

Use of Thermistors for Spring Road Management

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The purpose of this paper is to discuss the use of subgrade temperature data, measured by permanently installed temperature sensors called thermistors, to administer spring road restrictions on asphalt surface roads within the Kootenai National Forest (northwestern Montana). The restrictions normally apply to logging trucks (three axles plus two axle trailers—approximately 80,000 lb gross). The interpretation of the data from the thermistor installations has provided an acceptable, rational approach to timing the spring restrictions. At present there are about 70 thermistor strings scattered over 300 miles of roads. Data are collected on the thermistor strings starting in December on a weekly basis, a schedule that is stepped up to daily readings as thaw conditions approach. The readings from just below the asphalt mat and the average reading for the whole string are analyzed with weather forecasts for use in predicting the need for load restrictions. The actual restrictions are placed when the thermistors located just below the mat on one or more strings indicate a thawed or nearly thawed condition. The success of the program can be attributed to the effort put into an information and education program aimed at the principal users and Forest managers. Problems with installations have been minor. Each thermistor string installation ranges in cost between \$250 and \$450; however, during the past 3 yr, surface maintenance repair costs have been reduced significantly (up to 50 percent annually on some roads).

The purpose of this paper is to discuss how the data collected from thermistor installations on the Kootenai National Forest are used to determine when road restrictions should be placed in the spring. It is a report on the effectiveness of the thermistor program that has been working since it was initiated in 1984. Those interested in the technical details on materials, equipment, testing, procedures, research, and installation should read the paper prepared by McBane and Hanek in 1986 (1). This paper minimizes the duplication of technical details covered in their paper.

The thermistor program on the Kootenai National Forest has provided road managers with a cost-saving tool. The idea to use thermistors on the Kootenai was brought to the Forest by Hanek and McBane in the early eighties. They were trying to find a way to lower road maintenance cost due to spring break-up. The success of the program on the Forest can be attributed to their information and education efforts.

Currently, there are nearly 70 installations on paved roads used by timber haulers (see Figure 1). These installations are monitored periodically during the winter months and the data are collected. The data are interpreted and used to determine when to apply haul restrictions on specific roads or road segments. The timeliness of the recent restrictions has resulted in reduced road maintenance costs. On the whole, the program has been very successful, with only a few minor problems.

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BACKGROUND

The Kootenai National Forest is located in northwestern Montana, with a small portion occupying northeastern Idaho. On the north it is bounded by British Columbia, Canada. Figure 1 is a map showing the general location of thermistor strings on the Kootenai National Forest. In all, about 2.5 million acres (1.0 million hectares) of federal lands are managed by the Forest. These lands are intermingled with privately owned lands and are accessed by more than 6,600 miles (11,000 km) of Forest Service roads plus many county and private roads. Federal Routes 2 and 93 and Montana State Routes 37, 56, and 508 provide access to county and Forest Service roads. Elevations range from the lowest in Montana, about 1,800 ft, to over 8,700 ft (540 to 2650 m). Precipitation ranges from 14 in. to 120 in. (35 to 300 cm), with much of it falling as snow during the winter months. Frost penetration often exceeds 5 ft (1.5 m).

The Forest Service is in a unique situation to manage its road system because technically it is not a public road agency. It not only has the administrative authority to restrict size, weight, speed, and type of vehicle, but it can also close roads to all motorized vehicles. With the ability to close roads or severely restrict their use, the Forest Service very seldom designs roads to support traffic loads for all-season use because of the additional cost required to provide for the few weeks of worst subgrade conditions. Most low-volume roads elsewhere in the world are not built to provide all-season, full traffic load support for the same economic reason.

In addition to the 6,600 miles (11,000 km) of existing road under Kootenai National Forest's jurisdiction, about 180 miles (300 km) are added annually. Most of the roads were and are being built to accommodate timber hauling. The roads include narrow single-lane, native surfaced (5 to 15 mph—8 to 25 kph); single and double lane, aggregate surfaced (10 to 35 mph—17 to 58 kph); and single and double lane, asphalt paved (15 to 55 mph—25 to 92 kph). About 6 percent of the Forest's roads are paved. Pavements vary from a penetration treatment with a single chip seal to 4 in. (10 cm) of asphalt concrete mats.

Higher volume roads in the Kootenai National Forest may have seasonal daily traffic volumes of up to 300 vehicles, of which one third are log haul vehicles (typical five axle, 18 wheels with a gross weight of 80,000 lb, or 36 metric tons).

REASON FOR PROGRAM

The Kootenai National Forest has 420 miles (700 km) of asphalt-paved roads, of which only about 10 percent are capable of

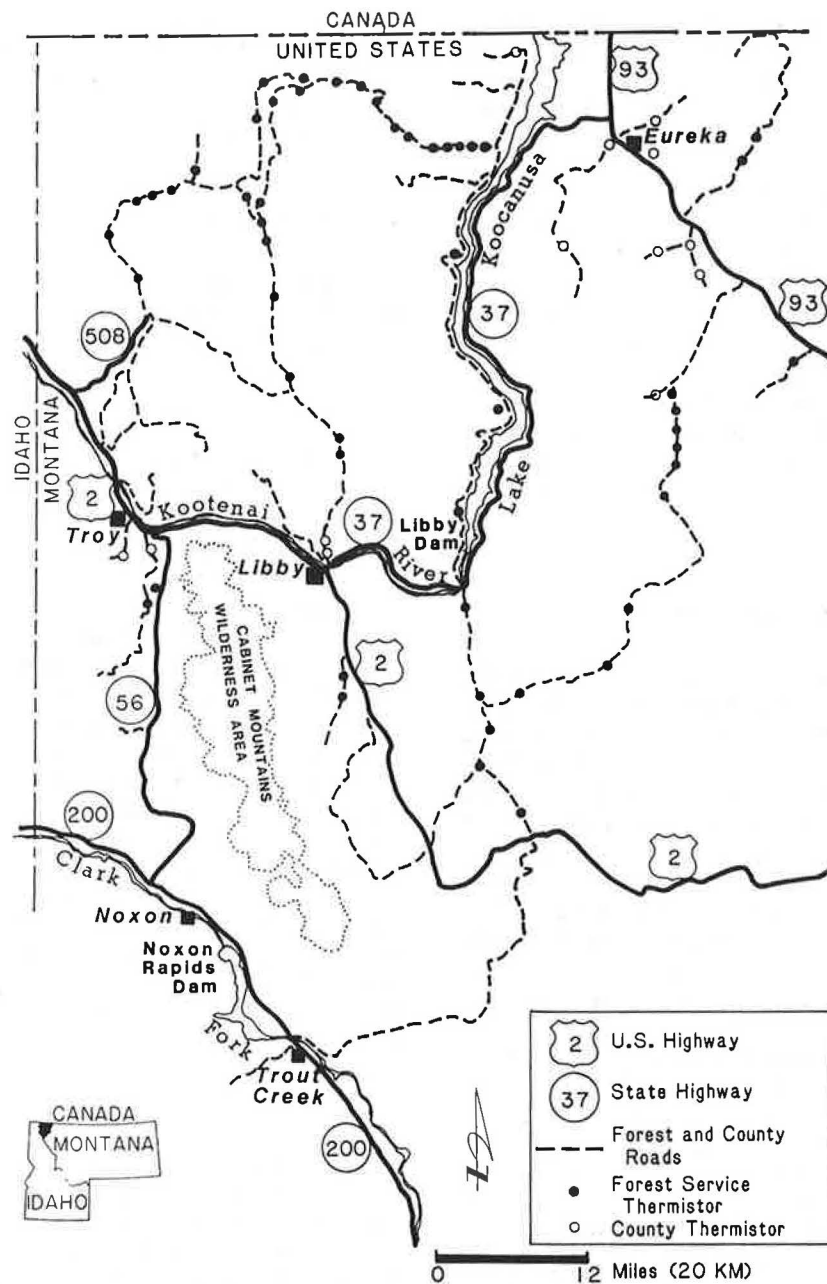


FIGURE 1 Thermistor locations on Kootenai National Forest.

handling year-round traffic. Those roads capable of handling year-round traffic were built by the Corps of Engineers in conjunction with the Libby Dam Project and were later turned over to the Forest Service. None of the roads has been designed to prevent frost heave. Roads can be constructed to prevent frost action if free draining aggregates are used, but the Kootenai National Forest could not economically justify the aggregate thicknesses needed. To protect roads during periods when thawing is occurring in the top few feet where the structural strength is weakest, haul restrictions have been applied for many years. In the past, decisions to restrict the roads were based on visual observations of the pavement surface and ambient air temperature conditions.

Visual observations normally detect damage only at the pavement surface. During break-up, initial damage that is not

visible occurs to the underlying structure. In the past, there were disagreements with timber haulers when Forest Service management wanted to restrict road use, because the haulers were normally trying to build up their mill inventories in anticipation of haul restrictions. As a result, haul was most often allowed until visual surface damage was noted; therefore, maintenance costs for paved roads were excessive.

Reducing the maintenance costs for paved roads was deemed paramount. It was perceived that, by measuring the pavement structural capacity during the thawing period, Forest Service management would have better information from which to determine more accurately when to apply restrictions before serious damage occurred to the road structure. Actual measurements of the pavement deflection were either expensive, cumbersome, or untimely. It was decided that temperature

measurement of the base and subgrade could be used to establish in a timely manner when a road was thawing, and haul restrictions could be placed accordingly.

The road structure initially starts to weaken when the frost starts to leave the base just under the asphalt mat and before all the base and subgrade was thawed. At this time the moisture from the melting ice is trapped between the impervious frozen layer below, the edges of the pavement structure, and the asphalt mat above. Even the base, normally constructed of free draining rock, may become supersaturated as snow on the shoulders can insulate it, retarding thaw and thus preventing free water from escaping to the ditch line. The weakened condition often persists until the whole structure is totally thawed and the excess water can drain from the base and subbase. Several destructive conditions can occur when the road is in this weakened condition: contamination of the base, rutting of the base and subgrade, and cracking or breaking up of the asphalt mat.

INFORMATION AND EDUCATION PROGRAM

There was strong support for reducing the costs of maintaining paved roads, but there was no commonly understood, quantitative basis for consistently and fairly placing the necessary limits on timber hauling. The designers of the system, McBane and Hanek, performed their greatest service by developing an excellent informational and education program. Through their efforts in making presentations to Forest Service management, timber haulers, and county personnel, they were able to sell their concept and get a consensus on what measured conditions would cause administrative haul restrictions to occur. Cooperation was excellent when it came time to restrict roads in the spring on the basis of the thermistor readings.

The information and education program was primarily based on the narrated slide program but together by McBane and Hanek. In their program they covered past research, calibration testing of actual thermistors (ice water baths), laboratory testing of soils (determination of freeze-thaw temperature for typical soils in the area), typical installation of thermistor strings, use of the Benkelman beam (to correlate road structure strength and depth of thaw), and how the temperature data collected could be analyzed and interpreted. Their thorough explanation left little doubt in their audience's mind of the program's soundness.

Generally the cooperation has been good throughout the Forest Service and by users of the road system. There is, however, a continuing need to keep newcomers informed about the process.

GLOSSARY

Thermistor sensor is a small semiconductor where the electrical resistance varies with temperature fluctuations.

Thermistor string is a multistrand electrical cable with several thermistor sensors attached and sealed at specified intervals.

Thermistor installation consists of a thermistor string placed in a vertical hole below the road surface, lead cable, a ther-

mistor sensor for air temperature, and a readout box to which the electric thermometer can be attached.

Electric thermometer measures electrical resistance in a circuit through a thermistor sensor and displays the correlated temperature reading.

INSTALLATIONS

A thermistor string used on the Kootenai National Forest is made of multistrand cable, eight or more thermistors, and an electronic box for taking data readings (see Figure 2). The thermistors are soldered and sealed to the last 3 to 5 ft of the cable. This portion is then inserted vertically into a core drill barrel after the inner barrel has been removed (cave-in is often a problem). The spacing of thermistors on a string has been standardized for preassembly; however, they are not spaced for all the varied conditions that could be found. At any specific site, spacing can easily be varied to meet the conditions that are determined to be necessary for monitoring.

The Kootenai National Forest has determined that reliable information can be obtained when the top thermistor is placed in the asphalt mat; the second is placed just below the asphalt mat; the third is placed 6 in. below the asphalt surface; the fourth, fifth, and sixth are placed 12, 18, and 24 in. below the surface; and the remaining are normally placed at 1-ft intervals below the sixth. One thermistor is mounted in the shade (referred to as #0 on figures) to record air temperatures near the readout box. Twenty to 40 ft of cable separate the thermistor from the data collection box.

At the present time there are 67 thermistor string installations on paved roads used by timber haulers. Thirteen of these are on county roads and the remainder on Forest Service roads. The installations have been placed only under bituminous surfaces. These are the Forest Service heavy-use roads that are more often in the valley bottom where thawing first occurs.

With the lower elevation and heavy-use roads restricted, it was determined that the higher elevation and branch roads did not need to be monitored through the use of thermistors. There are several reasons why it was felt that branch roads and higher elevation roads need not be monitored. Investments in the branch roads are considerably less. Normally they are not paved, and excess moisture is readily visible on the surface, easily permitting a decision to restrict hauling to be made on these observations. When the higher elevations begin to thaw, timber harvest is normally curtailed as a result of excess moisture in the forest soils. Therefore, timber hauling normally ceases. The locations for individual thermistor installations have been selected with care. Normally, at least two sites are selected for each segment of road—one to try to match the earliest thaw and the other, the latest thaw. Elevation and the amount of exposure to the sun are major criteria in selecting locations. Often two sites are selected close together, one in a sunny spot and the other in a shaded area. This gives a better indication of how the overall road is thawing.

Initial restrictions are placed at the time thaw begins or shortly after thaw begins in the warmer sites. Sometimes the damage that occurs on the 200- to 400-ft (60- to 120-m) stretch of road around the warmest site is more acceptable than to restrict the entire road a few days earlier. After the subgrade

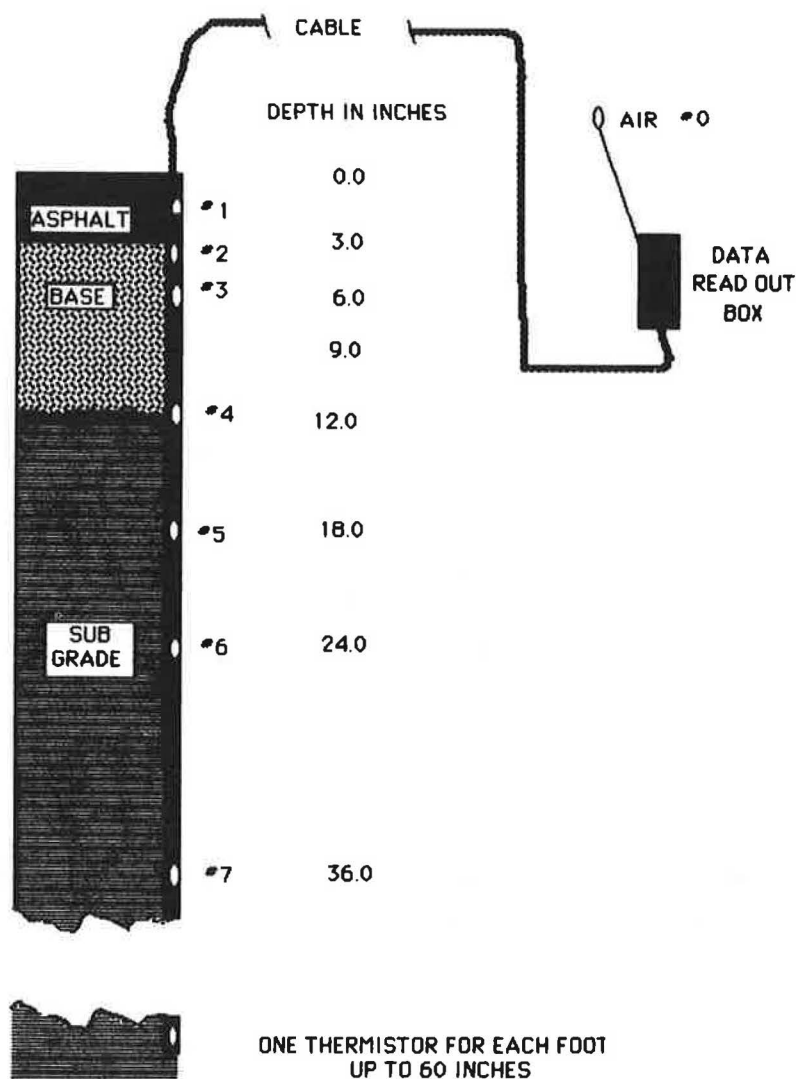


FIGURE 2 Typical thermistor string installations.

has thawed on the colder sites, consideration is given to lifting the restrictions.

DATA AND INTERPRETATION

Data readings of the individual thermistors normally start in December and continue through March. Higher elevation installations are read even later. Frequency of readings may start biweekly or weekly and then be increased to daily readings as weather conditions and thermistor data indicate that thaw conditions are imminent. A hand-held electric thermometer is plugged into the circuits, and individual sensor readings are taken and recorded manually. The collected data are then entered in a computer.

The temperature at which thawing starts is the critical information sought. This happens at around 31.7°F (-2°C), because of the chemical consistency of pore water in the area soils (1).

The temperature data from individual sensors on a thermistor string are aggregated to produce a weighted average

(1). Graphs of the average readings of individual installations are used for ease in spotting warming trends (see Figure 3). By putting a trend line on the temperature plots and projecting it through the thaw point, an estimate of the beginning of thawing at the site can be made. The interpreted trends, combined with the weather forecast, are used to make predictions on when break-up will occur. Typical data printouts are shown in Figures 4 and 5. The data readouts can be traced from December into March.

The actual decision to restrict a section of road is made when one or more strings show thawing temperatures in the sensor located just below the asphalt pavement. Figure 4 shows that thawing occurred just below the mat on 11 February (see box). Haul restrictions were placed starting 12 February on this road.

"THAW WEAKENING MONITORING RECORD—SITE NUMBER D6-36-2.8" has two thermistors not working (see Figure 5). It is still capable of supplying useful data, however. By adjusting the weightings for temperature readings to compensate for the missing thermistors, an average temperature can be calculated. This string would be consid-

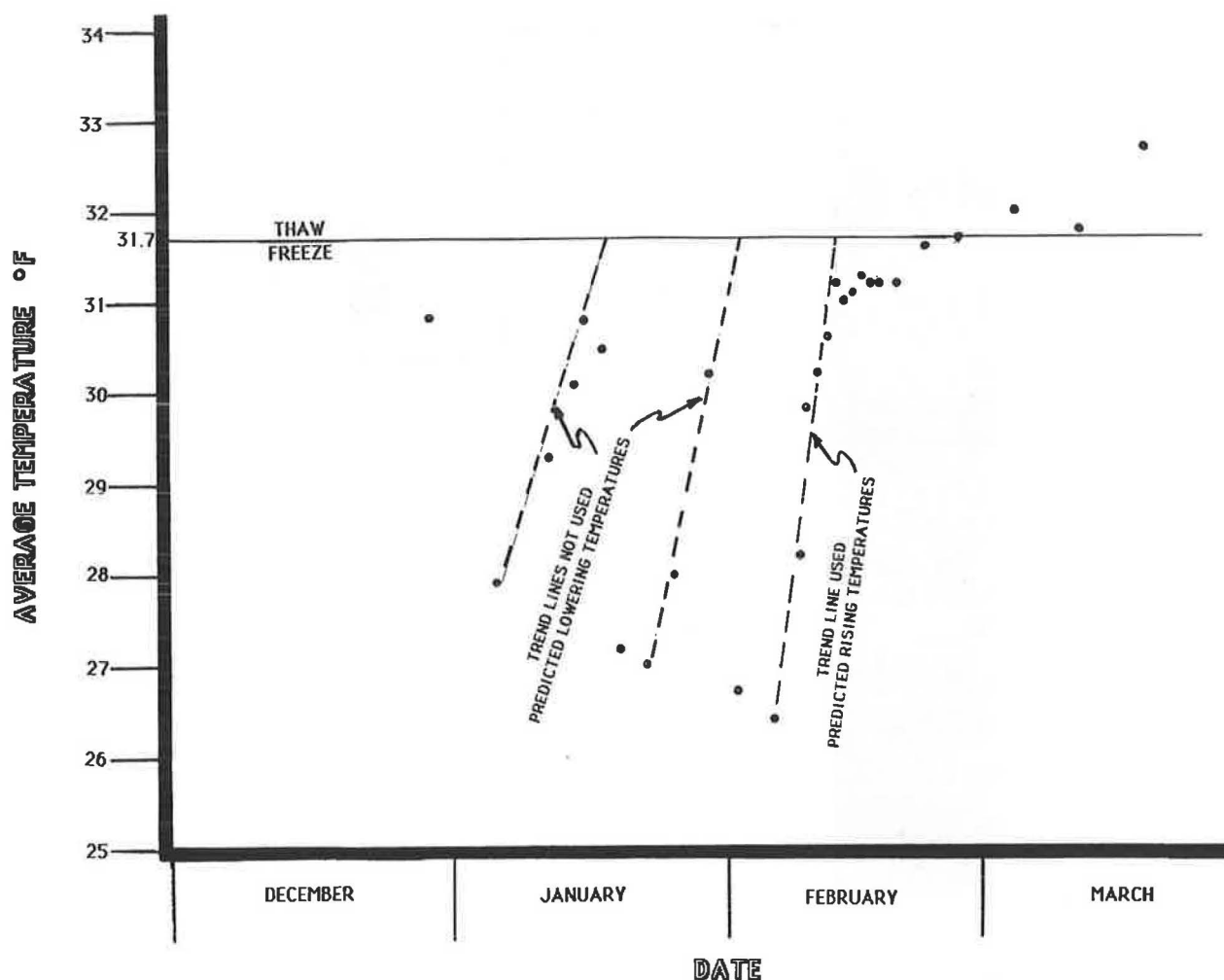


FIGURE 3 Average temperature graph for Site Number D6-763-0.95 used for predicting trends.

ered nonfunctional if the sensor just below the mat failed, or if any more sensors on the string failed.

When it appears that break-up is coming, notices are sent to personnel in the county, timber haulers, and Forest Service organizations. This can be related to the sequence that a racing starter goes through: "On your mark, get set, go." The "go" phase is when the haul restrictions are placed. Figure 6 shows a series of three messages that led up to restricting haul on certain roads.

BENEFITS

The benefits that the program has brought the Kootenai National Forest are a better basis for placing haul restrictions in the spring and a significant lowering of maintenance costs on paved roads. In addition, some of the timber haulers have become strong proponents of the thermistor program. They have seen annual maintenance costs of paved roads reduced (more dollars in their pockets in cases where they were the principal road maintainers). They now no longer pester the Forest management to keep roads open for "just another week."

The savings from reduced maintenance costs on one 17-mile (28-km) segment of road during the first year of operation paid for the development and installation costs. The savings amounted to about 50 percent of historical annual maintenance costs (see Figure 7). This convinced the Forest management team to expand the program to cover the remainder of the asphalt-paved roads in the Forest.

A typical thermistor string costs between \$150 and \$250 to construct or buy. This includes a readout box, 5 to 6 ft (about 1.75 m) of electrical conduit, 30 to 45 ft (9 to 13.5 m) of multistrand cable, 8 to 10 thermistors, and miscellaneous materials. Installation costs run between \$100 and \$200 for sawing the pavement, drilling the hole, installing the thermistor string, and sealing the saw cut and hole. The large variation in costs are due to the availability of different drilling equipment, site conditions, and skill and cost of labor.

PROBLEMS

There are some problems with the system as described. About 5 percent of the individual sensors fail annually. Whole strings are replaced when either a sensor just below the asphalt pave-

Enter TIME in military time
Enter TEMPERATURES in degrees F. to the nearest tenth of a degree
Average soil temperature will be automatically calculated
 $(([*],5]*1.5)+([*,6]*7.5)+([*,7]*12)+([*,8]*9)+([*,8]+[*],9)*1.5)/33$

DATE	TIME	0(AIR)	1(MAT)	2(BASE)	3(6.0)	4(18.0)	5(30.0)	6(42.0)	7(48.0)	8(54.0)	9(60.0)	AVE. TEMP.
LV BLANK												
NOV 18, 87	1232.0	24.7	30.1	30.3	32.8	38.2	42.4	45.3	45.5	47.5	48.4	38.3
DEC 08, 87	1120.0	31.3	31.3	31.4	36.3	37.1	38.7	40.3	41.4	42.4	43.3	36.9
DEC 15, 87	1312.0	26.0	28.4	28.0	30.9	34.2	37.1	39.4	40.6	41.6	42.6	34.3
DEC 29, 87	1142.0	21.9	23.5	23.1	25.5	31.4	34.2	36.7	37.9	39.1	40.1	30.8
JAN 05, 88	1142.0	9.9	15.1	15.7	20.7	28.5	33.0	35.5	36.7	37.9	39.0	27.9
JAN 11, 88	1255.0	35.3	27.6	26.3	25.2	29.4	32.0	34.5	35.8	37.0	38.1	29.3
JAN 14, 88	1302.0	36.8	31.1	30.1	23.6	29.0	31.8	34.2	35.4	36.6	37.7	30.1
JAN 15, 88	1345.0	37.3	31.8	31.0	30.1	29.8	31.8	34.1	35.3	36.5	37.5	30.8
JAN 17, 88	1109.0	29.5	25.3	27.1	29.1	30.3	31.8	34.0	35.1	36.3	37.3	30.5
JAN 19, 88	1308.0	25.3	22.5	19.0	20.3	27.8	31.8	33.9	35.0	36.1	37.2	27.2
JAN 22, 88	1144.0	26.2	22.2	20.2	21.4	26.7	31.3	33.7	34.3	35.9	36.9	27.0
JAN 25, 88	1235.0	34.2	23.5	25.2	24.2	27.3	31.1	33.5	34.6	35.7	36.7	28.0
JAN 29, 88	1306.0	43.7	33.7	31.0	29.7	29.4	31.0	33.1	34.3	35.3	36.3	30.2
FEB 01, 88	1332.0	21.7	16.1	14.7	19.1	23.3	31.2	33.1	34.1	35.1	36.1	26.7
FEB 05, 88	1245.0	24.1	24.0	22.4	22.1	25.7	29.8	32.8	33.9	34.9	35.9	26.4
FEB 08, 88	1246.0	39.7	30.8	28.3	26.2	26.3	30.3	22.6	33.7	34.7	35.7	28.2
FEB 09, 88	1131.0	37.0	31.4	30.7	29.6	28.9	30.4	32.5	33.6	34.6	35.6	29.8
FEB 10, 88	1155.0	37.3	32.0	30.3	30.1	29.6	30.6	32.5	33.6	34.6	35.6	30.2
FEB 11, 88	1119.0	46.3	35.0	31.6	30.7	30.0	30.8	32.5	33.6	34.5	35.5	30.6
FEB 12, 88	1433.0	58.1	44.9	39.2	31.1	30.3	31.0	32.5	33.5	34.5	35.4	31.2
FEB 13, 88	1115.0	41.2	34.9	33.0	31.2	30.5	31.0	32.5	33.5	34.5	35.4	31.0
FEB 14, 88	1324.0	40.4	33.1	31.0	31.4	30.6	31.1	32.5	33.5	34.4	35.3	31.1
FEB 15, 88	1154.0	39.0	38.7	35.4	31.4	30.7	31.2	32.5	33.5	34.4	35.3	31.3
FEB 16, 88	1056.0	32.5	31.0	31.2	31.5	30.8	31.2	32.5	33.5	34.4	35.2	31.2
FEB 17, 88	1023.0	36.5	31.3	31.0	31.5	30.8	31.3	32.5	33.4	34.3	35.2	31.2
FEB 19, 88	1104.0	31.5	31.3	30.7	31.5	30.9	31.3	32.5	33.4	34.3	35.2	31.2
FEB 22, 88	1335.0	46.8	44.6	35.5	31.6	31.1	31.4	32.5	33.4	34.3	35.1	31.6
FEB 26, 88	1330.0	49.9	47.0	36.7	31.5	31.2	31.5	32.6	33.4	34.3	35.0	31.7
MAR 04, 88	1310.0	43.7	46.5	41.0	32.1	31.2	31.6	32.6	33.4	34.2	34.9	32.0
MAR 11, 88	1240.0	43.2	45.7	35.7	31.8	31.4	31.6	32.7	33.4	34.1	34.8	31.8
MAR 18, 88	1252.0	55.7	54.7	45.6	33.3	31.5	31.7	32.7	33.4	34.1	34.8	32.7

NOTES:

1. Road haul restrictions were effective 12 February 88.
2. Thermistors 1 through 9 are followed by depth below road surface in inches.
3. There is an apparent error in the data entry of thermistor number 6 on 8 February of ten degrees.
4. Maximum frost depth at this site was between 30 and 42 inches (75 and 105 cm).

FIGURE 4 Thaw-weakening monitoring record (data printout), Site Number D6-763-0.95.

Enter TIME in military time
Enter TEMPERATURES in degrees F. to the nearest tenth of a degree
Average soil temperature will be automatically calculated
 $(([*_5]*3.7)+[*_7]*8.3)+[*_8]*6)+[*_9]*9)+[*_{10}]*6))/33.0$

DATE	TIME	0(AIR)	1(MAT)	2(3.0)	3(6.0)	4(12.0)	5(18.0)	6(24.0)	7(36.0)	Ave. Temp.
LV BLANK										
NOV 18, 87	1404.0	27.4		29.3	15.5	34.0	36.5	39.1	43.2	37.0
DEC 8, 87	1146.0	32.1	-110.6	32.0	21.6	36.2	37.6	38.5	39.0	37.1
DEC 15, 87	1337.0	28.8		28.4	15.4	31.2	32.9	34.5	36.5	33.1
DEC 29, 87	1241.0	24.4		24.1		25.1	26.3	28.3	31.1	27.3
JAN 5, 88	1238.0	8.5		12.7		13.3	21.4	24.7	29.0	21.9
JAN 11, 88	1324.0	34.1		25.3		25.0	25.7	26.8	29.1	26.5
JAN 14, 88	1327.0	35.3		30.0		27.8	27.8	28.3	29.7	28.5
JAN 15, 88	1411.0	40.0		31.4		29.9	29.6	29.6	30.1	30.0
JAN 17, 88	1138.0	26.8		25.9		29.2	29.9	30.3	30.7	29.5
JAN 19, 88	1333.0	25.7		21.1		23.3	25.6	27.8	30.2	26.0
JAN 22, 88	1235.0	28.0		22.7		22.8	24.5	26.4	29.2	25.2
JAN 25, 88	1336.0	31.9		24.6		24.7	25.8	27.1	29.3	26.4
JAN 29, 88	1335.0	41.0		31.6		29.8	29.5	29.5	30.3	30.0
FEB 1, 88	1359.0	19.1		16.3		22.6	25.5	28.5	30.6	25.5
FEB 5, 88	1312.0	24.4		23.7		23.8	24.5	26.3	28.8	25.5
FEB 8, 88	1310.0	38.1		26.7		27.9	28.2	28.9	29.9	28.5
FEB 9, 88	1237.0	36.3		29.1		30.7	29.5	29.6	30.2	29.9
FEB 9, 88	1730.0	33.5		30.6		30.9	29.6	29.7	30.3	30.2
FEB 10, 88	1245.0	36.1		30.3		31.4	30.2	30.0	30.4	30.6
FEB 11, 88	1148.0	46.7		32.5		32.7	30.9	30.7	30.8	31.5
FEB 12, 88	1454.0	51.1		35.9		32.9	31.4	31.1	31.2	32.2
FEB 13, 88	1144.0	39.2		34.4		32.2	31.6	31.3	31.0	31.9
FEB 14, 88	1347.0	40.4		36.9		32.3	31.8	31.5	31.2	32.3
FEB 15, 88	1313.0	39.6		35.2		32.7	31.9	31.6	31.2	32.4
FEB 16, 88	1203.0	39.3		31.3		33.3	32.2	32.1	32.0	32.3
FEB 17, 88	1126.0	32.5		31.7		32.5	32.0	32.0	32.0	32.0
FEB 19, 88	1225.0	39.0		31.5		32.0	31.8	31.8	31.3	31.7
FEB 22, 88	1412.0	47.4		35.0		32.1	31.8	31.8	32.0	32.3
FEB 26, 88	1352.0	50.5		33.2		32.0	31.9	31.8	33.0	32.2
MAR 4, 88	1416.0	47.4		43.7		33.8	33.4	32.5	33.5	34.4
MAR 11, 88	1314.0	45.3		42.3		35.0	35.6	35.3	35.2	36.1
MAR 18, 88	1324.0	57.0		51.3		37.8	38.0	37.5	37.9	39.3

NOTES:

1. Road haul restrictions were effective 12 February 88.
2. Thermistors 1 through 7 are followed by depth below road surface in inches.
3. Thermistors number 1 (mat) and 3 (3.0) are not functioning but data from the string is still providing useful information.

FIGURE 5 Thaw-weakening monitoring record (data printout), Site Number D6-535-0.35.

ON YOUR MARK

Postmark: Feb 01,88 9:26 AM

The prerecorded phone message is up and running. The recorded message can be checked out by calling 293-7421. I sent the information to all interested parties and the papers in Libby, Eureka, and Kalispel. I'll give you copies of the news release that you can give to the purchasers. Mike

GET SET

Postmark: Feb 08,88 7:28 AM

Weather forecasts project days @ mid 40's and nights @ hi 20's for the rest of the week. Provided there is no change, current proposal is to post Fisher #1 @ 80,000* and Fisher #2 at 10,000* on Wed. 2-10; followed by Wolf Creek & Mc Killop @ 10,000 on Thurs. 2-11. We will be monitoring thermistors daily. If a cold spell sets in and the road subgrade firms up restrictions may be delayed. Larry

GO

Postmark: Feb 11,88 5:17 PM

Effective Friday 2-12, log haul will be restricted on entire Fisher River system (80,000 * weight on Fisher #1; 10,000* on Fisher #2, Mc Killop, and Wolf Creek). Message is on phone answering service. I have advised state, Champion, and purchasers. Information will be posted on the ground Friday morning. Restrictions will be lifted if colder weather sets in and the thermistors verify frozen road conditions. Larry

FIGURE 6 Copies of informational messages leading up to placing restrictions on Kootenai National Forest roads for spring break-up.

ment fails or too many fail on a single installation. Entire thermistor strings are being replaced at about 10 percent annually as a result of failure of thermistors, damage during road maintenance activities, and periodic reconstruction of roads. Also, a few strings have been discontinued in favor of a new location that is perceived to yield more reliable data. This past field season (1988) the Forest installed 14 strings. None were installed in the 1987 field season.

Initial acceptance of the thermistor program could be a major administrative problem if a good information and education program is not undertaken. Every change in management, whether Forest Service, timber hauler, or county, requires that the information and education program be repeated.

The biggest drawback to the thermistor program is that interpretation of the data cannot be used with all soil types to indicate when to lift the hauling restrictions. The Forest still uses visual observation of moisture conditions in the ditch line and cracks in the pavement. It has not been a significant problem on the Kootenai because the timber haulers do not usually want to resume hauling for approximately 2 to 3 months after initial restrictions. By then, the roads have had time to drain the excess moisture and regain strength. A study in Region 6 of the Forest Service (National Forests in Oregon and Washington) on different moisture-sensing devices may aid the Kootenai Forest in selecting a system to determine

when pavement strength has returned and restrictions can be lifted.

APPLICATIONS FOR OTHERS

The Forest Service is unique in that it has the option of being able to place varied load restrictions, including total road closure. Most road agencies do not have that option and can only place haul restrictions that are much less stringent than those often used on the Kootenai National Forest. Initially, thermistor temperature data need to be correlated with either pavement deflections or other road strength tests to define the interaction of depth of thaw and road strengths. On the basis of pavement structure strengths at different thaw depths, agencies should be able to determine when to institute partial haul restrictions on their roads.

Many variations in the spacing and number of thermistor sensors on a thermistor string are acceptable. The Kootenai National Forest has tried to standardize spacing of sensors for its own use. Good temperature data are still available even after the failure of one or two sensors placed in the subgrade. Economically it makes more sense to place extra sensors at \$10 each and allow for some failure than to replace a whole string for \$300. The computer spreadsheet program used to

MACHINE AND HAND PATCHING YAAK VALLEY ROAD 92
MILE POST 12.5 TO 29.5

YEAR	AMOUNT IN \$1,000
1981	54
1982	37
1983	34
1984	121
1985	35

USE OF THERMISTORS ON YAAK 92 AS A MANAGEMENT TOOL ESTABLISHED

1986	17
1987	16

FIGURE 7 Annual pavement maintenance costs.

develop a weighted average can easily be adjusted to account for the sensor spacing.

SUMMARY

Two individuals perceived a need and provided a cost-effective method for the Kootenai National Forest to prevent

road damage and to lower asphalt road maintenance costs through timely restrictions at the beginning of the spring break-up period. The method involves installing thermistor strings in and below the pavement and monitoring the temperature changes before and during the spring break-up period. Success has been documented through on-the-ground field application. Information and education efforts were very important in establishing the new program. Information is continually sent to groups and individuals as it appears the roads are reaching a thaw stage. The data collected and interpreted provide a rational approach to restricting hauling on asphalt-paved roads.

The Kootenai Forest is still replacing thermistors and adding a few new installations each year. The problems encountered with the system have been fairly minor and the benefits, worthwhile. The program will continue until a better system can be found.

REFERENCE

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