FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

NORTHWEST REGION ALASKA WATER LABORATORY

EFFECTS OF FOREST FIRES ON WATER QUALITY IN INTERIOR ALASKA

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EFFECTS OF LARGE SCALE FOREST FIRES ON WATER QUALITY IN INTERIOR ALASKA

by

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INTRODUCTION

Forest Fires in Alaska

Large and frequent fires are not new to the Taiga of Alaska, nor is Alaska unique among northern regions in this respect. In his study of the ecological effects of fires in Alaska, Lutz (1956) also cites many examples of extensive fires in Canada, Siberia, and Scandinavia. The present mosaic of vegetational patterns in Alaska is caused by previous fires, both in the historic and prehistoric past. Aborigines were careless with their fires and Lutz believes that many prehistoric fires were caused by them, although a significant number of fires were caused by lightning. When mining activity became a part of early Alaskan history, the number and size of fires increased because of carelessness and increased activity associated with mining. No attempt was made to control these early fires because of unavailable manpower and also because it was felt that control was unnecessary.

Interior Alaska was very dry in the summer of 1966 and thunderstorms were frequent. The fire on which this report is based was caused by lightning on July 23, 1966, and burned into September, covering a total of over 1/4 million acres. The day the fire started, the potential for fire was great and the Bureau of Land Management had planes patrolling to report fires. This fire, later designated as Y34, was first reported at 3:00 p.m. during a thunderstorm in the Dennison River watershed about 20 miles south of Chicken, Alaska.

Within two hours, 15 smoke jumpers were dispatched from Fairbanks. Nine of these jumped a nearby fire and the remaining six jumped Y34, which by then covered about 100 acres (Figure 1). Unable to contain the fire, the six jumpers did clear two heliports. By the next day the fire was about one mile long by 1/2 mile wide. The control plan was to keep the fire in the Cement Creek watershed, but adverse winds and very dry conditions allowed the fire to burn out of control and it spread south across the ridge toward Big Timber Creek, resulting in an estimated 40,000 acres being burned by August 1 (see map for sequence of events). The fire crossed Dennison Fork on July 29; no control was possible from August 1-9.

The fire, which crossed the Taylor Highway on August 5, had burned over 150,000 acres by August 9. Rainy weather halted spread of the fire from August 9 to the 17th and some equipment and personnel were transferred to other urgent fires. On August 17, when strong south winds caused the fire to break out, new crews were brought in. By August 19 the fire had spread to the line shown in Figure 1. Winds on August 19 caused breakouts along Walker Fork and south of Chicken. By August 23 the fire was generally under control, although there were several small breakouts that were subsequently brought under control. Cloudy, moist conditions during August 25-26 allowed direct attack along most of the fire line, with only a small part of the northern line being critical. General light

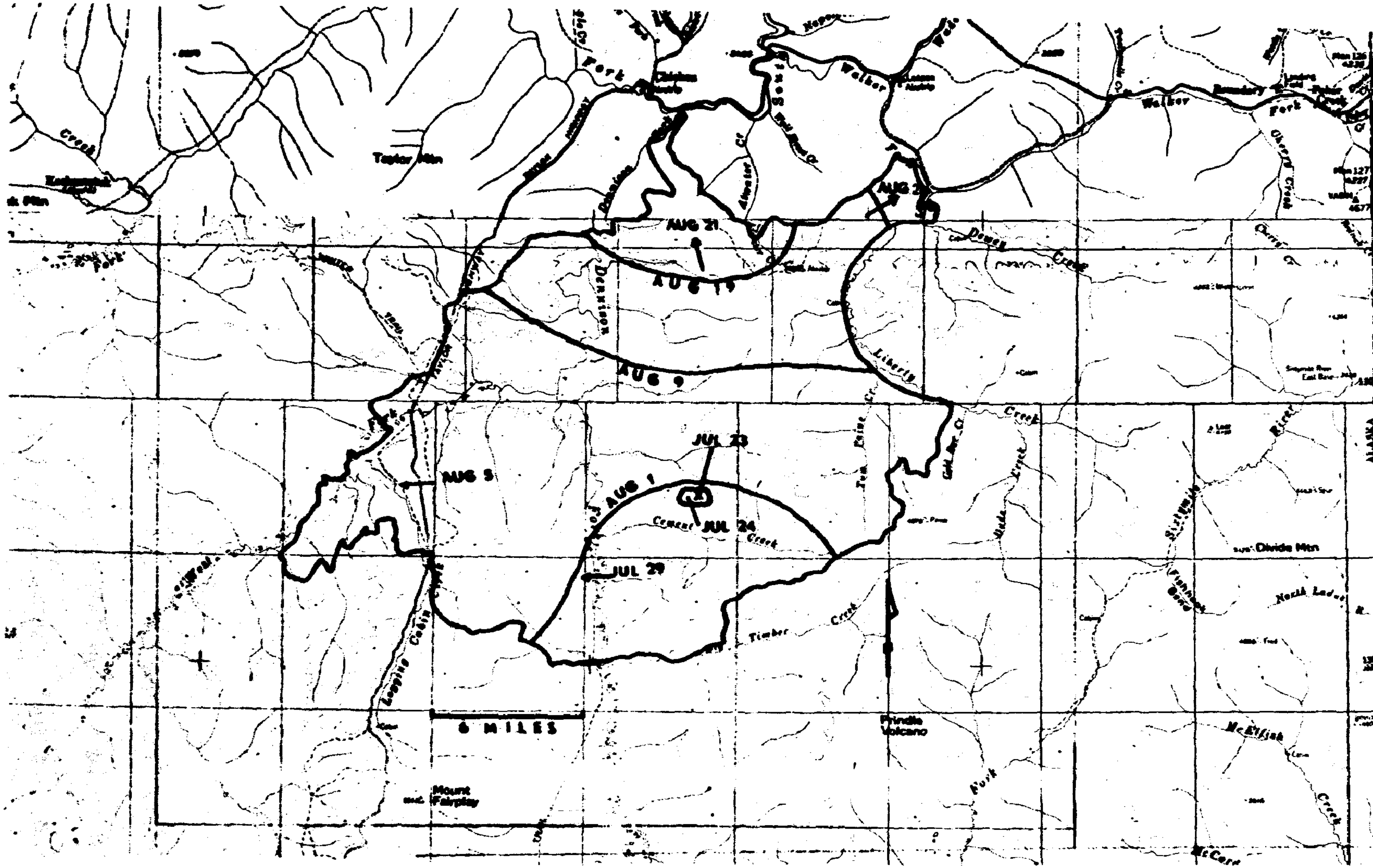

Taylor Mtn
Fork
Chicken
Walker
Walker
Boundary
AUG 21
AUG 19
AUG 9
AUG 5
AUG 1
JUL 23
JUL 24
JUL 29
Dennison
Liberty
Cement
Creek
Timber
Creek
Logging Cabin
Divide Mtn
North Ladue R.
6 MILES
Prindle
Volcano
Mount
Fairplay
McCord
64°00'
45'

Figure 1

rains on September 1 prevented spread of the fire. Heavier rains by September 5, with snow at higher elevations, kept the fire under control; demanning started during this time and was completed by September 13.

At one time a total of 600 men were fighting the fire, which eventually burned an area of 250,000 acres during a period of 44 days. In all, more than 400 miles of fire-trails were built. This fire was an example of one that defies strenuous efforts at control because of adverse winds and extremely dry fuel during a very hot summer. Conditions for fire were predicted, a patrol was in the vicinity and reported the fire soon after it started, smoke jumpers were on the scene a few hours later, but it still became a major fire.

About two months after termination of the fire, representatives of the Bureau of Land Management (BLM) contacted scientists from the Alaska Water Laboratory (AWL) for assistance in evaluating some effects of this large fire. After exploring several means of assistance, it was agreed that AWL would conduct a research study in cooperation with BLM. AWL would conduct field and laboratory studies and prepare a report on the findings. BLM was to furnish general logistical support and helicopter transportation to sampling sites because the fire area was inaccessible to surface means. In addition, BLM would provide information on the fire history, control methods used, and such technical assistance as they had available. It was agreed that AWL would make five sampling trips to the fire area at specified times, the first trip, just before breakup, to be in May 1967.

Objectives

Objectives of the study were: (1) to develop sufficient understanding of the effects of forest fires on water quality of Alaskan streams so that it may be possible to make rational decisions for allocating manpower and funds for controlling specific fires, and (2) to develop an understanding of needs for rehabilitation (revegetation, erosion prevention, etc.) to control immediate and future polluting effects of the fire on the aquatic environment.

SUMMARY AND CONCLUSIONS

1. In general, burning was not severe enough to destroy the entire organic layer.

2. The depth of thawing was not affected by the fire.

3. Burning of the organic layer causes a decrease in the cation exchange capacity of the soil.

4. Only the organic layer is useful in diagnosing the changes in soil chemistry.

5. The only evidence of increased erosion was in the fire trails.

6. Potassium is increased in the burned organic layer.

7. Burning may release significant quantities of soluble material which, because of the permafrost, remains in the organic horizon.

8. There is an increase in the chemical oxygen demand concentration in streams in the burned area.

9. Potassium concentrations are higher in streams draining burned areas than in streams draining unburned areas.

10. There was no change of statistical significance to the benthic fauna of the streams that can be attributed to the effects of the fire.

11. Fire control methods may cause more serious, long-lasting damage to the aquatic ecosystem within the burned area than the

fire itself. In developing a fire control plan, sufficient forethought should be given to the possible consequences of control measures to prevent extensive damage to the taiga ecosystem.

RECOMMENDATIONS

The following recommendations are based solely on data and observations collected during the course of the study (conclusions and recommendations of the Bureau of Land Management are included in the appendix) and reflect recommendations and conclusions of both agencies.

1. If a fire cannot be controlled early by smoke jumpers, fire fighters with hand tools, or aerial application of retardants, serious consideration of soil types, topography, and permafrost should be made before constructing fire lines with bulldozers or other heavy machines.

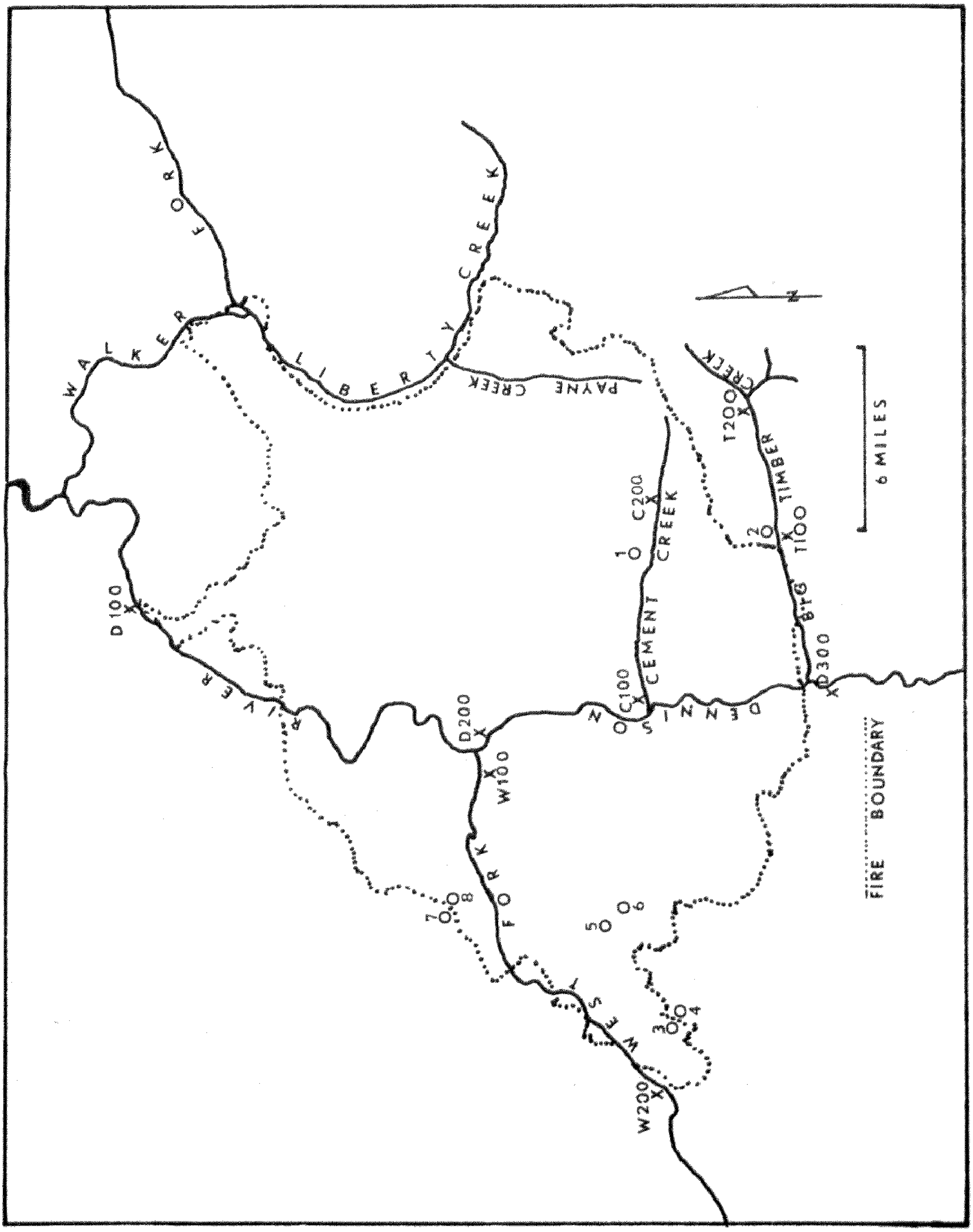
2. Artificial revegetation should not be attempted where burning was not severe enough to remove the entire organic horizons or where revegetation would expose mineral soils and cause melting of permafrost. Natural processes will revegetate a burn more rapidly than artificial means if burning is not severe or a nearby seed source is available.

3. A long-range, more in-depth investigation should be undertaken to study the after-effects of fires in the taiga of Alaska. Results of the present study indicate that soil analyses can be limited to saturation extracts and that the benthic community requires immediate study after a fire followed by continuous surveillance. Comparison of severely to moderately burned areas to assess the effects of fires on water quality should receive high priority.

DESIGN OF PROJECT

The over-all project required analyses of soils, water, and aquatic organisms on unburned and burned areas. Thus, it would be possible to determine changes in soil chemistry caused by burning and associate these with changes in water chemistry which in turn could cause changes in stream biota. Five stream sampling trips were scheduled: breakup in 1967 (May), after breakup (late May or early June), low water just before freezing (September), breakup in 1968 (May), and after breakup (June 1968). Soil samples were to be collected only in 1967.

After extensive map reconnaissance and consultation among AWL scientists and BLM specialists, nine sampling stations were established. These stations are shown in Figure 2 and are as follows: Dennison River downstream from the fire (D-100) (Figure 3), just upstream from its confluence with the West Fork (D-200), and upstream from the fire area (D-300), and the West Fork upstream from the fire area (W-200) (Figure 4), and a short distance upstream from the Dennison River (W-100). Two small east-west streams were selected east of the Dennison River to represent streams with similar watersheds. Cement Creek represented a burned watershed and Big Timber Creek represented an unburned watershed. Two stations were established on each stream: (C-100) at the mouth of Cement Creek and C-200 (Figure 5) several miles upstream;



WALKER FORK
LIBERTY CREEK
PAYNE CREEK
CEMENT CREEK
TIMBER CREEK
DENNISON
RIVER
WEST FORK
D100
D200
D300
C100
C200
T100
T200
W100
W200
6 MILES
FIRE BOUNDARY
N

Figure 2

Figure 3. The Dennison River at Station D-100, showing ice blocks just after the ice had broken out. Much of the bottom was still covered with anchor ice (May 1, 1967).

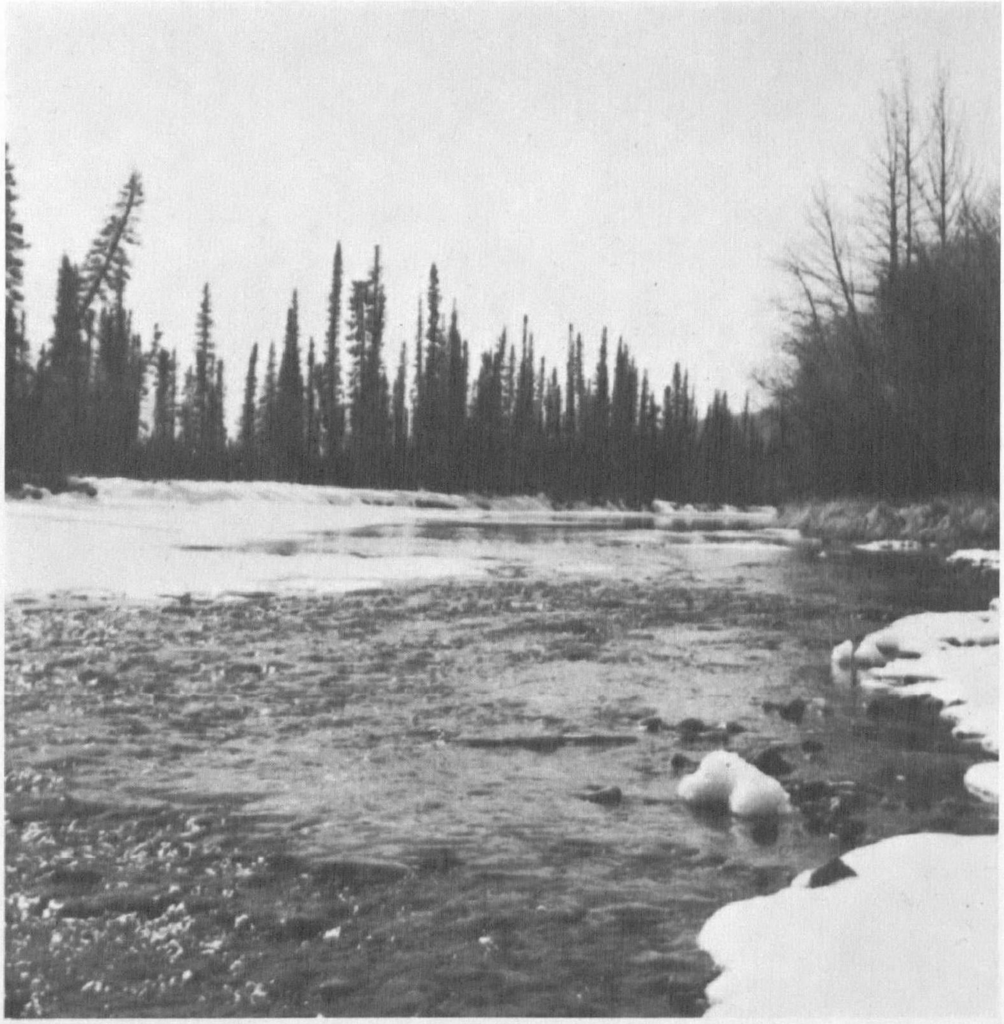


Figure 4. West Fork at Station W-200 showing extensive open water with some surface ice remaining. Anchor ice was extensive (May 1, 1967). Surface ice at W-200 remained several days later than for W-100 or stations on the Dennison River.

Figure 5. Cement Creek at Station C-200, showing water flowing over surface ice (May 1, 1967). These small creeks appear to freeze solid during winter and melt-water at break-up flows over the ice, giving the appearance of flood stage because the channel is still filled with winter ice.

Figure 6. Big Timber Creek at Station T-200, showing the stream bank full over the ice (May 1, 1967). This creed did not break up as early as Cement Creek in the burned area; this was noted in May 1968. Timber Creek also has condsiderable groundwater that forms aufeis, which was not true for Cement Creek.

Figure 7. Soil profile near Station C-200. Ruler is 15 cm (6 inches) long. Here the organic layer was nearly destroyed, but 4-6 cm remained, as can be seen. Bottom of the ruler is resting on frozen soil (May 3).

Figure 8. Sampling soil near Station T-100. Here the moss and organic layer was about 20 cm thick, with the mineral soil frozen (May 3).

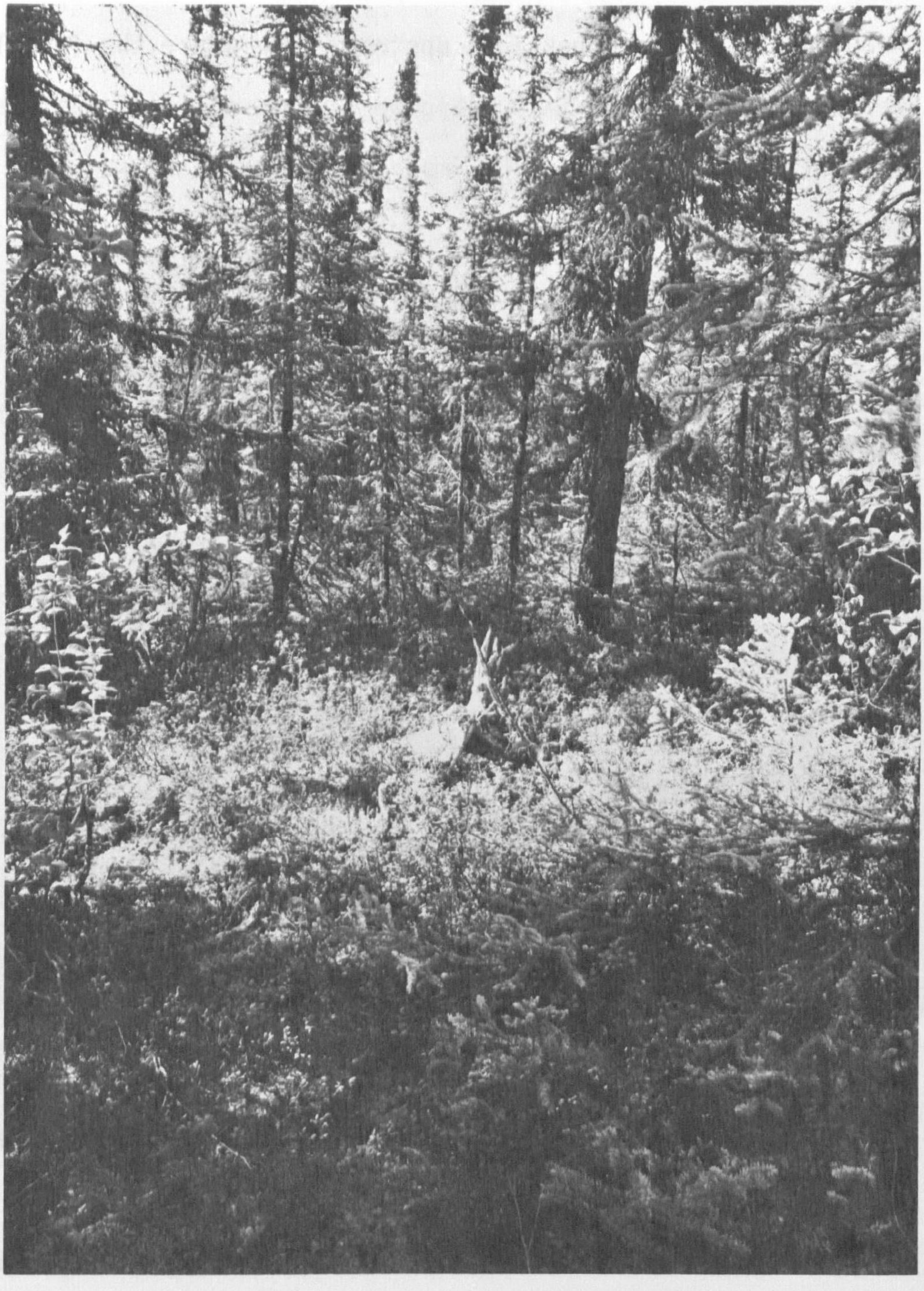


Figure 9. Soil sampling site on unburned Logging Cabin Creek watershed, showing the forest and understory vegetation as it appeared before the fire (June 20, 1967).

T-100 on Big Timber Creek just upstream from where the fire line crossed the creek, and T-200 (Figure 6) several miles upstream. None of the watershed of Big Timber Creek above the sampling sites had been burned.

Biological samples were collected at each water sampling station. Quantitative benthic samples were collected with a Surber sampler and qualitative samples with a long-handled dip net. All samples were preserved in formaldehyde in the field and sorted and identified at the Alaska Water Laboratory.

The actual number of samples that were collected was less than planned. During the first sampling trip in 1967, water samples were collected at all stations, but because of bottom ice, no biological samples were obtained. Soil samples were collected at sites shown in Figure 2 on a burned area about 1/2 mile north of Cement Creek (1) (Figure 7), on Big Timber Creek (Figure 8) about 1/4 mile north of Station T-100 (2), on the West Fork watershed, burned and unburned (3 and 4), and along the Taylor Highway, burned and unburned (7 and 8). At this time, the soil was frozen to the bottom of the moss layer except for site 1, which was black, on a southern exposure, and thawed to a depth of about four inches.

No water samples and only two biological samples were collected during the sampling trip scheduled in June 1967, because all helicopters under contract to BLM were engaged in firefighting activities and none were available for our use. However, soil samples were

Figure 10. Soil sampling site on burned Logging Cabin Creek watershed, showing the complete kill of spruce trees. Much of the organic layer remained to protect the soil and many shrubs were alive. Soil was thawed to a depth of about 30 cm (June 20, 1967).

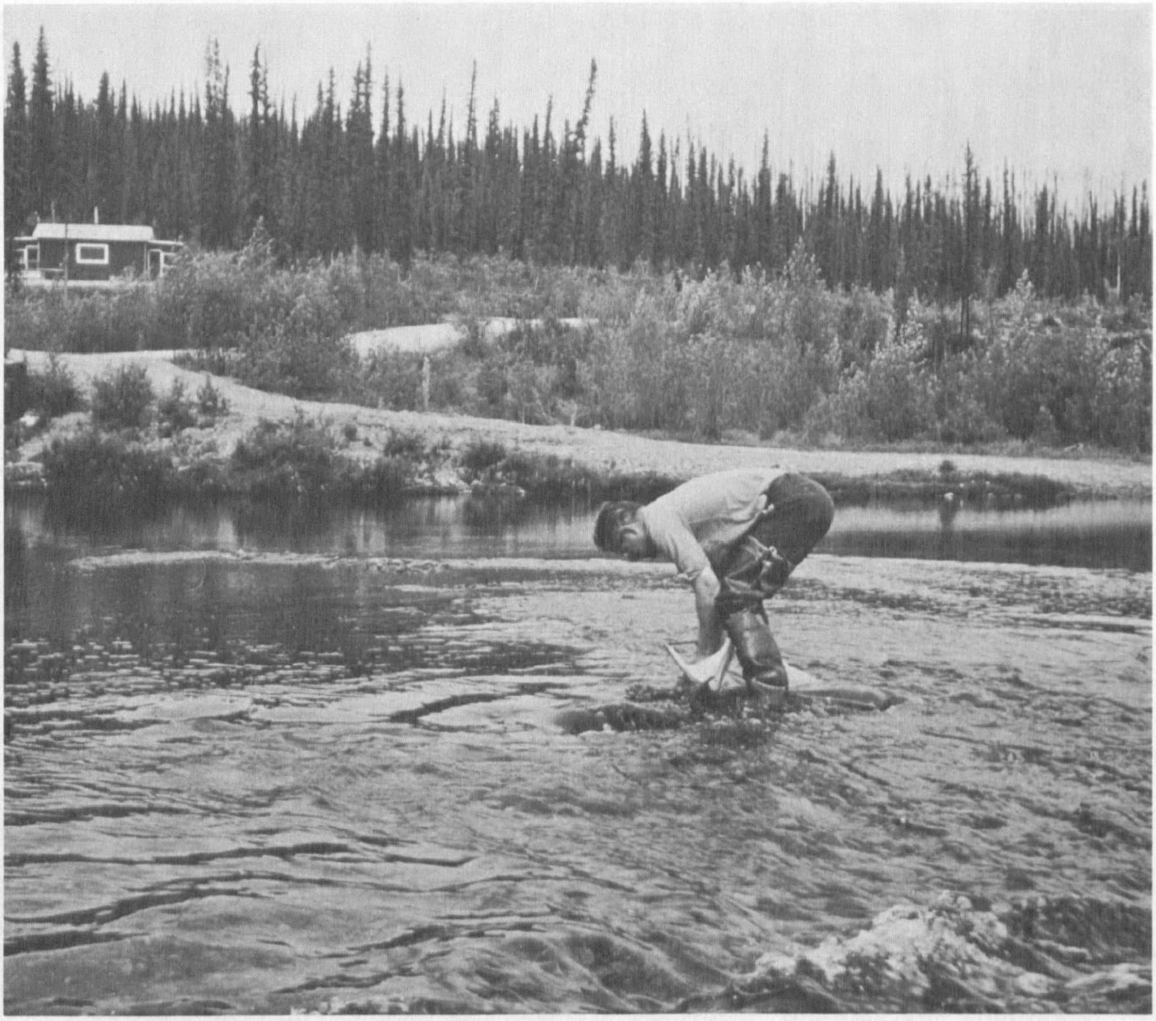


Figure 11. Aquatic biologist sampling the benthic community on West Fork River (June 20, 1967). This was not a designated sampling site, but an alternate one selected when helicopter transportation was not available.

Figure 12. Shrub community on low land slopes a year after the fire (September 1967). Here the fire burned over the entire area, but burning was not severe enough to kill the shrubs.

Figure 13. Erosion of a bulldozed fire line in a small valley one year after the fire (September 1967). This ditch was caused primarily by melting ice; when the organic layer was removed, enough water was released by melting to carry away the soil. This ditch ranges in depth from 5-15 feet.

collected from the site on Taylor Highway and from another site on the highway about six miles to the south, where samples from burned and unburned areas were collected (5 and 6). Figures 10 and 12 show how the vegetation appeared before and after burning and is representative of the entire burned-over area except for that small portion above timberline. The soil was thawed to a depth of about 16 inches at all sites. There was no significant difference in the depth of thawing between burned and unburned profiles.

In September 1967, complete sets of all samples were collected. Depth of thawing was 26 inches under undisturbed forest and 28 inches on the burned site at Cement Creek. Soil temperature at the one-foot depth was 1°C for all measured profiles. The entire measured profile was saturated with water, as indicated by slumping of the walls of the soil pit during sampling. This sampling trip completed the schedule of soil samples.

In May 1968, another scheduled sampling trip was made to the fire area and a complete set of water samples collected. Breakup was in progress and both Cement Creek and Big Timber Creek had water flowing over the ice. Water in Cement Creek was brown colored, whereas that in Big Timber Creek was nearly clear.

The last sampling trip was completed in June 1968. During this trip, biological and water samples were collected from all stations on Dennison River and West Fork; however, because of heavy rains which caused Cement Creek and Big Timber Creek to be in flood stage, only water samples were obtained on these streams.

RESULTS AND DISCUSSION

Soil Analytical Data

Properties

Soils were first sampled before they had thawed in the spring of 1967, following the very dry summer of 1966. Nutrients released by burning should have remained on or near the soil surface and movement of water from snow melt and rain should have carried these nutrients deeper into the profiles. The samples collected in June should reflect this initial movement and the samples collected in September ought to reflect maximum downward movement of released nutrients.

Permafrost is a complicating element in this region. In temperate regions, water moves freely downward until it reaches groundwater (if precipitation is sufficient); however, in the arctic, a frozen layer prevents this movement, causing a perched water table. Such a phenomenon probably explains the saturated condition of the soil when sampled in June and September.

Surface samples were collected from the lowermost organic layer; contact with the organic and inorganic horizons was distinct and, for gravelly profiles, was marked by a horizontal alignment of pebbles. Mineral soil samples were taken at measured depths instead of at horizon delineations because no clear horizonation was present. Samples were collected from 0-5, 5-10, and 10-20 or 10-30-cm depths except when the soil was frozen.

Samples were brought to the laboratory in plastic bags, dried, crushed, passed through a 2mm sieve, and stored in glass containers. Chemical analyses were made on the soil, saturated water extracts, and NH_4OAC extracts. Chemical analyses of the soil included pH, total carbon, nitrogen, phosphorous, exchangeable cations (calcium, magnesium, sodium and potassium), and total acidity. Cation exchange capacity was determined by summation because these soils were all acid and this method is suggested for such soils (1965). Chemical data from saturation extracts included total carbon, calcium, magnesium, potassium, and conductivity; procedures for all these anayses were from Methods of Soil Analysis(1965).

Data collected by previous workers, mostly in coterminous U. S., suggest that forest fires cause some changes in soil properties, the magnitude of which depends on the severity of the fire. For example, even slight burning of desert shrub was found by Klemmedson et al (1962) to increase soluble salts and available nitrogen. Wright (1966) showed that high temperatures result in loss of total nitrogen from forest soils. Likewise, with severe burning, potassium, phosphorous and pH tend to increase and cation exchange capacity tends to decrease, probably because of the destruction of organic matter with its high exchange capacity (Klemmedson, et al. 1962, Tarrant, 1956). Scotter (1963), working in northern Saskatchewan, concluded that soil physical properties were not significantly changed unless burning is intense enough to destroy the forest floor. Intense burning may cause changes in physical properties that result in less stable aggregation and decreased percolation (Dyrness and Youngberg, 1957; Tarrant, 1956). Changes in percolation rate and reduced aggregation may pose an increased erosion hazard (Sweeney and Biswell, 1961). Most of the cited work was done in temperate climates; soils in permafrost areas of Alaska may not react similarly because water stays perched in the active zone above the frozen subsoils.

This discussion will first describe chemical properties of soil and compare those of burned with unburned areas. At no sampling site was it observed that the entire organic layer had been consumed; even on Cement Creek, where the fire started and was most severe, the lowermost 5-0 cm of duff remained to give some protection from surface erosion and raindrop impact. A site on the north slope of Big Timber Creek was chosen to compare soil properties with those of the profile on Cement Creek; these two sites were separated by about five kilometers. The sites on West Fork were about 50 meters apart, those on Taylor Highway about 100 meters, and those on Logging Cabin Creek about one kilometer apart. Textures of comparative profiles were similar. Figure 2 shows the sampling sites and Tables 1-4 present the analytical data.

TABLE 1. SOIL ANALYTICAL DATA FROM CEMENT AND BIG TIMBER CREEK PROFILES

		Sample	Depth Inches	Texture	pH	C%	N%	C/N	Mg/g	Ex. Cations (meq/100g)				TA	CEC
										CA	Mg	Na	K	(meq/100g)	
May 2	Burned	1	2-0	Fib.	4.35	23.10	0.92	23.1	0.041	7.4	5.1	0.23	1.20	37.3	51.2
		2	0-2	Si.	4.57	1.98	0.11	18.5	0.001	13.8	3.8	0.10	0.31	5.9	23.9
		3	2-4	Si.	4.67	1.30	0.08	16.3	0.001	6.4	3.3	0.12	0.23	2.5	12.5
		4	4-6	Si.	4.82	1.74	0.08	21.7	0.001	12.6	3.5	0.17	0.20	14.2	30.7
	Unburned	5	2-0	Fib.	5.52	30.47	1.40	21.8	0.011	35.3	10.1	0.42	0.32	38.0	84.1
		6	0-2	Si.	5.07	3.74	0.26	14.2	0.002	6.9	3.5	0.19	0.18	7.8	18.6
September 12	Burned	32	4-0	Fib.	5.12	24.28	0.96	25.4	0.011	22.1	9.8	0.30	1.01	45.8	79.0
		33	0-2	Si.	5.17	3.79	0.23	16.5	0.00	7.2	3.5	0.14	0.23	13.2	24.2
		34	2-4	Si.	5.15	3.85	0.23	16.8	0.00	6.8	3.0	0.18	0.18	19.4	29.6
		35	4-8	Si.	5.12	3.34	0.21	15.9	0.00	6.5	3.5	0.16	0.20	21.1	26.6
	Unburned	28	3-0	Fib.	4.80	22.77	1.05	21.8	0.003	20.5	6.2	0.39	0.48	57.5	85.1
		29	0-2	Si.	5.62	2.76	0.16	16.8	0.00	8.5	3.3	0.17	0.15	11.0	23.2
		30	2-4	Si.	5.67	1.76	0.13	13.8	0.001	7.4	2.8	0.13	0.15	19.0	29.5
		31	4-12	Si.	5.73	2.43	0.16	15.2	0.000	7.2	2.8	0.17	0.16	31.4	41.8

Fib. = Fibrous
Si. = Silt

TABLE 2. SOIL ANALYTICAL DATA FROM WEST FORK PROFILES

		Samples	Depth Inches	Texture	pH	C%	N%	C/N	P Mg/g	Ex. Cations (meq/100g) Ca	Mg	Na	K	TA (meq/100/g)	CEC
May 2	Burned	7	2-0	Fib.	4.46	19.13	0.83	23.3	0.007	10.1	6.1	0.24	0.97	44.3	61.7
	Unburned	8	2-0	Fib.	4.73	15.85	0.80	19.8	0.00	8.6	6.5	0.29	0.39	43.6	59.3
		9	0-4	Gr.Si.	4.67	9.14	0.48	16.2	0.00	7.2	5.3	0.32	0.27	26.1	39.2
September 13	Burned	40	3-0	Fib.	4.66	18.92	1.18	17.2	0.001	12.5	7.9	0.31	0.92	57.2	78.8
		41	0-2	Gr.Si.	4.95	2.01	0.11	17.9	0.00	3.7	3.5	0.12	0.12	10.0	17.4
		42	2-4	Gr.Si.	5.10	1.37	0.09	14.9	0.001	3.7	4.2	0.13	0.10	7.6	15.7
		43	4-12	Gr.Si.	5.28	2.63	0.15	17.8	0.00	5.8	5.0	0.20	0.14	10.0	21.1
	Unburned	36	3-0	Fib.	4.10	15.48	0.70	22.0	0.001	9.2	2.9	0.28	0.63	62.8	75.8
		37	0-2	Gr.Si.	5.39	0.70	0.06	12.3	0.00	3.1	2.7	0.09	0.15	11.8	17.9
		38	2-4	Gr.Si.	5.50	0.53	0.04	12.0	0.001	3.8	3.1	0.10	0.16	-	7.2
		39	4-12	Gr.Si.	5.65	0.50	0.05	9.6	0.001	4.6	3.3	0.08	0.14	0.8	8.9

Gr.Si. = Gravelly Silt

TABLE 3

SOIL ANALYTICAL DATA FROM TAYLOR HIGHWAY PROFILES

Date	Treatment	Sample	Depth Inches	Texture	pH	C%	N%	C/N	P Mg/g	Ex. Cations (meq/100g) Ca	Mg	Na	K	(meq/100g) Ta	CEC
May 3	Burned	11-A	2-0	Fib.	4.97	10.88	0.50	21.8	0.004	15.7	10.7	0.28	0.19	17.3	44.2
		11-B	0-2	Si.Cl.	5.60	3.42	0.20	16.8	0.001	13.2	8.8	0.24	0.24	-	22.4
	Unburned	10	0-2	Si.Cl.	5.50	2.78	0.17	16.2	0.12	9.2	5.3	0.19	0.31	-	15.0
June 20	Burned	20	4-0	Fib.	4.83	14.91	0.88	17.0	0.00	13.4	6.1	0.24	0.42	44.4	64.5
		21	0-2	Si.Cl.	5.93	1.33	0.10	13.4	0.06	7.6	6.3	0.18	0.22	23.6	37.9
		22	2-4	Si.Cl.	6.10	1.34	0.10	13.1	0.00	8.6	5.5	0.18	0.23	9.7	25.2
		23	4-8	Si.Cl.	6.48	1.14	0.09	13.3	0.001	8.0	6.8	0.18	0.26	-	15.2
	Unburned	24	2-0	Fib.	4.24	17.96	0.90	20.0	0.004	9.4	7.7	0.29	0.63	59.7	77.7
		25	0-2	Si.Cl.	5.23	2.34	0.17	13.8	0.001	8.1	7.9	0.18	0.32	16.1	32.6
		26	2-4	Si.Cl.	5.55	1.73	0.12	14.3	0.001	8.0	5.1	0.18	0.27	11.6	26.0
		27	4-8	Si.Cl.	5.58	1.68	0.12	14.4	0.001	8.1	8.1	0.40	0.23	2.3	19.1
September 14	Burned	44	2-0	Fib.	4.40	22.18	0.82	27.0	0.030	12.8	10.0	0.30	0.87	50.5	74.5
		45	0-2	Si.Cl.	6.61	1.81	0.12	15.0	0.00	2.9	6.8	0.39	0.43	2.5	13.0
		46	2-4	Si.Cl.	6.88	0.85	0.07	12.0	0.001	7.7	5.1	0.17	0.40	-	13.4
		47	4-12	Si.Cl.	6.87	0.77	0.06	12.6	0.001	8.1	6.0	0.27	0.45	0.4	15.2
	Unburned	48	2-0	Fib.	3.92	23.60	0.70	34.0	0.016	29.8	6.2	0.43	1.15	54.8	92.4
		49	0-2	Si.Cl.	5.12	3.34	0.16	21.4	0.001	9.3	9.9	0.33	0.48	10.8	30.8
		50	2-4	Si.Cl.	6.28	1.85	0.13	14.0	0.001	10.2	9.9	0.36	0.43	4.4	25.3
		51	4-12	Si.Cl.	6.20	2.14	0.13	16.1	0.00	10.0	9.9	0.33	0.41	5.4	26.0

Si.Cl. = Silty Clay

TABLE 4. SOIL ANALYTICAL DATA FROM LOGGING CABIN CREEK PROFILES

Date	Treatment	Sample	Depth Inches	Texture	pH	C%	N%	C/N	Mg/g	Ex. Cations (meq/100g) Ca	Mg	Na	K	TA (meq/100g)	CEC (meq/100g)
June 18, 20	Burned	12	3-0	Fib.	4.50	13.31	0.68	19.5	0.002	7.3	6.1	0.26	0.47	40.7	54.6
		13	0-2	Gr.	4.58	1.49	0.11	14.9	0.001	1.8	3.8	0.12	0.16	1.0	6.9
		14	2-4	Gr.	4.43	1.04	0.08	13.7	0.00	1.8	2.7	0.11	0.14	-	4.7
		15	4-8	Gr.	4.70	0.68	0.04	18.9	0.001	5.0	3.0	0.10	0.13	-	8.2
	Unburned	16	4-0	Fib.	3.85	20.16	0.67	30.9	0.001	1.9	3.9	0.29	1.06	49.7	56.9
		17	0-2	Gr.	4.40	0.56	0.04	14.7	0.001	0.7	1.2	0.08	0.15	-	2.1
		18	2-4	Gr.	4.86	0.22	0.02	10.5	0.000	1.3	1.6	0.07	0.10	-	3.1
		19	4-8	Gr.	5.30	0.16	0.02	8.9	0.001	1.7	1.7	0.08	0.10	6.9	10.5
September 14	Burned	56	3-0	Fib.	4.44	26.65	1.03	25.9	0.012	9.7	9.0	0.21	1.33	64.4	83.6
		57	0-2	Gr.	4.98	1.46	0.08	18.5	0.00	3.7	3.7	0.11	0.22	28.8	36.5
		58	2-4	Gr.	5.17	0.73	0.04	20.3	0.00	3.3	2.5	0.12	0.14	27.3	33.3
		59	4-12	Gr.	5.26	0.38	0.02	17.3	0.00	2.7	1.9	0.13	0.10	20.2	25.0
	Unburned	52	4-0	Fib.	4.13	28.13	1.10	25.4	0.002	8.6	3.7	0.18	0.41	57.2	70.1
		53	0-2	Gr.	4.50	4.49	0.21	21.8	0.00	1.7	1.5	0.26	1.07	22.5	27.1
		54	2-4	Gr.	4.60	2.07	0.12	18.0	0.00	2.0	1.4	0.27	0.32	13.7	17.7
		55	4-8	Gr.	4.64	0.68	0.05	13.3	0.00	1.7	1.3	0.06	0.21	2.9	5.8

Comparing data from the Cement Creek area with that from Big Timber Creek (Table 1) discloses that pH of all samples was very strongly acid and did not appear significantly changed by burning. Carbon content data are inconclusive. Nitrogen appeared to decrease somewhat with burning in the organic layer and to increase with time at lower depths. Carbon to nitrogen ratios (C/N) of all horizons were slightly higher on burned soils. Phosphorous concentration was low and differences between burned and unburned appear insignificant. None of the exchangeable cations showed a consistent trend, with the exception of potassium which appeared to increase somewhat with burning. Cation exchange capacity of the organic layer decreased with burning, probably because of the destruction of organic matter as postulated by Klemmedson et al (1962). A significant portion of exchangeable cations is contributed by total acidity, which is to be expected for these acid soils.

Burning for the West Fork profiles was judged as light. All horizons of these soils were strongly to very strongly acid and burned and unburned profiles did not appear to be significantly different (Table 2). Carbon concentration in burned profiles was higher than in unburned profiles. This holds true for nitrogen content also, but for both elements, the trends were not consistent. This inconsistency was reflected in C/N, which varies widely, although it appeared to be greater in burned soils. Phosphorous concentration was low in these soils and differences are insignificant. Exchangeable cations behaved similarly to those noted for Cement and Big Timber Creek soil samples with potassium somewhat higher in the organic layer of burned soils. Cation exchange capacity is not significantly different between these profiles; total acidity contributed a majority of the exchange cations.

The profiles along Taylor Highway are considered to be the most representative of all sites because these profiles were extremely similar in texture, aspect and vegetation (Table 3). These soils are silty clay in texture and had the highest pH of all soils sampled in this study; two horizons of the burned soil sampled on September 14 were in the neutral range for soils. The only significant differences in carbon, nitrogen and C/N for these profiles appear in the organic horizons. In these horizons the burned soil contained more carbon than did the unburned soil before the soil had thawed. Later in the season, carbon was higher in unburned soil. Nitrogen behaved similarly, although the concentration in the burned soil was slightly higher in September. Trends for C/N were similar to those for C, but none of these trends establishes a definite pattern. Phosphorous content was low and differences were insignificant.

The burned soil contained more calcium and magnesium early in the summer; however, this weak trend appears to be reversed later in the season with the deeper horizons gaining these elements.

Sodium was low in all horizons and, aside from a small accumulation in deeper horizons late in summer, trends do not appear to be significant. Potassium behaved differently in these soils than in those described earlier. At the other sites burned organic layers contained more potassium than did unburned layers; here the reverse was true. Again, there seems to be a slight accumulation of potassium with time. Exchange capacity was high in the organic layers and was chiefly caused by total acidity associated with the organic matter. In the mineral horizons, the sum of bases contributed more to the exchange capacity; some of the least acid samples did not have any measurable total acidity. Cation exchange capacity was higher in the unburned organic layers except for the initial samples collected in May. The trends in the deeper horizons were erratic and not considered to be significant.

Soils on Logging Cabin Creek were not sampled in May; the first samples were collected in June when they had thawed to about 40 cm. Data for these soils are presented in Table 4. Soils at this site were gravelly (20-25% gravel) and developed on weathered schist that was disaggregated but retained its mineral identity. Burning was moderately severe on this site, although no mineral soil was exposed. Figures 3 and 4 are from these sites and illustrate the condition of the forest before and after the fire.

These soils ranged from strongly to extremely acid in all horizons with no significant differences between burned and unburned soil. Carbon content of the organic layer was higher in the unburned soil; otherwise, no definite trends appear. Nitrogen content under both conditions was not significantly different; the same held true for C/N except that C/N of the unburned organic layer was higher in June than was that of the burned soil. Phosphorous concentration was low and differences were insignificant as before. Calcium concentration was lower in these soils than in those discussed earlier and the burned soil contained more calcium at both sampling dates. Magnesium was similar to calcium both in concentration and behavior. The gravelly nature of these soils and the high acidity are probably contributing factors to this observed behavior. Sodium concentration, although detected, was low and differences between profiles were insignificant. Potassium content was erratic, being higher in the organic layer of the unburned soil in June that in September. Cation exchange capacity of these soils was caused mainly by total acidity; when total acidity was low, cation exchange capacity was low. No significant difference between burned and unburned soils was apparent.

In summary, these data do not show consistent trends on the effects of burning. Severity of burning seems to cause a decrease in cation exchange capacity of the organic layer and an increase in potassium because this element is released by burning. Phosphorous was low in all samples and no trends were apparent between burned and unburned soils. Calcium and magnesium contents did not exhibit any significant trends with burning although, on the gravelly soil at Logging Cabin Creek, both of these elements showed an increase with burning in the organic layer. Thus, texture seems to be a factor in whether burning causes enrichment of a particular element.

These analytical data do not entirely confirm results from other areas. Nitrogen and carbon are lost if burning is intense enough to consume the entire organic horizon because that is where most of them are present. Moreover, potassium seems to be enriched by burning. The presence of permafrost does not permit downward drainage of water within the profile, which normally occurs in thawed soils. This phenomenon should influence processes in the soil profile and cause elements to behave differently than that expected in warmer climates. At none of these sites was burning severe enough to entirely destroy the organic layer which on unburned soils was about 20 cm thick. Another significant observation is that the depth of thawing in September was nearly the same for burned as for unburned soils, both profiles thawing to about 70 cm. All profiles were very wet and cold (1.0°C at 30 cm) and roots of spruce trees were confined to the organic layer and the upper 6 cm of mineral soil.

Soil Saturation Extracts

In addition to the data obtained from analyzing soil samples, water extracts of these soils were analyzed for several constituents. Constituents of such extracts should be similar to concentration levels found in runoff from a saturated soil.

Extraction was done by Richard's funnel technique (Anonymous, 1965) and cations measured with an atomic absorption photometer. All water extract samples were stabilized with a few drops of mercurous chloride to prevent microbial activity. Total carbon of the extracts was measured with a Beckman Carbonaceous Analyzer* and conductivity with a Beckman bridge. These data are presented in Tables 5-8.

Comparing data from Cement Creek with those from Big Timber Creek (Table 5) shows that for the May samples, extracted total carbon from the unburned soil was approximately 1/10 that of the burned soil. However, by September, total carbon of the burned profile was much lower than in May, with the two profiles being about equal, except for the organic horizon. In the organic horizon the unburned soil was about five times that of the burned soil. Soluble calcium was much higher, up to 165 mg/l, in the burned soil, especially in May, and the organic horizon contained

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*Use of product and company names is for identification only and does not constitute endorsement by the U. S. Department of the Interior or the Federal Water Pollution Control Administration.

TABLE 5

CHEMISTRY OF SATURATION EXTRACTS FROM SOILS OF CEMENT AND BIG TIMBER CREEK PROFILES

		Sample	Depth Inches	Total C mg/l	Cations (mg/l) Ca	Mg	K	Cond. μmhos/cm
May 2	Burned	1	2-0	5250	165	12.8	-	455
		2	0-2	640	-	4.5	6.5	90
		3	2-4	410	21	3.8	5.0	118
		4	4-6	470	111	3.2	3.4	135
	Unburned	5	2-0	450	112	6.5	4.2	205
		6	0-2	66	62	7.3	4.8	210
September 12, 13	Burned	32	4-0	83	116	10.1	11.2	300
		33	0-2	47	28	5.3	2.4	145
		34	2-4	50	20	3.2	1.8	130
		35	4-8	42	20	2.5	1.8	118
	Unburned	28	3-0	2150	21	6.0	6.1	220
		29	0-2	56	13	6.7	1.6	188
		30	2-4	48	81	4.5	1.8	160
		31	4-12	48	-	10.5	2.0	170

TABLE 6

CHEMISTRY OF SATURATION EXTRACTS FROM SOILS OF WEST FORK PROFILES

Sample	Depth Inches	Total C mg/l	Cations (mg/l) Ca	Mg	K	Cond. µmhos/cm
7	2-0	630	50	5.3	15.7	245
8	2-0	38	10	1.7	1.7	59
9	0-4	30	38	2.5	3.9	80
40	3-0	2540	148	9.3	12.2	250
41	0-2	47	105	4.1	2.7	112
42	2-4	36	56	2.9	1.5	100
43	4-12	38	20	2.5	1.6	100
36	3-0	3750	84	5.3	8.9	170
37	0-2	55	35	4.5	3.1	130
38	2-4	36	128	4.3	2.9	122
39	4-12	29	43	3.8	4.1	120

TABLE 7

CHEMISTRY OF SATURATION EXTRACTS
FROM SOILS OF TAYLOR HIGHWAY PROFILES

		Sample	Depth Inches	Total C mg/l	Cations (mg/l) Ca	Mg	K	Cond. µmhos/cm
May 3	Burned	11-A	2-0	780	214	15.5	-	222
		11-B	0-2	46	199	8.2	2.0	155
	Unburned	10	0-2	52	27	10.1	-	200
June 20	Burned	20	4-0	45	100	4.3	2.3	145
		21	0-2	28	18	8.1	2.9	140
		22	2-4	24	21	5.9	1.9	112
		23	4-8	25	21	6.0	2.0	113
	Unburned	24	2-0	42	33	5.3	4.5	140
		25	0-2	35	18	7.7	3.0	150
		26	2-4	56	18	15.5	2.5	170
		27	4-8	26	56	5.4	1.5	120
September 14	Burned	44	2-0	9500	90	10.7	16.7	242
		45	0-2	48	11	8.7	1.0	225
		46	2-4	27	163	6.7	1.0	158
		47	4-12	87	-	12.5	1.0	150
	Unburned	48	2-0	5340	20	12.8	10.0	350
		49	0-2	4600	22	8.7	3.4	260
		50	2-4	540	90	7.4	2.5	195
		51	4-12	400	22	3.8	2.0	160

TABLE 8

CHEMISTRY OF SATURATION EXTRACTS FROM SOILS OF LOGGING CABIN CREEK PROFILES

Date	Treatment	Sample	Depth Inches	Total C mg/l	Cations (mg/l) Ca	Mg	K	Cond. µmhos/cm
June 18, 20	Burned	12	3-0	450	30	4.1	3.9	118
		13	0-2	610	20	9.9	2.8	160
		14	2-4	440	10	4.7	2.2	110
		15	4-8	340	30	3.8	2.0	95
	Unburned	16	4-0	2900	-	9.1	15.1	282
		17	0-2	74	13	4.3	4.2	138
		18	2-4	21	18	1.4	3.5	92
		19	4-8	12	-	23.0	2.0	71
September 14	Burned	56	3-0	2920	56	15.0	21.3	350
		57	0-2	1680	20	3.8	1.8	140
		58	2-4	368	109	3.2	1.5	115
		59	4-12	455	54	3.2	1.1	130
	Unburned	52	4-0	3540	54	5.1	11.8	160
		53	0-2	2300	20	3.0	5.3	120
		54	2-4	705	62	3.0	4.5	96
		55	4-8	850	15	2.8	4.8	130

116 mg/l of this element in September. Magnesium in the surface layer was 12.8 mg/l in the burned soil; however, in the mineral soil layers, it was approximately equal in all samples. Soluble potassium was considerably increased with burning and generally followed the trend set by calcium and magnesium. Specific conductance verifies these trends.

Table 6 presents data from the West Fork site, portraying trends similar to those just discussed. At this site burning was light, although spruce trees were killed. Higher concentrations of calcium, magnesium and potassium in these burned organic horizons indicate that the burning released salts.

At the Taylor Highway site (Table 7), trends in the distribution of soluble salts do not follow those for the preceding sites. Total extracted carbon in the organic horizon was 780 mg/l on burned soils in May, yet in June little difference existed. In September, total extracted carbon rose to 5340 mg/l in the extracts from the unburned soil, although the organic layer contained about half that of the organic layer of the burned soil. Calcium content was 214 mg/l in the organic layer of the burned soil early in the season, and in general the burned soils contained more of this element. Data for magnesium suggest that it was released in the burned organic horizon early in the season; however, later in the season these differences disappeared. Data for potassium are incomplete and the trends inconsistent.

Specific conductance verifies these inconsistencies. This soil has a finer texture and a higher pH than all other soils sampled in this study. These properties evidently must be considered as factors when evaluating the effects of burning.

In June at Logging Cabin Creek, total carbon in the organic horizon of the unburned soil was 2900 mg/l (Table 8). By the end of the summer both profiles were similar. Changes in calcium are insignificant in these profiles, although this is a moderately burned area. Magnesium concentrations are similar to calcium except that in September the magnesium content of the organic layer of the burned soil was 15 mg/l, which was higher than all other surface horizons. In June potassium content was 15.1 mg/l in the unburned organic layer; otherwise, these profiles were similar. By September both profiles showed high potassium in the organic layer, the unburned profile containing 11.8 mg/l, compared to 21.3 mg/l in the burned. Unlike the other three sites, conductivity at this site did not tend to increase in the organic layer of burned soil except in September. These soils behaved strangely during the procedure of making a saturating paste. They became very compact at saturation and any excess water appeared on the surface; moreover, these samples yielded a small volume of extract under vacuum. Such behavior probably results from the particle size distribution of these soils, which is an important factor in the compactability of soils.

The large potassium concentrations probably originated in the mica minerals so prominent in these profiles.

In summarizing these extract data, it appears that only the organic layer can be useful in indicating changes in soil chemistry caused by burning. This does not prohibit using other horizons of a profile under severe burning when the organic layer is destroyed; however, none of the sites sampled in this study had been burned severely enough to expose mineral soil. Almost without exception, extracts of the organic horizon yielded higher concentrations of total carbon, calcium, magnesium and potassium. Conductivity of these extracts was generally higher than those from the mineral soil horizons. Moreover, the volume of extract from the organic horizons was greater than those from mineral horizons. This suggests that burning may release significant quantities of soluble material which remains in the organic horizon. Since percolation is impeded by permafrost, excess water must be disposed of by surface or near surface (within the organic horizon) runoff. These processes would add soluble material to the streams and the soluble carbonaceous material from burned or unburned soils would color the water.

Water Chemistry

Samples were collected from the stations indicated in Figure 2 on May 5, 1967, September 19, 1967, May 3, 1968, and June 26, 1968. Samples were taken in plastic bottles or glass dissolved oxygen bottles, then transported to a field laboratory, where determinations of dissolved oxygen, pH and conductivity were made. In all cases, these analyses were made within six hours after collection. In situ temperature measurements were made with a calibrated thermometer reading directly to 0.1°C. Samples were then frozen prior to transportation and kept at a temperature of -70°C. Alkalinity was measured on an unfrozen sample taken to the laboratory at College.

After transporting to the Alaska Water Laboratory, samples were transferred to a freezer for storage at -20°C. Immediately prior to analysis, samples were thawed and, if analysis was not complete on the same day, refrozen until it could be completed.

Trace element determinations were made on a Beckman Model 979 or a Perkin-Elmer Model 303 atomic absorption spectrophotometer. In the case of calcium and magnesium, 1% lanthanum solution was added to the sample to prevent interference by phosphate and sulfate. In addition, calcium and magnesium were measured using the acetylene-nitrous oxide flame.

Iron, potassium, sodium, manganese and copper were determined by using the air-acetylene flame. In the Beckman instrument, the Beckman laminar flow burner was used; in the Perkin-Elmer instrument, the Boling 3-slot burner head was the principal burner, although for higher concentrations, especially for sodium, the short path burner head was used. In determining calcium and magnesium with the Perkin-Elmer instrument, the specially developed nitrous oxide burner head was used. As source lamps, the Westinghouse or Perkin-Elmer hollow cathode lamps were used for calcium, magnesium, iron, copper and manganese. Osram spectral-discharge lamps were used for sodium and potassium.

The azide modification of the Winkler technique was used for dissolved oxygen. Samples were fixed in the field by the addition of manganous sulfate, alkaline iodide azide, and sulfuric acid reagents, and transported to the field lab for titration. pH was measured in the field, using a Beckman Model N2 pH meter. Values were corrected to 25°C. Conductivity was determined, using an Industrial Instruments conductivity bridge and a cell with a constant of 0.1. Conductivity is reported as corrected to 25°C. Total hardness was determined by titration with ethylene diamine tetraacetic acid. Alkalinity was determined by titration with sulfuric acid to a pH of 4.60. In all cases total alkalinity rather than phenolphthalein alkalinity was recorded, as the pH of all samples was so low that phenolphthalein alkalinity was zero.

Chloride, sulfate, chemical oxygen demand, ammonia and nitrate were determined using Standard Methods, 12th Edition (1965). Nitrate was determined using the modified brucine method (Jenkins and Mesdker, 1964). Total and orthophosphates were determined colorimetrically by the method developed by Riley and Murphy (1962).

The effects of a major ecological disturbance on the general chemistry of a watershed and its reflection in the streams themselves might be observed in many ways. In unpopulated areas, the principal source of organic materials in gravel bedded, fast running streams is extraction from the soil organic layer by runoff water. An increase in runoff caused by removal of vegetative cover may result in an increased quantity of organic materials in the streams. This could also result in increased turbidity and color.

Waste products of the burning process may also be transported to the stream, either through surface drainage or wind action. These might include nutrient materials, particulate organic and inorganic debris, and soluble organic compounds resulting from the partial burning of plant materials.

Part of the study plan was to select two streams, one a control whose watershed was completely outside the fire area, and one with a similar watershed, but which was completely inside. Big Timber Creek was chosen as the control stream and Cement Creek as the experimental stream. Although these streams were quite similar in watershed type, both being westerly-flowing into the Dennison Fork of the Forty Mile River, this selection later proved to be poor. This is particularly evident when we observe the conductivity of these streams during the early May sampling periods in 1967 and 1968. During both of these times, the conductivity of Big Timber Creek was found to be much higher than that of Cement Creek. This is reflected in other measurements such as total hardness, trace elements, and alkalinity. As this time period should show the least effect of pollutants from the fire itself, these great differences would indicate that the selection of these streams for future comparison was poor.

Table 9 contains data collected from all stations. Samples taken in May show temperatures very close to 0.0°C, since there was considerable ice cover at all stations. At a few stations the water samples may have been surface water running over anchor ice. The nonavailability of helicopter transportation caused cancellation of a scheduled trip to the area in June 1967; hence, chemical samples were not collected. However, on June 26, 1968, temperatures in the rivers were approaching their maxima. It is interesting to note that temperatures in the lower rivers, such as the Dennison and the West Fork, were quite high, with a maximum of 11.9°C, whereas the stream tributaries of these rivers, Cement Creek and Big Timber Creek, were as low as 3.5°C.

TABLE 9

MISCELLANEOUS CHEMICAL ANALYSES OF STREAM WATERS

	STATION	5 May 1967	19 Sept 1967	3 May 1968	26 June 1968	5 May 1967	19 Sept 1967	3 May 1968	26 June 1968	5 May 1967	19 Sept 1967	3 May 1968	26 June 1968
		DISSOLVED OXYGEN (Mg/l)											
Burned	CC 100	12.1	11.34	12.2	10.6	7.10	6.75	7.0	6.48	0.2	3.0	0.0°	5.5
Burned	CC 200	12.2	11.45	12.0	11.2	7.05	6.67	6.9	6.50	0.2	2.8	0.0°	4.5
Burned	D 200	11.7	11.23	12.2	10.1	7.10	7.27	6.9	6.90	0.4	3.9	0.0°	11.9
Burned	W 100	11.0	10.70	12.4	9.9	7.08	6.80	6.9	6.92	0.3	5.2	0.0°	11.7
Unburned	D 100	12.0	11.4	7.0	9.4	6.90	7.27	6.7	-	0.5	3.1	0.0°	10.8
Unburned	D 300	8.4	11.23	7.6	9.7	6.93	6.90	6.7	6.85	0.4	4.3	0.0°	11.4
Unburned	T 100	12.1	11.2	12.3	11.2	6.40	6.90	7.6	6.69	0.5	-	0.0°	3.5
Unburned	T 200	12.0	10.7	12.0	11.0	6.60	6.75	7.3	6.50	0.4	4.5	0.0°	3.5
Unburned	W 200	7.2	10.6	12.3	9.3	7.00	6.80	6.7	6.88	0.5	4.8	0.0°	11.3
		HARDNESS TOTAL as $CaCO_3$				CONDUCTIVITY µmho/cm. CORR. to 25°C				ALKALINITY As $CaCO_3$			
Burned	CC 100	36.9	56.9	44.9	34.0	100	77	122	46	10.0	13.0	28.0	9.7
Burned	CC 200	41.8	41.1	39.2	22.0	112	84	114	51	10.0	14.8	23.0	9.8
Burned	D 200	41.0	26.5	27.5	26.8	110	58	76	57	16.0	18.6	23.6	19.4
Burned	W 100	41.3	26.5	32.6	52.8	104	66	94	54	16.6	14.8	15.0	17.6
Unburned	D 100	42.6	30.8	61.2	20.0	122	60	147	54	17.0	18.8	52.6	21.3
Unburned	D 300	72.2	33.6	51.6	35.4	126	66	123	52	58.4	16.4	42.4	17.1
Unburned	T 100	148.6	25.7	147.9	21.6	275	66	342	39	75.8	15.6	86.4	11.7
Unburned	T 200	97.3	26.1	102.0	17.4	190	55	235	32	62.2	14.0	78.0	9.4
Unburned	W 200	75.8	28.8	44.9	28.0	178	90	119	51	42.2	13.8	12.0	15.7

TABLE 9 (Continued)

	STATION	5 May 1967	19 Sept 1967	3 May 1968	26 June 1968	5 May 1967	19 Sept 1967	3 May 1968	26 June 1968	5 May 1967	19 Sept 1967	3 May 1968	26 June 1968
		CALCIUM, Mg/l				MAGNESIUM, Mg/l				IRON Mg/l			
Burned	CC 100	9.0	6.9	12.1	5.7	5.1	0.2	3.4	2.6	0.22	0.43	.14	.10
Burned	CC 200	10.5	10.2	10.8	5.8	5.4	0.8	4.2	2.7	0.18	0.32	.14	.20
Burned	D 200	9.0	6.6	7.4	10.3	5.2	0.2	1.9	2.0	0.21	0.50	.10	.20
Burned	W 100	9.8	10.5	7.7	8.3	5.1	0.2	3.7	2.8	0.23	0.56	.10	.35
Unburned	D 100	10.7	8.4	15.3	7.6	5.6	0.6	4.9	1.5	0.24	0.38	.06	.20
Unburned	D 300	15.9	13.5	13.8	6.8	8.6	1.5	3.5	3.8	1.65	0.56	.10	.20
Unburned	T 100	36.6	11.7	21.2	6.4	19.2	1.3	13.6	1.6	0.07	0.56	.06	.35
Unburned	T 200	25.6	44.4	23.6	3.6	11.4	3.1	9.6	0.8	0.07	1.02	.06	.20
Unburned	W 200	17.4	8.1	10.5	10.2	9.5	0.6	3.8	2.9	1.52	0.56	.18	.20
		POTASSIUM, Mg/l				SODIUM, Mg/l				MANGANESE (Mg/l)			
Burned	CC 100	8.8	.93	4.6	0.7	2.9	2.7	4.4	4.4	0.18	.05	.02	.01
Burned	CC 200	8.5	.75	4.8	0.7	4.2	2.6	4.6	3.9	0.29	.04	.02	.01
Burned	D 200	8.2	.63	3.7	0.6	5.8	2.2	3.5	4.4	0.19	.05	.02	.03
Burned	W 100	7.6	.54	5.2	0.6	3.4	2.2	3.5	4.8	0.18	.06	.00	.03
Unburned	D 100	8.7	.65	1.00	0.7	3.9	2.2	7.3	4.5	0.19	.03	.75	.05
Unburned	D 300	2.0	.67	0.6	0.7	7.0	2.6	4.4	4.9	0.24	.05	.25	.05
Unburned	T 100	3.6	.78	2.6	0.8	11.5	2.8	7.85	4.2	0.10	.06	.13	.02
Unburned	T 200	2.7	.10	1.6	0.5	7.2	2.9	7.7	4.4	0.10	.15	.10	.03
Unburned	W 200	2.0	.47	4.6	0.5	14.7	2.2	3.0	4.2	1.04	.05	.04	.03

TABLE 9 (Continued)

	STATION	CHLORIDE (Mg/l) 5 May 1967	19 Sept 1967	3 May 1968	26 June 1968	COPPER (Mg/l) 5 May 1967	19 Sept 1967	3 May 1968	26 June 1968	SULFATE (Mg/l) 5 May 1967	19 Sept 1967	3 May 1968	26 June 1968
Burned	CC 100	4.6	2.0	2.7	2.4	.02	.05	.02	.01	19.0	16.2	16.8	79.8
	CC 200	3.2	1.5	2.7	1.2	.02	.01	.01	.01	29.2	17.0	14.4	80.7
	D 200	3.3	1.2	2.8	1.5	.02	.041	.02	.05	20.5	12.2	8.3	36.0
	W 100	3.7	1.5	2.4	4.2	.009	.005	.02	.01	15.1	16.7	14.9	17.0
Unburned	D 100	3.5	1.2	2.0	2.4	.024	.0025	.02	.023	20.3	14.2	10.4	36.0
	D 300	1.4	1.3	1.8	2.0	.018	.0145	.02	.05	15.8	17.4	7.2	66.0
	T 100	1.1	1.5	1.2	1.4	.02	.035	.01	.01	52.0	16.7	67.4	14.0
	T 200	0.9	1.7	0.9	1.4	.009	.0533	.02	.023	24.6	27.5	32.7	23.0
	W 200	5.0	1.4	2.4	2.0	.008	.0145	.01	.01	17.6	16.9	24.0	36.5

	STATION	TURBIDITY (Mg/l)	COD			
Burned	CC 100	4.4	94.0	55.3	82.3	-
	CC 200	2.6	87.4	42.9	84.8	-
	D 200	6.0	92.9	43.0	75.9	-
	W 100	3.7	102.6	66.4	87.0	-
Unburned	D 100	8.3	94.4	48.0	51.6	-
	D 300	3.7	67.0	64.5	35.4	-
	T 100	3.7	44.1	65.8	43.6	-
	T 200	10.6	40.6	74.5	25.6	-
	W 200	4.4	42.5	65.5	75.5	-

By September the temperatures had dropped; the highest temperature found in September 1967 was at the lower reach of the West Fork, where temperature was 5.2°C. Temperatures also seemed to be quite similar throughout the system; by this time Cement Creek and Big Timber Creek were be ween 3 and 5°C.

Samples collected immediately prior to the ice breakup on the streams (that is, those collected in May) were primarily composed of groundwater during low runoff conditions, as is reflected in the conductivity measurements. However, in September 1967 and June 1968 the samples were composed of groundwater mixed with surface water. This was especially noted on June 26, 1968, when samples were collected following a period of heavy rainfall which significantly diluted the waters. September 1967 followed a summer of abnormally heavy rainfall throughout interior Alaska. For this reason the usual fall low-flow conditions did not prevail.

Organic materials introduced into the system from erosion or surface transport of detritus from the fire area might be expected to cause a lowering of dissolved oxygen in the waters. However, the dissolved oxygen concentrations in Big Timber Creek, completely outside the burned area, appear to be quite similar to those found in Cement Creek, within the burned area. On May 3, 1968, the lowest Dennison station indicated a lower dissolved oxygen concentration than the upper stations and also a great deal lower than the West Fork. The reason for this depletion is unclear.

Organic material transported from the burned site to the river system as a result of increased erosion should be reflected in an increase of the chemical oxygen demand of the water. This does appear to happen, as shown by comparison of Big Timber Creek with Cement Creek in May 1967 and 1968. Chemical oxygen demand values of Big Timber Creek are less than half of those found in Cement Creek. Observation of the West Fork and the Dennison Fork show similar trends, the chemical oxygen demand concentrations increasing as these streams enter the fire areas. Little change or, as on May 3, 1968, an actual decrease was noted in the chemical oxygen demand concentrations of the Dennison Fork as it left the fire area.

The fact was mentioned in the soils section that the conductivity of extracts of the burned layer was usually higher than that of the unburned layer. In addition, certain metals, particularly calcium, magnesium and potassium, were found to be higher in these same extracts. We found this trend to be reflected in the flowing waters, as a principal source of these constituents should be the extraction by surface water and subsequent transport to the streams.

Conductivity of the streams, however, did not appear to be influenced by the fire. The highest conductivity measurements found were on Big Timber Creek, completely outside the fire area. In almost all cases, conductivities were lower in the lower reaches of the streams--Big Timber Creek being the exception. The apparent anomaly to this statement is the case of the lower Dennison station, which is invariably higher than the station inside the fire area; this may result from groundwater influences in that area. This may also be an explanation for the low dissolved oxygen mentioned above.

Trace element concentrations in the streams should be similarly affected. These may be more easily seen than the conductivity changes, as conductivity is a gross estimate of all ions. Specific concentrations thus might be more indicative of true effects. Potassium concentrations appear to show the most pronounced increase in waters flowing through the burned area, Big Timber Creek showing consistently lower potassium concentrations than Cement Creek. The West Fork consistently had higher values of potassium in the lower stations than in the upper station. The Dennison Fork does not show such pronounced changes. This is probably because it is a much larger stream, much of which is outside the burned area, and the total effect would not be as noticeable as in a smaller stream, such as Cement Creek, whose watershed lies entirely within the fire area.

Neither magnesium nor calcium shows effects similar to that of potassium. The highest concentrations of these ions were usually found in Big Timber Creek, which accounts in part for its high conductivity. Trace metals, iron, manganese and copper also do not show any particular trends that might be attributed to the fire. Sodium, which frequently shows trends similar to potassium, does not appear to do so here.

Of major importance to the biological community are the nutrient cycles (Table 10). Nitrogen and phosphate content of the water is of particular interest here, as they are primary food sources for phytoplankton. Nutrient cycle changes noted here that could be explained as resulting from the fire are questionable. Total and orthophosphate are consistently higher in Cement Creek than they are in Big Timber Creek. The West Fork and the Dennison also show an increase in phosphate concentrations in areas within the fire area as compared with upstream stations, but these changes are not uniform: e.g., Cement Creek does not show consistent changes. In addition, increases in nutrient concentrations downstream are typical of most streams. Big Timber Creek shows an increase in phosphates downstream, except for total phosphates sampled on May 5, 1967, and orthophosphate are not available for May 5, 1967, and June 26, 1968.

TABLE 10. NUTRIENT CHEMISTRY ON STREAM WATERS

STATION	5 May 1967	19 Sept 1967	3 May 1968	26 June 1968	5 May 1967	19 Sept 1967	3 May 1968	26 June 1968	5 May 1967	19 Sept 1967	3 May 1968	26 June 1968
	NITRATE (Mg/l)				NITRITE (Mg/l)				AMMONIA as N			
CC 100	.01	.12	.05	-	.78	.01	.00	.00	2.+	1.1	1.7	1.0
CC 200	.01	.32	.06	-	.65	.00	.00	.00	2.+	0.7	1.8	1.2
D 200	.01	.13	.03	-	.73	.01	.00	.00	2.+	0.9	1.8	1.4
W 100	.01	.07	.03	-	.88	.01	.00	.00	2.+	1.4	1.8	1.4
D 100	.01	.12	.08	-	.825	.01	.00	.01	2.+	1.23	1.10	1.7
D 300	.02	.08	.07	-	.400	.01	.00	.00	1.42	1.31	0.78	1.3
T 100	.00	.00	.04	-	.295	.00	.00	.00	0.89	1.09	0.67	1.008
T 200	.00	.02	.04	-	.250	.02	.00	.00	0.88	1.31	0.59	0.903
W 200	.01	.00	.18	-	.290	.01	.00	.01	1.41	1.17	1.64	0.575

STATION	5 May 1967	19 Sept 1967	3 May 1968	26 June 1968	5 May 1967	19 Sept 1967	3 May 1968	26 June 1968
	PHOSPHATE - Total				PHOSPHATES - Ortho			
CC 100	0.50	.14	1.60	.022	-	.03	1.30	-
CC 200	0.44	.21	1.00	.000	-	.05	1.16	-
D 200	0.63	.17	1.20	.067	-	.04	0.81	-
W 100	1.03	.11	1.51	.220	-	.04	0.98	-
D 100	0.91	.25	2.58	.06	-	.03	0.00	-
D 300	0.04	.22	1.01	.03	-	.05	0.02	-
T 100	0.04	.20	0.81	.00	-	.07	0.06	-
T 200	0.50	.17	0.72	.00	-	.09	0.02	-
W 200	0.01	.13	1.32	.17	-	.03	0.45	-

A similar pattern is observed with respect to the nitrogen cycle. Examination of results for ammonia, nitrite and nitrate indicates that Cement Creek was consistently higher than Big Timber Creek. The West Fork shows increase in ammonia only, nitrate and nitrite changing insignificantly or lowering as the stream enters the fire area. Changes in the Dennison Fork are slight and not considered to be significant.

pH does not appear to reflect changes due to the fire. Changes in Cement Creek and the West Fork appear insignificant. In general, this is also true of the Dennison Fork; although station D-200 shows a considerably higher pH than D-300, this trend does not continue to station D-100.

In summary, it would appear that the only significant changes observed in the streams under regular flow conditions would be increases in chemical oxygen demand, resulting from added organics, and possibly potassium.

It might be expected that during periods of increased runoff, suspended sediment would increase in streams draining the fire area due to increased erosion. This was not noticed during any of our sampling periods; however, as is mentioned elsewhere, deep erosion ditches were observed where cat trails were made in attempts to control the fire. In addition, a local resident who operates a lodge on the Dennison River below the fire area remarked that the river, which is used as a water source, could not be used during high runoff periods after the fire because of the sediment loads.

Stream Biology

To evaluate the effects of a large scale forest fire on the aquatic organisms within the burned area becomes an ecological study. Broadly defined, ecology is the study of interrelations between living organisms and their environment. Therefore, to understand the reason why change has or has not taken place, one must study not only the organisms, but also the environment.

In a forest fire such as this, the aquatic environment was disrupted during and after the fire. During the fire, smoke reduced the amount of sunlight entering the stream, which could interfere with the emergence pattern of the aquatic insects. Soot, ash and other debris entered the water and the water temperature itself may have been raised because of the fire. After the fire, the burned-over soil and duff layer had been altered. Sooner or later these changes manifest themselves in the chemical constituents of the water in the streams. These changes, if drastic enough, affect the aquatic organisms within the streams.

These aquatic organisms are an extremely diverse conglomeration of animals and plants that forms a closely knit community, each member of which is affected in some manner by every other organism in the community. Ideally, to evaluate the effects of such a fire, one should be able to look at this entire community; however, this is virtually impossible because of restrictions in time and resources. Therefore, a portion of the whole must be examined with the hope that what has happened to the entire group can be predicted from that portion. The decision of which portion to examine is not easy in itself. Since the primary producers are the start of the food chain, should they be studied? If so, what can be told about the intermediate links or the end of the food chain, the fish? Perhaps the fish population should be studied, since it is that portion of the community in which man is most interested. Unfortunately, the fish populations within the streams in the study area do not lend themselves to the type of study to which we were restricted. For example, there is a movement of fish up and downstream in relation to temperature and other factors, and since it was only possible to take samples at predetermined times, a distorted picture might be obtained.

So, after these considerations, the macro fauna portion of the benthos was chosen for study. This lends itself nicely to such a study because its organisms are quite stable, with life cycles ranging from several months to several years. They can be adversely affected because the fire interferes with emergence and may have other effects. They are able to reestablish themselves rapidly. And finally, they are a very important portion of the community because they are important food items of fishes.

The benthos is in reality a community within the larger aquatic community, consisting of a very diverse group of animals for which the degree of diversity is dependent upon water quality. For example, in clean, unpolluted mountain streams such as those in this study, the benthos consists of many different species with no great numbers of individuals within one species.

When something happens to the environment which changes the quality of the water, making it more desirable for one species than another, that species or group of species becomes dominant in number and the entire community composition changes. If, on the other hand, a condition develops which wipes out a section of the entire community and that condition is subsequently removed, the area becomes repopulated quite rapidly by drifting organisms, upstream migration, repopulation by flying adults or egg-laying adults, or other means (Larrimore, 1959; Frey, 1961; Macan, 1963).

Generally speaking, this aquatic community is fundamentally different from terrestrial plant communities, where one or a few plants establish dominance and become a potent influence upon the other members of the community (Macan, 1963). This is logical since the animals which constitute this community are motile and are not so restricted in their diet that they cannot take advantage of changing food supplies. They also differ from plant communities in that their numbers fluctuate greatly during the course of a year, and this is a disadvantage when using them as indicators of pollution. However, if there is an awareness of this fluctuation and its causes, it can be overcome. To do this, a sampling schedule must be established that will sample the population at its various stages and will compare like populations. With this in mind, the sampling schedule was established.

As mentioned before, it is very likely that the population was affected somewhat during the actual fire. This is especially true since many of the forms studied have an emergence pattern coinciding with the fire. However, it was impossible to study the population during or immediately after the fire, so the first sampling period was set for the following spring just prior to breakup. This period was selected in an attempt to establish the condition of the population before it was exposed to whatever effects the fire might have had on the population through the flushing action of melting snow during breakup. Prior to this sampling period, a buildup of bottom ice in the streams made collecting a representative bottom sample impossible.

The next sampling period was set for approximately June 1967, or such a time when the river returned to normal after breakup. This sampling period was selected to evaluate any effects which were brought about by runoff from the burned area.

It was to take place immediately after breakup, but before the population had an opportunity to readjust itself after runoff. This series of samples was never collected because helicopter transportation was not available. However, in an attempt to salvage something from this sampling period, samples were collected from one station on the West Fork which was in the burned area. These were not from stations designated in the original plan. The third or fall sampling period was selected to measure the reproductive capacity and over-wintering populations within the stream. This sampling trip was successful in all ways.

The fourth sampling date was again before breakup in the spring of 1968. Once again, icing conditions made it impossible to collect reliable biological samples.

The last sampling period was after breakup in 1968 and again established to determine whether there were any further effects due to runoff the second year after the burn. This again was only partially successful because of extremely heavy rains in the area, which made it impossible to collect representative samples from Cement Creek and Big Timber Creek.

The exact sites of the nine stations described earlier were carefully selected to insure similarity of bottom type, riffle versus pond area, and bank cover. Since the composition of the benthic community is determined by these and other factors, it was important that all sites be similar in order to have similar community composition. Apparently there was a high degree of success in the site selection, since sample communities from the various sites were closely related. Figure 16 portrays an example of the method used for quantitative sampling of the benthic community with a Surber sampler.

The schedule of sampling periods and stations just described was selected to sample the benthos at important intervals in the post-fire history of the area and would have produced valuable information on the effects of such a fire on the aquatic fauna had it been followed. Unfortunately, the schedule could not be followed and as a result, the data are scattered to the extent that it is hazardous to draw definite conclusions. However, several factors are worthy of note.

When utilizing the community concept as a tool to evaluate the effects of a catastrophe on the aquatic environment, it is necessary to examine the community both qualitatively and quantitatively. If the catastrophe has had a drastic effect, the diversity of the community will have been disrupted and it will have changed, with new species entering, or groups of organisms missing. If, on the other hand, the effect has not been drastic, it is possible that no groups have been eliminated, but that the standing crop has been affected. In that case the quantitative data are of value. However, quantitative data are difficult to analyze and evaluate since the standing crop tends to fluctuate considerably during the course of a year and truly representative samples are difficult to collect. In this study we utilized both methods in an attempt to evaluate the effects of this fire.

In analyzing the data, we find there were only three taxonomic groups (from this point forward they will be referred to as taxa groups) present above the fire, while there were seven taxa within the fire area and five below the fire area in the Dennison Fork in September, 1967 (Table 11). In June 1968, there were 12, 18, and 12 taxa respectively (Table 11). Close scrutiny of the tables reveals no significant differences within the stations. The difference in numbers of taxa between the two sampling dates is probably due to the time of the year. The quantitative data from Dennison Fork also show no significant differences.

In September the numbers ranged from 33.1 organisms per square meter in the station in this upper unburned area to 79.1 in the middle station and 202.4 in the lower station (Table 12). Annelids and dipterans dominated the lower two stations, but the percentage of plecopterans was high in the upper station. This probably resulted from environmental conditions unrelated to burning, since the same condition did not exist in June 1967.

In June 1968 numbers per square foot ranged from 1357.9 in the upper station to 4164.8 in the middle station and 201.5

TABLE 11

A QUALITATIVE COMPARISON OF ORGANISMS COLLECTED
FROM THREE STATIONS ON THE DENNISON FORK, CHICKEN, ALASKA

ORGANISM	September 14, 1967			June 26, 1968		
	D-100	D-200	D-300	D-100	D-200	D-300
Oligochaeta						
Naididae	X	X		X	X	X
Hirudinea						
Piscicola sp.						
Arachnida						
Hydracarina			X			
Plecoptera						
Isoperla sp.		X	X		X	X
Alloperla sp.					X	X
Ephemeroptera						
Ephemerella sp.	X	X		X	X	
Rhithrogena sp.				X		
Ironodes sp.				X	X	
Ameletus						X
Trichoptera						
Polycentropus sp.					X	
Lepidostoma sp.				X	X	X
Micrasema				X		
Ptilostomis					X	
Phryganea					X	
Limnephilus	X	X	X		X	
Brachycentrus						X
Coleoptera						
Helodidae						
Diptera						
Tipulidae						
Prionocera sp.		X		X		X
Tipula sp.	X					
Simuliidae						
Prosimulium				X	X	X
Chironomidae						
Cricotopus sp. A	X	X				
Smittia				X	X	X
Procladius		X		X		
Nanocladius				X		
Cricotopus sp. B.				X	X	
Ablabesmyia					X	
Pseudochironomus					X	
Micropsectra					X	X
Chironomus						X
Tabanidae					X	
Ceratopogonidae						
Dasyhelea					X	
Mollusca						
Pisidium						X
GROUP FREQUENCY	5	7	3	12	18	12

TABLE 12

NUMBER AND PERCENTAGE OF ORGANISMS PER SQUARE METER OF BOTTOM FROM THREE STATIONS ON DENNISON FORK IN 1967 AND 1968

ORGANISM	September 14, 1967						June 26, 1968					
	D-100		D-200		D-300		D-100		D-200		D-300	
	1*	2**	1	2	1	2	1	2	1	2	1	2
Annelida	128.8	63.6	30.4	38.4	6.4	19.4	67.2	33.3	36.8	0.9	416.8	30.7
Plecoptera	0.0	0	2.8	3.5	9.2	27.8	9.2	4.6	34.0	0.8	2.8	0.2
Ephemeroptera	12.0	5.9	0.0	0	2.8	8.3	39.6	19.6	168.4	4.0	34.0	2.5
Trichoptera	15.6	7.8	15.6	19.7	2.8	8.3	18.4	9.2	110.4	2.7	18.4	1.4
Diptera	46.0	22.7	30.4	38.4	12.0	36.2	67.2	33.3	3815.2	91.6	886.0	65.2
TOTAL	202.4	100	79.1	100	33.1	100	201.5	100	4164.8	100	1357.9	100

*1--Number of organisms per square meter
**2--Percentage of total numbers per square meter

in the lower station. This would seem to be a significant difference. However, there was an influx of blackfly larvae before this sampling period. Blackfly egg clusters are attached to rocks and when they hatch, the larvae tend to remain attached to the rocks in great numbers. Therefore, if the sampler, when placed at random in the stream, covers one of the rocks that harbor the blackfly, great numbers are collected. On the other hand, had the sampler failed to cover the rock where the great mass of larvae was attached, only a minimal number or even one would have been collected. This probably explains the great variation in number. Once again, the annelids and dipterans dominated the community in all stations (Table 12).

As expected, the data from the West Fork show the same trend of larger numbers of taxa in June 1968 than in September 1967. In 1967 there were five groups in the upper unburned area and six in the burned area, while in 1968 there were 15 in the unburned and 18 in the burned area (Table 13). It is highly improbable that the fire was responsible for the larger numbers of groups within the burned area, even though this is consistent within all of the streams. It is more probable that this is because of ecological differences in the environment, due perhaps to elevation, groundwater intrusion or stream gradient. Annelids and dipterans once again dominated the quantitative data in the West Fork (Table 14) as they did in the Dennison Fork.

TABLE 13

A QUALITATIVE COMPARISON OF ORGANISMS COLLECTED FROM TWO STATIONS ON THE WEST FORK, CHICKEN, ALASKA

ORGANISM	September 14, 1967		June 26, 1968	
	WF-100	WF-200	WF-100	WF-200
Annelida				
Naididae	X	X	X	X
Arachnida				
Hydracarine			X	X
Plecoptera				
Hastaperla *sp*.			X	
Isoperla *sp*.		X	X	X
Pseudocloeon *sp*.				X
Ephemeroptera				
Ephemerella *sp*.		X	X	X
Ameletus *sp*.			X	
Ironodes *sp*.			X	
Centroptilium *sp*.				X
Trichoptera				
Lepidostoma *sp*. A	X	X	X	X
Lepidostoma *sp*. B			X	
Brachycentrus *sp*.			X	X
Platycentropus sp.			X	
Ptilostomis *sp*.			X	
Micrasema *sp*.				X
Polycentropus *sp*.				X
Diptera				
Deuterophlebiidae				
Deuterophlebia *sp*.				X
Tipulidae				
Prionocera *sp*.	X			X
Simuliidae				
Prosimulium *sp*.			X	X
Chironomidae				
Pentaneura *sp*.			X	X
Cricotopus *sp*.	X		X	X
Crionomus *sp*.			X	
Smittia *sp*.			X	
Diamesa *sp*.			X	
Tanytarsus *sp*.	X			
Dolichopodidae	X	X		
Group Frequency	6	5	18	15

TABLE 14

NUMBER AND PERCENTAGE OF ORGANISMS
PER SQUARE METER OF BOTTOM FROM TWO STATIONS
ON WEST FORK IN 1967 AND 1968

ORGANISM	September 14, 1967				June 26, 1968			
	WF-100		WF-200		WF-100		WF-200	
	1*	2**	1	2	1	2	1	2
Annelida	67.2	52.5	6.4	11.1	138.0	11.8	110.4	8.6
Plecoptera	2.8	2.2	2.8	4.8	0.0		0.0	
Ephemeroptera	0.0		0.0		124.2	10.6	55.2	4.3
Trichoptera	12.0	9.4	12.0	20.6	41.4	3.5	100.4	8.6
Diptera	46.0	35.9	36.8	63.5	869.4	74.1	1002.8	78.5
TOTAL	127.9	100	58.0	100	1173.0	100	1278.8	100

1* - Number of organisms per square meter
2** - Percentage of total numbers per square meter

However, where the Plecoptera were the next most frequent organisms in the Dennison, the Trichoptera held that position in the West Fork. In neither of the two sampling periods was there a significant difference in either the diversity or the total number of organisms per meter.

The next four stations that were compared consist of two stations on Big Timber Creek lying outside the burned area and two stations on Cement Creek lying inside the burned area. Since the gradient in these streams is quite steep, it is necessary to compare stations from comparable areas on the two streams. Group frequency in all cases was very low, since the data consist of only the September 1967 sampling period. There is, however, no significant difference in either the qualitative or quantitative data (Tables 15 and 16). Of ecological interest is the fact that the Annelida are no longer a significant portion of the total number in these two creeks, but the Plecoptera are the dominating group.

When it became apparent that we would not be able to collect samples from the prescribed sampling points during the June 1967 sampling period, a series of samples was collected from one site on the Mosquito Fork draining an unburned area and one set of samples from the West Fork, draining a portion of the burned area. These rivers were not wholly comparable, but were closely enough associated to supply some data for that time

TABLE 15

A QUALITATIVE COMPARISON OF ORGANISMS COLLECTED FROM BIG TIMBER AND CEMENT CREEK, CHICKEN, ALASKA
September 14, 1967

ORGANISM	STATION T-100	C-100	T-200	C-200
Oligochaeta				
Naididae			X	
Hirudinea				
Piscicola sp.		X		
Plecoptera				
Isoperla sp.	X	X	X	X
Brachyptera sp.		X	X	
Ephemeroptera				
Epeorus		X		
Cinygmula sp.			X	
Trichoptera				
Ecclisomyia sp.	X	X		
Brachycentrus sp.	X			
Limnephilus sp.		X		
Diptera				
Tipulidae				
Tipula sp.	X			
Chironomidae				
Cricotopus sp.				X
Rhagionidae				
Antherix sp.	X	X		X
Group Frequency	5	7	4	3

TABLE 16

NUMBER AND PERCENTAGE OF ORGANISMS
PER SQUARE METER OF BOTTOM FROM TWO STATIONS
ON CEMENT AND BIG TIMBER CREEK ON SEPTEMBER 14, 1967

ORGANISM	T-100		C-100		T-200		C-200	
	1*	2**	1	2	1	2	1	2
Annelida	0.0	0.0	6.4	2.7	6.4	3.3	2.8	0.7
Plecoptera	174.8	86.4	122.4	50.6	150.0	77.6	199.6	53.5
Ephemeroptera	15.6	7.7	12.0	4.9	2.8	1.4	2.8	0.7
Trichoptera	2.8	1.4	0.0	0.0	0.0	0.0	2.8	0.7
Diptera	9.2	4.5	101.2	41.8	34.0	17.7	165.6	44.4
TOTAL	202.4	100	242.0	100	193.2	100	373.5	100

1* - Number of organisms per square meter
2** - Percentage of organisms per square meter

of the year. The qualitative data indicate no difference in the two streams. There were 12 taxa representing the unburned area and 11 in the burned (Table 17). It is of interest to note that on the West Fork, a burned area was represented by 11 taxa in 1967, but a similar area in 1968 was represented by 18. There is a possibility that this might be the result of fire or the original runoff from the fire. This is only conjecture, however. The quantitative data (Table 18) is again biased by large numbers of blackflies. If they are removed from the data, there is no significant difference.

The quantitative data represented in this paper consist of three $0.092m^2$ (1 $ft.^2$) samples for each station and sampling period. All of these data were subjected to the t-test for related measures. In no case was there a difference in the two groups at the 95% confidence limit. The qualitative data are represented by 1/2 hour of concentrated effort with a dip net, covering all representative areas in a sampling site.

The data discussed above suggest that the effects of the fire on the benthic macro-organisms were negligible or so ephemeral that they returned to normal in a short time before it was possible to evaluate the effects. There is some indication that there may have been fleeting effects due to the fire or fire control methods. It is difficult to imagine that the erosion noticed in the cat trails mentioned earlier in the paper did not at some

TABLE 17

A QUALITATIVE COMPARISON OF ORGANISMS COLLECTED FROM THE WEST FORK AND THE MOSQUITO FORK ON JUNE 18. 1967

ORGANISM	MOSQUITO FORK	WEST FORK
Plecoptera		
Isoperla sp.		X
Alloperla sp.	X	X
Brachyptera sp.	X	X
Ephemeroptera		
Ephemerella sp.	X	X
Trichoptera		
Lepidostoma sp.	X	X
Brachycentrus sp.	X	X
Ptilostomis sp.	X	X
Diptera		
Simuliidae		
Prosimulium sp.	X	X
Tipulidae		
Tipula sp.		X
Chironomidae		
Polycentropus sp.	X	
Pentaneura sp.	X	X
Smittia sp.	X	
Cricotopus sp. -A	X	
Cricotopus sp. -B		
Rhagionidae		
Atherix sp.		X
Group Frequency	12	11

TABLE 18

NUMBER AND PERCENTAGE OF ORGANISMS

PER SQUARE METER OF BOTTOM FROM MOSQUITO FORK AND WEST FORK

ON JUNE 18, 1967

ORGANISM	Mosquito Fork		West Fork	
	1*	2**	1	2
Plecoptera	144.4	12.1	14.1	4.5
Ephemeroptera	126.0	10.5	58.0	1.9
Trichoptera	172.0	14.3	223.6	7.2
Diptera	757.2	63.1	2695.6	86.4
TOTAL	1200.0	100	3117.9	100

1* - Number of organisms per square meter

2** - Percentage of organisms per square meter time increase the turbidity in the streams enough to cause some damage to the organisms present. However, if there was some damage, it did not extend into our sampling periods, or it was so slight that our methods were not sensitive enough to measure it.

Even though we have been able to show some changes in the chemical makeup of the water, especially some of the nutrients and potassium, these changes must have been below the magnitude necessary to effect a change in the portion of the aquatic population we examined. To further substantiate this hypothesis, fish collected from the burned area were no more difficult to obtain than from outside the area and were in good physical condition, feeding voraciously on the aquatic insects from the streams.

General Discussion

Data and observations collected during this study failed to show that the fire had any significant detrimental effect on soils, waters, or benthic organisms. Despite its size and the vast numbers of trees killed, very little mineral soil was exposed by burning all the organic layers. A possible reason for this is the total thickness of the organic layers; their lower several inches remain wet even during hot, dry summers. Moreover, permafrost did not thaw deeper than about 29 inches, even where burning was most severe, and the entire thawed profile remained very wet and cold. Another possible reason is that in these forests, fuel is insufficient to produce a fire hot enough to dry and burn the lowest duff layer. Most of the trees are standing and little fuel is lying on the ground.

Analysis of soil did not show any reliable trend in soil properties caused by burning. Potassium content of the duff layer might be offered as an exception, although the differences between burned and unburned soil are small. On the other hand, analysis of water extracts of these soils did produce evidence that salts and soluble organic substances are released by burning. Burning evidently releases organics, potassium, and small quantities of calcium and magnesium, but these remain as soluble substances and do not penetrate into the soil. Instead they remain in the duff layer and are removed by runoff waters. The presence of permafrost prevents percolation of soil waters; hence any soluble material remains near the surface. We conclude, therefore, that analysis of water extracts is sufficient to detect changes in soil chemistry caused by forest fires in Alaska.

Even though there was no statistical evidence that the fire had caused changes in the biota of the streams, there were some indications that there may have been some early effects from the fire. It is unfortunate that it was impossible to collect pre-breakup samples because they would have been most indicative of any immediate effects of the fire. It will be well to note that early winter samples may be the answer to problems encountered in pre-breakup sampling.

It is also unfortunate that the entire first set of June samples could not be collected, since indications from the two sets not originally in the sampling schedule but collected at that time are that populations were lower in June 1967 than in June 1968. Of course, this is only conjecture, since there is only one set of samples to compare. This difference in population could be the effect of the fire through reduction of standing crop or possibly the inability of the organisms to reproduce due to the time of the fire.

Chemical and soil data indicate a rise in COD and potassium. At no time did the potassium concentrations rise to a level that would be harmful to the aquatic organisms. On the other hand, COD levels could have a very definite effect. It is doubtful that the small increase in numbers of organisms in the burned area can be attributed to the increase in COD; however, it is possible that an increase in COD in streams such as those studied here would be beneficial for the entire food chain of organisms at the levels measured in this study.

Although trees were killed, even with moderate to light burning, most shrubs remained alive and in September 1967 we noted that most of the shrubs were growing and that the darkest burned areas were turning green, caused by shrubs and grasses that had invaded the area (Figure 12). In June 1968 we noted that over much of the entire burned area the shrub understory was recovering and with the invading grasses (see appendix) gave the appearance of rapid recovery from the effects of burning. However, this did not apply to the trees killed by the fire, which remained black, standing testimony to the eradication of this portion of the forest community over much of the burned-over area.

Burning appears to cause a marked increase in the brown color of streams draining a burned-over watershed. Observations from the air during breakup in May 1968 showed that Cement Creek was distinctly more highly colored than was Big Timber Creek, above the fire. This verifies the chemical data, both from soil extracts and water samples. The significance of this increase in soluble organics is a moot point; however, it is one established fact that fires do cause this increase.

Erosion arising from the fire appeared to be a minor contributor to increased turbidity during runoff after heavy rains, except for the color. Few landslides were observed and these were on very steep slopes that may slide whether the slope was burned or not. Although relatively minor from the total effect standpoint, several cat trails were observed to be contributing high silt loads to the streams. It was only where the cat trails were in small valleys or in the stream course that this erosional process was observed (Figure 13). Where these trails were in shallow soils or on rocky ridges, erosion did not appear to be significant.

A major contributing factor to the erosion of fire lines is the melting of permafrost caused by removing the organic layer in building fire lines. In deep silty soils, generally in the bottom of valleys, melting permafrost is the chief agent responsible for the increased silt load arising from the fire.

Wickstrom (see appendix) observed several areas of more widespread landslides in a portion of the burn not studied by us. Here extensive landslides appeared to be the result of protective cover removal by fire and not due to mechanical means during fireline construction.

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We wish to acknowledge the cooperation of the Bureau of Land Management in furnishing helicopter transportation within the fire area and several flights from Fairbanks and the fire area for reconnaissance, and to Merric Helicopters for providing excellent air transportation to reduce overland walking to a minimum in difficult terrain.

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APPENDIX

FIRE Y-34

FIRE RECOVERY, WATER POLLUTION & EROSION OBSERVATIONS

June 6, 1968

by

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FIRE Y-34 FIRE RECOVERY, WATER POLLUTION AND EROSION STUDY

On June 6, 1968 a trip was made by helicopter to the area of Fire Y-34 for the purpose of orientation of PSC and Forest Science Lab personnel as well as to establish transects and photo points. Present for the trip were myself, Jerry Wickstrom, Fairbanks District Wildlife Specialist; Glenn Lipscomb, PSC; Jim Hagihara, PSC; and Dr. Leslie Viereck of the Forest Science Lab at the University of Alaska.

General observations of the fire found that erosion activity was at that time becoming active. The large erosion channel on the west side of the fence which was examined in the fall of 1967 was dumping a large stream of muddy water into the Dennison River. Cat lines on the east side of the fire in the Liberty Creek drainage were the most active, although temperatures were not yet high enough to actively thaw permafrost along the erosion channels. Numerous slides were observed to have occurred on severely burned areas of the fire--especially on the Liberty Creek side. Most of these were the result of natural thawing and slippage as a result of the fire and not mechanical disturbance. One large slide on the east side of the fire was initially started by minor tractor disturbance. This was observed to be starting in the fall of 1966 at which time the tracks of the cat were still visible at the head of the slide. The cause of this slide is no longer apparent.

Vegetation was continuing to come in strong except for cat lines. The lower two-thirds or more of most slopes were heavily covered with sedges, grasses (Calamagrostis) and eriophorim. Intermixed with the grass and sedges were blueberry, cranberry (Vac. Vitis-idea), dwarf birch, willow and ledum.

On the highest slopes and ridges above 2500 feet, revegation of blueberry, ground cranberry, dwarf birch and willow was just beginning. On severely burned areas and cat lines, no revegetation was noted. In addition to the resprouting shrubs, small mosses such as Polytrichum are beginning to appear, as well as Epilogium, scattered fescues and Calamagrostis grasses and, infrequently, various forbs. One common plant--crowberry (Empetrum nigrum)--was not noted to have sprouted at any location examined.

It was hoped to establish many more transects and photo points than the six that were accomplished; however, it was found to be quite time consuming to locate representative sites and then establish and read the transects. The transects and photo points that were established are accessible with some effort without a helicopter; however, if future observations of this burn are made, it will probably continue to be most expedient to utilize a helicopter. The transect and photo point locations are shown on the 1-inch-to-the-mile map. See also Illustration #1 for transect layout diagram.

During the summer of 1968 additional flights were made over the area and persons familiar with the area were questioned concerning the water quality of the Forty Mile River. It was observed that after a rain period or heavy rainfall, the Forty Mile River was turned as brown as the Tanana with silt pouring in from eroding cat lines and from the burn itself. Outside the fire area, the Dennison, the West Fork of the Dennison, the Mosquito Fork, Dewey Creek, Walker Fork and Liberty Creek remained completely clear or became only slightly off-color during these periods. Mr. and Mrs. Bob McComb of South Fork Lodge, long-time residents of the Chicken area, stated that the water quality of the Forty Mile River was worse at times than they had seen during days of active mining. The McCombs have used Forty Mile River water for domestic purposes for years; however, since the fire, sediment has been so heavy on occasion that the water is scarcely usable.

Walker Fork of the Forty Mile River, which borders the fire on the east, is another clear water stream which exhibits extreme muddiness during periods of rainfall. This stream borders a BLM campground and was never observed to be muddy at any time before the fire, according to information that could be gathered from local residents and from personnel and other BLM observations of this stream previous to the burn. Starting from the campground, a fire line was cut up the valley approximately 2-1/2 miles to the burn. This line is severely eroded and was actively dumping sediment into Walker Fork in 1968. Liberty Creek, which dumps into Walker Fork, also carries a heavy load of silt during runoff periods.

As a result of observation on this fire and on others on which I participated in control operations, I have come to the conclusion that much of the damage caused by erosion as a result of control methods is unnecessary and could be prevented through adoption of some simple guidelines for cat line construction and rehabilitation. Erosion can be prevented or lessened on permafrost areas, steep slopes and loess materials by doing the following:

1. Put cat lines on ridges, not in drainage bottoms. Even if the bottom is dry, it may not be the common situation. The most active erosion occurring on Y-34 is the result of a cat line in a drainage bottom. The small stream in the bottom was dry in 1966, but now, especially in spring, it runs strongly and has transferred its path into the cat line, which is rapidly eroding and dumping silt into the Forty Mile River.

2. Construct cat lines on ridges and slopes in such a manner as to prevent water from running more than 30-50 yards. Methods of constructing line on permafrost to prevent erosion are shown in Illustration #3. Standard water barring will not work on permafrost ground.

3. Construct standard water bars on non-permafrost areas. These will be sufficient in most cases to prevent erosion.

4. Halt all cat line construction at least 50 feet and preferably 100 feet from the edge of all lakes and streams (Illustration #3). Timber in the remaining strip can be walked or cut down, burned out or a hand line cut through if necessary. Stream banks have been areas of extreme erosion in the past.

5. Seed the critical areas on the cat lines with adapted species such as Polar Brome, meadow foxtail, or bluegrass. This can be accomplished by crews who are patrolling the fire line. Seeding rate should be 15-20 lbs. per acre or to 1/4 mile of 33-ft. cat line. It would also be a good idea to apply 10-20-20 fertilizer at a moderate rate if possible. Planting of grasses should not in most cases be carried out past the middle of August.

If seeding cannot be accomplished at the time of the fire, it should be delayed until probably late April or early May of the following year and then seeded by helicopter.

6. Rehabilitate cat lines if at all possible while heavy equipment is on the fire. If preventive work is not accomplished immediately, the lines will be too soft to work on until freeze-up in October. Trial rehabilitation efforts were started on fires O-E-7, Z-40, and Z-76 at Chicken in September 1968 using the method shown in Illustration #4. It was found that the cat

lines were much too soft to operate on and work was postponed until after freeze-up. The principle to be employed on post-fire rehabilitation of critical areas involves pushing the berm across the line at 35- to 50-yd. intervals, depending on slopes. Seeding is planned to follow on these areas in the spring of 1969. Inasmuch as this has been planned as a trial effort, a number of variations in seeding and barrier construction will be tried and evaluated during the next year.

Conclusion

It is my conclusion that Fire Y-34 has destroyed approximately 200,000 acres of good to excellent caribou winter range. It is now rapidly revegetating itself, following the general vegetative ecological succession pattern as outlined by Lutz (1956). The amount of potential moose range created is felt to be minimal and a poor trade for the caribou range lost. From observations of this fire during its course and for two years afterward, it was observed that:

(a) revegetation starts immediately on the lower slopes and wetter areas with the sedges, fire weeds and willows beginning to sprout almost immediately.

(b) In the fall following the fire, these foregoing species and grasses will be strongly prevalent on at least the lower 1/3 of all slopes.

(c) Revegetation in the upper slopes and ridges can be expected to begin to occur in the second season following the fire, especially Calamagrostis grass, dwarf birch, Vaccinium Vitisidea and Vaccinium uliginosum, and Epilobium.

(d) Severely burned areas will not show any revegetation by two years following the burn.

(e) Cat lines can be expected not to start any meaningful revegetation within two seasons of the fire. On the wetter lines when erosion was not active, a scattered growth of very small mosses was apparent in the fall of 1968.

(f) Erosion can be expected to start almost immediately on cat lines on permafrost areas and be especially active for the first two seasons following from the permafrost melt and intermittently active thereafter as the result of light to moderate rainfall.

(g) Erosion on cat trails probably is not serious on over 10% of the total lengths.

(h) Considerable slippage, leaching, slides and erosion channels develop on severly burned slopes without mechanical disturbance. In many cases the silt from such erosion does not reach drainage waters because of the isolated pattern of slippage and the vegetal debris interrupting its flow.

(i) Cat line erosion has contributed significantly to the siltation of formerly clear streams.

(j) Prevention of cat line erosion is possible if the procedures outlined in this report ary followed in fire line construction.

(k) Rehabilitation of cat lines is felt to be possible. Final analysis of current rehabilitation work will give a basis for judgment and decision on procedure.

(l) Intermittent studies of this fire should be continued to actually determine the ecological succession rates of lichens. Complete aerial photos of the area are available, which will enable later reference as to location, degree of burn and general vegetative type present at the time of the burn.

(m) Continued studies should be made on the rate of erosion progress and recovery of the fire. The current Alaska Water Laboratory study and report should give a good indication of what has happened to water quality.

FIRE Y-34

WATER POLLUTION-FIRE ECOLOGY STUDY (SEPTEMBER 1968)

FIRE Y-34

WATER POLLUTION-FIRE ECOLOGY STUDY (SEPTEMBER 1968)

The third scheduled sampling period for the water pollution study was completed on the Chicken burn the week of September 12-15, 1967. Persons taking part included Dr. Fred Lotspeich, Ernst Mueller and Paul Frey of the Alaska Water Laboratory, and Jerry Wickstrom of the Bureau of Land Management. This sampling was actually the first complete sampling, since biological sampling was also completed. No biological samples had been taken in the previous spring sampling, and the second sampling period in June was cancelled because of the fire outbreak. In addition to the sampling, some time was available for general observation by the Wildlife Specialist of vegetative recovery of the burn and effect of erosion on the burn.

Originally, it was planned to continue the project two more days to provide the time to study the vegetative aspects of the area and establish some plots, transects, and photo points. Water flow measurements were also to have been taken by the University of Alaska Water Institute. Members of the Alaska Department of Fish and Game and the Forest Science Laboratory were unable to take part in the study, as originally hoped for.

None of this extra study was accomplished because of the mechanical failure of the helicopter on September 15, which caused it to be crash landed on the south side of the Dennison River near South Fork Lodge, with moderate damages.

Observations

During the course of the water study, most of the cat lines on the north side of the fire were flown over. Vegetative recovery of these lines has been slight. The only vegetation present are patches of very small mosses. Most of the lines cut in the bottoms along the contour line are very wet, with water standing in much of the swath. Little erosion has occurred on these areas or on the higher ridge sites, which are for the most part rocky and dry. Some slumping has occurred on the trails crossing permafrost areas in the bottom. Severe erosion has occurred on creek banks at crossing points and on trails on the north slopes that cut across contour lines.

Some erosion observed was already 5-15 feet deep and 5-20 feet wide and over a mile long. This is coming about because of the melting of the ice lenses and permafrost and the active erosion of the melted water, plus the natural drainage waters of the slopes. It is likely that such erosion is now uncorrectable and that erosion will continue to increase until the sides slump to a natural angle of repose or until bedrock is reached. In some spots, bedrock has already been exposed; however, in other places the overlying soil, composed primarily of loess, may be 50-100 feet deep.

Little erosion was noted in the burn where mechanical disturbance had not occurred. There was some weeping of silt on burned sedge-black spruce slopes where the fire had burned intensely.

Severe erosion was noted by other BLM personnel near Walkers Fork, and erosion involving large portions of hillsides has been observed, starting in the fall of 1966 when the first examination of the fire was made. These two areas were not examined on this trip, because of the helicopter failure.

It does not appear that severe erosion is occurring on or over 10% of the total length of cat trails; therefore, it is felt that prevention or prompt correction of a similar situation is feasible.

Vegetative recovery on the burn has been rapid on parts of the burn itself, but very slow on the cat lines. On the burn, recovery has been rapid in the bottom and lower half of the slopes, but negligible on the ridge tops and upper drier slopes.

Sedge and grasses are coming back in well and provide 50% or more covering on the wetter slopes. Willow (believed to be Sebb) has returned very well and in some locations it is estimated that a willow plant or sprout occurs on approximately every 10-20 square feet. These plants were very obvious from the air because of their yellow green color. Plants have sprouted to maximums of 20 inches. Tom Paine drainage, which was uniformly burned over its entire area, appears very green with regeneration of sedges, grasses (Calamagrostis) and willows. Other species noted that have reappeared are Ledum and dwarf birch.

The 53 Mile Taylor Highway burn of the early 1950's was flown over to evaluate the vegetative recovery of an area similar to Y-34. It was originally intended to land and make a close evaluation of this burn; however, this could not be accomplished because of the helicopter failure. From the air, the Taylor Highway burn appeared to be completely covered with vegetation--mainly grasses, sedges, and shrubs. Trees that have come back on this site are made up, it appears almost entirely of aspen and birch; little willow was noted.

Recommendations

It is recommended that the study be continued next spring to complete the ecological and erosion observations not completed this fall.

In the future, cat trails on north slopes or following drainages should be covered following the fire with the old vegetative material scraped aside. This may not be possible in the case of an early fire. If the trail is not covered, erosion will proceed so rapidly that preventive measures will have little chance of success.

It is recommended that plans be investigated by fire control to alter control methods in permafrost areas, north slopes and bottom areas so that erosion is prevented. Methods must also be investigated as to the feasibility of erosion prevention on cat trails that must be cut on permafrost areas. This is especially important in stream bank areas where trails enter river bottom.

The best time to engage in rehabilitation work is while the trail, construction of water barriers, covering limited areas with straw mulch or wood chips, and seeding. The last solution is probably suitable for only limited areas such as stream banks.

Attached to this report are a number of pictures showing erosion damage and vegetative recovery. Most of these pictures were taken in the small drainage in Sections 1 and 12, T 25 N., R. 17 E., CRM, and Section 7, T 25 N., R. 18 E., CRM (see attached map). It is planned to establish a permanent measurement system on this erosion area to measure the rate at which it proceeds and stabilizes.

As use of heavy duty equipment increases, there will be increasing occurrence of erosion with destructive effects on fisheries and stream values because of the silting. Potential cures or preventatives for the problem are needed. The problem occurs not only on fire cat lines, but on other trails used by the Army, miners, and hunters. Permanent scars and vegetative changes result in the disturbed areas and it is likely that some type of regulation will be necessary to protect fragile areas. The BLM should take the lead in preventing or correcting such damage caused by cross country travel or fire control activities.

Note: The illustrations, maps and photographs which Mr. Wickstrom mentions are not included here, but are available at the Fairbanks office of the Bureau of Land Management.