye	10	20	20	5	30
Annual Rye	10			20	
Creeping Red Fescue	20	20	20	20	20
Red Top	5	5	5	5	10
Orchardgrass		5	20	15	
Meadow Foxtail	10	5	5	5	
Timothy	10				
Kentucky Bluegrass		15			
Grass Sub-Total	65	70	70	70	60
Legumes					
White Clover	5	10	15	10	10
Alsike Clover	10	10	15	20	20
Subterranean Clover	5				
Birdsfoot Trefoil					10
Sainfoil	15				
Red Clover		10			
Legume Sub-Total	35	30	30	30	40

good coverage in most areas. Personal observations during 1980-82 showed that these roadsides become a preferred grazing spot for deer.

I compared the seeding rate used in the Charlottes (84 kg/ha), with recommendations from other sources (Table 2). The rate falls within the range suggested by Carr (1980) for wet coastal B.C. of 50-100 kg/ha. Rates, of course, vary according to the composition of species in the mix with different size seed. These rates, however, are significantly greater than the maximum rates (35 kg/ha) suggested for roadside erosion control in coastal Oregon (Berglund 1976). The rationale given by Carr (1980) for

Table 2. Seeding rates used or recommended by various sources for roadside erosion control.

Roadside Truck Seedling	Seed (kg/ha)	Fertilizer (kg/ha)	Binder (kg/ha)	Mulch (kg/ha)
OSU Extension (Berglund 1976)[1]	17-35	N 45-90 P,K varies	ns[2]	ns
MB/CF (QCI) 1979 (Terrasol Contract)	84	370[3]	45[4]	112[5]
MB/CF (QCI) 1979 - 1983	84	370[6]	45	-
WFP (QCI) 1980 -	84	370[6]	56	-
Terrasol 1976 (Carr and Ballard 1980)	100	450[7]	33	670
B.C. Ministry of Forests (Carr 1980)	50-100	N 50-80 P 30-50 K 50-75	ns	ns
B.C. Ministry of Highways (A.D. Planiden, pers. comm. 1984)	84	225[8]	ns	1100[9]
B.C. Hydro (R. Roddick, pers. comm. 1984)	25	400[6]	34-67	900-1000
Richardson Seed Company (Newsletter, 1984)	56-84	ns	ns	ns

1 Based on an average 144 LPS/sq.ft. up to 300 LPS/sq.ft. maximum recommendation for W. Oregon, using the MB 1981/1982 species mix.

2 ns = not specified.

3 19-19-19 (N-P-K)

4 M-1 Binder (Terrasol Revegetation Erosion Control Ltd.)

5 Cellulose fibre

6 20-24-15

7 10-30-10

8 14-10-28

9 "Spra" Mulch, "Fibramulch", or "Silva-Fiber" average rate.

these high rates was: 1) seed is a small portion of the total cost of the operation so add plenty to ensure good coverage, 2) some seed is wasted as residue in the hydroseeder tank, and 3) some seed is damaged in agitation and pumping.

Fertilizer and binder rates used in the Charlottes were quite liberal. I have found 300 kg/ha of 20-24-15 to be adequate for roadcuts through gravelly, loamy textured glacial till. Binder rates of 25-40 kg/ha (10-15 kg per 500 gal. of slurry) proved adequate for steep roadcut applications this spring on Vancouver Island. Because binder is the most expensive component of the mixture, keeping rates as low as possible while still maintaining good tactifying and suspension qualities is an important economic consideration.

Helicopter Applications

The first helicopter seeding done in the Queen Charlottes was in June 1979 using a Hughes 500 helicopter and a monsoon bucket with a motorized propeller at the opening for spreading the slurry. This system was tried on several landslides near Haans Creek within MacMillan Bloedel's Hecate Division. Following this trial, Bill Marson of Queen Charlotte Helicopters and Bill Carr, contractor to the B.C. Ministry of Forests, modified the bucket to provide internal agitation and prevent settling of seed. This equipment was tested in May 1980 on Spur 29 of Crown Forest's Sandspit Operations and proved successful except for a problem with rotation of the bucket from the internal agitator (Carr and Marchant 1981). In April 1982, some different equipment was tried by Bill Carr and others near Squamish on the B.C. Mainland. A Simplex conventional dry-seeding bucket was used along with a new suspension agent -- J-Tac A.S. (Carr 1982). This method proved successful, without rotation or settling problems, and made use of readily available equipment.

We assessed the success of the helicopter hydroseeding in the Queen Charlottes in September 1983. The landslides on Spur 29 of Crown Forest have established a dense grass cover after four growing seasons. Small slumps continue to occur on the slope, but the soil eroded from these exposed areas is readily caught in the dense mat of grasses below. The vegetative cover appears to provide protection for tree seedlings planted on the slide from the adverse impact of erosion and slope movement and helps retain moisture on the site while its competitive influence has not seriously affected the seedlings. Seedlings had healthy green foliage, showing the benefit of fertilization and N-fixing legumes. Seedlings on similar slopes and soil without seeding showed poor vigor and color.

The helicopter seeded landslides near Haans Creek are steep-sided gullies, in contrast to the open slope debris slides of Spur 29. There is also less soil material and more exposed bedrock. The southerly exposure is more susceptible to summer drought than the northerly exposure of Spur 29. Consequently, grass cover is not as vigorous on the Haans slides, but the coverage is still substantial. Some natural seed-in of red alder has occurred.

Shrub Performance Trials

Six species of shrubs were planted on the Spur 29 slides in November 1980 with a total of 680 plants. Survival for large willow rooted cuttings, snowberry (Symphoricarpos albus), hardhack, dogwood (Cornus stolonifera), and salmonberry was 99-100% in June 1981. Willow sticks (55% survival) and thimbleberry (60% survival) did not do as well (Carr and Marchant 1981).

All of the shrubs observed in September 1983 had been browsed heavily by deer. A drier than normal summer in 1982 probably caused additional mortality and dieback (W.W. Carr, pers. comm.). Based on the performance of the species observed, willow and salmonberry show the most promise for future trials. Hardhack is a promising species for the bottom of gullies or lower portion of slides.

RESULTS AND DISCUSSION

Helicopter Hydroseeding

The hydroseeding operation at the Sue Lake slide was attempted in September 1983. Mechanical problems with the seeding bucket and poor weather conditions delayed the operation until early March 1984. A Bell 206 helicopter operated by Queen Charlotte Helicopters and a Chadwick seeding bucket rented from Okanagan Helicopters were used for the operation. The seeding bucket was filled from a pre-mixed 800 gallon capacity hydroseeder truck located on a road just below the slide. Table 3 gives details on the helicopter application, with data from two previous trials as a comparison. The average turn time of 5.7 minutes is quite close to that of previous trials. The first seven turns of the second tankful of slurry averaged 4.8 minutes per turn. Later turns were slower because the ground crew was directing the helicopter pilot to unseeded areas using radio contact. This was only partially successful due to the vantage point of the ground crew. A sketch map recording the area seeded as the operation progressed was found to be essential for keeping track of the areas covered. It also served as a record of areas that either received a double pass or were missed.

The actual application rate for the Sue Lake slide was somewhat greater than planned because only 1.5 ha of the 2.0 ha slide were covered. Seeding rates for the three trials in Table 3 range from 30 to 50 kg/ha. The actual amount of slurry applied per hectare, however, has varied substantially. The 1981 and 1982 trials used approximately one-third to one-fifth of the amount of slurry in the Sue Lake operation; consequently, this trial was a much "wetter" application than previously.

Seed Coverage

The seedling rate, based on the planned 40 kg/ha yields 638 seeds/sq.ft. or over 4 seeds per square inch. Actual seed counts were made from eight 50 x 50 cm screens placed from the base to top of the Sue Lake slide. The range in coverage was from 90 seeds/sq.ft. to 1300 seeds/sq.ft. The heavier coverage occurred on areas that received two passes. The Squamish J-Tac trial yielded about 144 seeds/sq.ft. (Carr 1982).

Foresters from MacMillan Bloedel's Queen Charlotte Division viewed the slide in July and observed the uneven coverage that the sampling screens had indicated. Some patches were missed entirely during the seeding. These should seed-in from the surrounding area with time. Coverage could be improved in future operations by including a dye in the slurry that would enable the helicopter pilot to see coverage more easily. A fluorescent orange dye used in chemical fire retardant aerial application

Table 3. Comparison of Sue Lake Helicopter Seeding with other trials.

	Sue Lake March 1984	Squamish (J-TAC)[1] April 1982	SPUR 29[2] May 1981
Area seeded	1.5 ha	1.6 ha	3.0 ha
Slurry applied	1500 gal.	320 gal.	1000 gal.
Slurry per hectare	1000 gal.	200 gal.	333 gal.
Materials*			
Fertilizer	20-24-15	19-19-19	20-24-15
Rate (kg/ha)	416 (312)	312 (320)	150
Seed-grass: Legume (by wt.)	60:40	70:30	70:30
Rate (kg/ha)	53 (40)	29 (38)	33
Binder	ECOLOGY M-1	J-TAC	ECOLOGY M-1
Rate (kg/ha)	40 (30)	15.6	18.3
% (by weight) of mix	0.9%	1.5%	1.2%
Application			
Total Flight Time	2.0 hrs	0.8 hrs	1.0 hrs
Average Payload	70 gal.	40 gal.	85 gal.
Number of Turns	21	8	12
Average Time Returns (minutes):	5.7	6.0	5.0
Filling of Bucket	2.0	2.0	1.0
Flight To/From site	3.3	3.5	3.0
Spreading Slurry	0.4	0.5	1.0
Equipment			
Helicopter	BELL 206	BELL 47-G3B2	HUGHES 500
Bucket	CHADWICK	SIMPLEX	QCH PROTOTYPE
Hydroseeder Truck	MB 800 gal.	AEROCON 800 gal.	CF 1000 gal.

* Rates given are actual and (plan).

[1] Carr 1982.

[2] Carr and Marchant 1981.

has been suggested. A co-pilot might also improve the operation, although this might necessitate a reduction in payload for some sites where lift is critical.

Tree and Shrub Planting

Planting occurred in April 1984. A 5 person contract crew was employed to plant the 3500 shrubs and 8500 sitka spruce seedlings. The overall productivity rate was 650 plants per manday. The patchwork of 50 plant blocks for the species performance trial, the large root systems on some shrub species, and the difficult footing on most of the slide lowered the productivity rate. Some damage occurred to the newly seeded grass and clover during planting. It would have been preferable to plant after the grass cover had been well established, but the availability of shrubs and trees made it impossible to postpone planting until the Fall. Had the original plan been successful, the seeding would have overwintered before planting. The weather during and after planting was cool and moist, making chances for survival favorable.

Application to Other Areas

Results from this project will be used to develop operational guidelines for our logging divisions for landslide reforestation and erosion control activities. Because of the high cost of helicopter seeding, its use will likely be confined to areas inaccessible to truck-mounted seeders where manual dry seeding is deemed unsuitable and where there are special aesthetic, productivity or fisheries concerns. The value of sitka alder and clover for biological nitrogen fertilization of disturbed or low fertility sites will also have application to our forestry operations on areas other than landslides.

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REFERENCES

Berglund, E.R. 1976. Seeding to control erosion along forest roads. Oregon State Univ. Extension Service Circular 885, Corvallis, Oregon, 19 pp.

Blaney, D.G. and G.E. Warrington. 1983. Estimating soil erosion using an erosion bridge. USDA Forest Service, Watershed Systems Development Group, 55 p.

Carr, W.W. 1980. Handbook for forest roadside surface erosion control. Land Management Report No. 4, B.C. Ministry of Forests, Victoria, B.C., 43 p.

Carr, W.W. 1982. Preliminary report: The use of J-TAC A.S. in aerial hydroseeding, initial test - 1982. B.C. Ministry of Forests Project E.P. 834: 02-02, 5 p.

Carr, W.W. and T.M. Ballard. 1980. Hydroseeding of forest roadsides in British Columbia for erosion control. J. Soil and Water Conservation 35(1): 33-35.

Carr, W.W. and C.J. Marchant. 1981. Erosion control in the Queen Charlotte Islands. In: Proceedings of the Can. Land Reclamation Conf., August 1981, Cranbrook, B.C., 28 p.

Miles, D.W.R., F.J. Swanson, and C.T. Youngberg. 1984. Effects of landslide erosion on subsequent Douglas-fir growth and stocking levels in the Western Cascades, Oregon. Soil Sci. Soc. Am. J. 48: 667-671.

Ranger, G.E. and F.F. Frank. 1978. The 3-F erosion bridge - a new tool for measuring soil erosion. State of California, Dept. of Forestry, Range Improvement Studies Report No. 23, 7 p.

Schiechtl, H. 1980. Bioengineering for Land Reclamation and Conservation. (Translation by N.K. Horstmann), Univ. of Alberta Press, Edmonton. 404 p.

Smith, R.B., P.R. Commandeur and M.W. Ryan. 1984. Vegetation succession, soil development and forest productivity on landslides, Queen Charlotte Islands, B.C., Canada. IUFRO Symposium on Effects of Forest Land Use on Erosion and Slope Stability, Honolulu, Hawaii, May 7-11, 1984.

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