COAL MINING AND TECHNOLOGY

Coal mining practices at Kaiser Resources Ltd.

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ABSTRACT

This paper describes mining conditions in the Kaiser surface and underground coal mines in the Sparwood area of southeastern British Columbia. Mining methods are explained, major mining equipment is listed and production rates are given. Reclamation methods and results are described. Data are given on safety organization, safety practices, accident statistics, safety inspections and absenteeism.

Introduction

The coal mines of Kaiser Resources Ltd. are located in the southeast corner of British Columbia. All present mining is in the Sparwood area, where operations began in 1900 with the opening of the Michel underground mines. Production increased rapidly at first, then went through successive periods of depression and prosperity. Following are the highlights. Quantities are in clean, short tons.

1900-1910—Rapid rise in production to a peak of 512,000 tons in 1910.

1911-1924—Reduced rate of production, averaging 238,000 tons per year, due to strikes, manpower shortage during World War I and post-war depression.

1925-1929—Second prosperous era, with production climbing to 383,000 in 1929.

1930-1933—Second depression—production falling to 231,000 in 1933.

1934-1942—Third era of prosperity—production recovered and new production peak of 908,000 tons reached in 1942 during World War II.

1943-1956—Continued prosperity, with production averaging 720,000 tons per year.

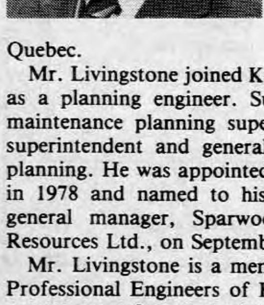
1957-1959—Loss of markets to oil and gas; production dropping to 517,000 tons in 1959.

1959-1969—Recovery due to new coal market in Japan; production climbing back to the 900,000-ton level.

1970-Present—Jump in production reaching 6.6 million tons in 1975. This was the result of the purchase of the property by Kaiser Steel, who negotiated a large-volume, long-term contract with Japan, built the coal port of Westshore, reduced shipping costs by instituting unit trains, and reduced production costs by investing in large-scale mining machinery and a new preparation plant.

Surface mining in the area began in 1948 and reached a peak of 300,000 tons in 1956. It then declined to 70,000 tons in 1960 and gradually increased to 467,000 tons in 1967. Opening of the Harmer area by Kaiser Resources increased surface mining to 2.5 million tons in 1970, with a continual increase to 6 million tons in 1975.

Recoverable coal reserves in the Sparwood area are estimated at nearly 400 million raw short tons. The coal is contained in a dozen seams (Fig. 2). All are low- to high-volatile coking coals. Nearly all the mining during the past 8 years has been confined to the bottom seam, designated as "10 Seam". This seam is 40 to 50 feet thick, low volatile, with excellent coking characteristics.



G.K. Livingstone

Gary Livingstone was born at Asbestos, Quebec. He graduated from Queen's University in 1967 with a B.Sc. in mining engineering. He was employed with the Iron Ore Company of Canada from 1967 to 1970, working as pit foreman at Labrador City and as systems analyst at Sept-Iles, Quebec.

Mr. Livingstone joined Kaiser Resources Ltd. at Sparwood in 1970 as a planning engineer. Subsequently, he served as pit foreman, maintenance planning supervisor, assistant pit superintendent, pit superintendent and general superintendent, mine engineering and planning. He was appointed as general manager, mining operations, in 1978 and named to his present position as vice-president and general manager, Sparwood Operations, Coal Division, Kaiser Resources Ltd., on September 6, 1979.

Mr. Livingstone is a member of the CIM and the Association of Professional Engineers of British Columbia. He has published two papers on surface coal mining technology.

Keywords: Coal mining, Kaiser Resources Ltd., Sparwood area, Balmer mines, Underground mining, Remote monitoring, Equipment, Open-pit mining, Safety programs, Reclamation, Hydraulic mining.

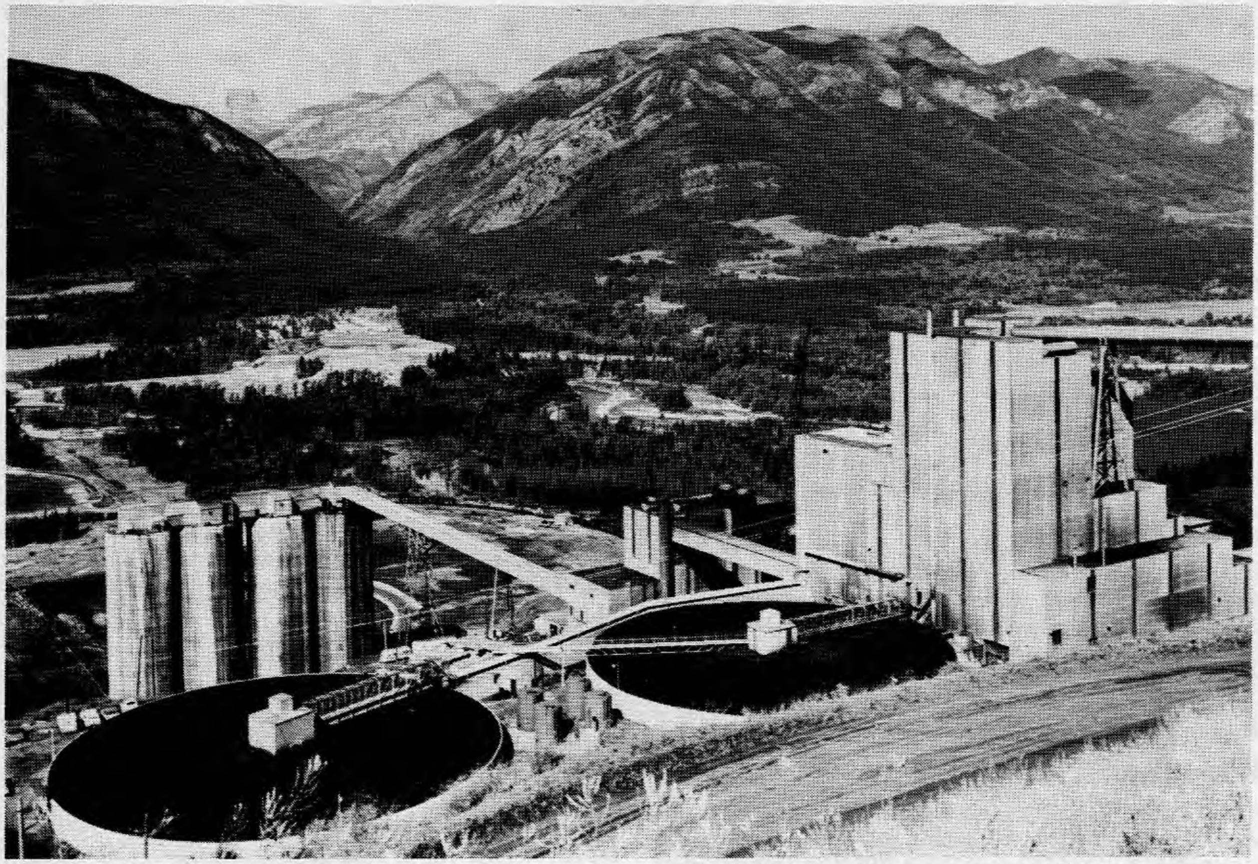
Underground Mines

Two underground mines are working at present—Balmer North and Balmer South. They are located on the north and south sides, respectively, of the Michel Valley. Both are extracting 10 Seam.

Balmer North

This is an old mine worked by the room and pillar method (See Mine Plan). Continuous miners dig the coal, while shuttle cars and belt conveyors carry it outside.

The seam is about 45 to 50 feet thick and pitches at 12 to 15 degrees. Triple entries, 16 feet wide and 10 feet high, are driven to the rise diagonally across the pitch. They are located next to the roof, which is supported by roof bolts. A conveyor is installed in the middle entry.



The Elkview coal preparation plant of Kaiser Resources has a rated capacity of 1600 tons of feed per hour and 7,000,000 short tons of clean coal per year.

Rooms are driven from the entries on the full pitch. They are connected to each other by cross-cuts. After rooms are completed, extraction coal is obtained by widening the rooms to 28 feet and also by taking 20 to 25 feet of the floor coal. The latter is done in two or three lifts which take advantage of the seam pitch.

The mine is worked by one continuous miner, which operates 3 shifts per day, 5 days per week. In 1978, this mine produced 150,000 raw tons.

The mine has a remaining life of about 2 years, but plans are in progress to extend mine life a further year or two.

Balmer South

In Balmer South, as in Balmer North, 10 Seam is 45 to 50 feet thick, but its pitch is much steeper, averaging 35 degrees. The mine is worked by the hydraulic method and consists of two major areas:

(1) Panel 5—under extraction;
(2) Panel 6—under development.

Panel 5

The schematic panel arrangement used by hydraulic mining is shown in Figure 4. Two entries are driven, rising at 5 to 6 degrees. After the entries reach the end of the panel, sub-levels are driven off the entries, rising between 7 and 10 degrees. Sub-levels are started inbye and progress outbye. Both entries and sub-levels are spaced to leave 85-foot pillars.

The positions of entries and sub-levels in the seam are important. The entries must be high enough off the footwall so that turns into sub-levels avoid cutting into the footwall. On the other hand, entries must not be too close to the roof, because the wedge of coal left next to the roof is difficult to support. The entries must, therefore, float in the seam about 5 feet below the hanging wall. The sub-levels, however, are kept near the footwall to maximize the coal which can be washed down by hydraulic mining.

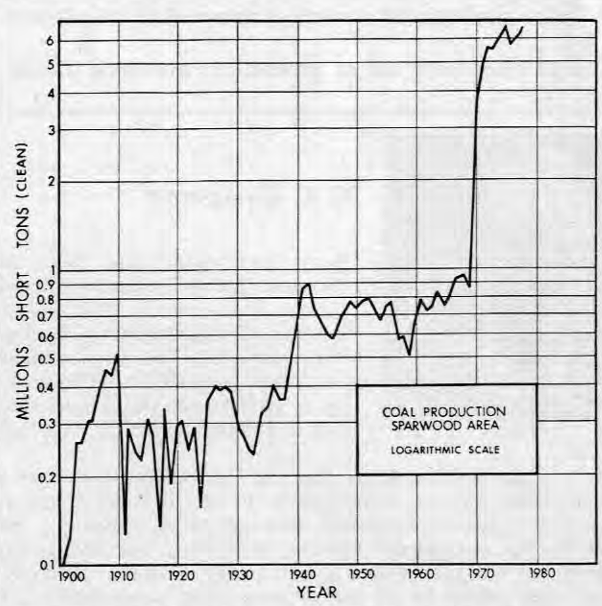


FIGURE 1. Coal production from the Sparwood area.

The entries and sub-levels are both driven by continuous miners. The coal from the miners is carried outside by water in flumes.

Entries and sub-levels are supported by steel sets (usually arches), which are completely lagged by 2-inch rough boards. The steel supports span 16 feet, are 10 feet high and are normally spaced every 5 feet.

In underground mining, Kaiser Resources uses the hydraulic method, applying water under high pressure to dislodge coal from the seam and fluming the coal out of the mine in slurry form. The hydraulic monitor is operated from a module 40 feet from the face, a major safety feature.

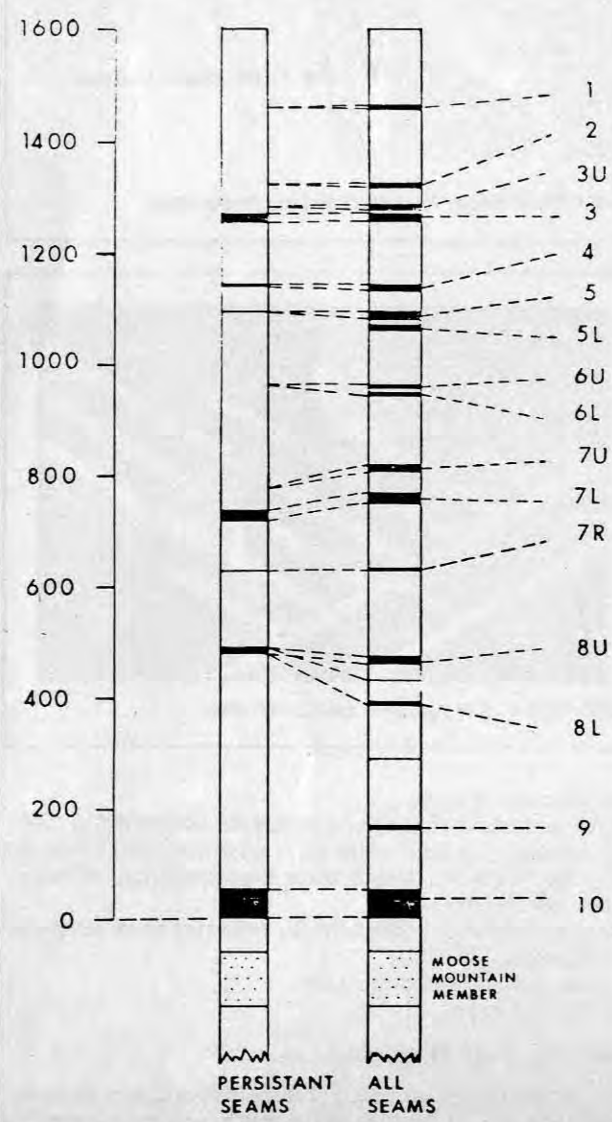


FIGURE 2. Columnar sections typical of the Sparwood area.

As sub-levels are completed, the hydraulic equipment is installed at their faces. The equipment consists of the monitor and a feeder-breaker. The monitor cuts the coal from the solid by a jet of water at a pressure of 1400 lb/in². Direction of the jet is remotely controlled by the operator stationed in a steel cabin 40 feet from the monitor (Figs. 5 and 6).

The coal/water mixture is washed down to the feeder-breaker. As stated previously, keeping the sub-levels near the footwall maximizes the volume of coal which can be washed down.

The feeder-breaker reduces coal to 6-inch size and its feed rate can be controlled. This helps avoid flume blockage during periods of exceptionally high production.

The monitor and a hydraulic winch are mounted on the feeder-breaker so that the entire assembly can be easily pulled back by the winch when all coal within reach of the monitor has been extracted. The "pull-backs" are usually 40 feet and occur every 3 to 5 shifts.

The hydraulic mining units are located in three working areas. This allows for one to be working while a second is pulled back and a third is on standby. The most common delays are caused by an extra-large lump of coal restricting the monitor movement or monitor damage due to falling coal.

One continuous miner can maintain sub-level development to support three monitor units. Two water systems are used:

(1) a high-pressure system for the monitor, delivering 1500 (US)gpm supplied by a 2500-hp pump on the surface via 8- and 6-inch pipes;

(2) a medium-pressure system for development, delivering 900 (US)gpm and requiring a 700-hp pump on the surface and 8- and 6-inch pipes.

Both systems pump their water from a holding tank fed from the static thickener overflow. The natural make of mine water is diverted into the systems. The systems are virtually closed and require only occasional make-up water.

Raw coal production from Panel 5 in 1978 was 619,000 tons. The equivalent of a month's production was lost due to an outbreak of spontaneous heating.

Panel 6

A diagram of Panel 6 is shown in Figure 7. The size of the panel required development from two different areas.

Two dipping rock tunnels were driven from the surface to the coal. At the coal contact, an underground dewatering station was built to partially dewater the coal coming from the No. 2 Access entries. The +3/8-inch coal is dewatered and transported by belt conveyors to the surface; the -3/8-inch coal and all the water are pumped to the surface dewatering station.

The underground dewatering station has two major sumps, one of 186,000-US-gallon capacity for normal usage and a second of 300,000-gallon capacity for emergencies.

Two continuous miners are driving the No. 2 Access entries at a 5-degree rise from the dewatering station toward the main body of the panel. Coal from the miners is transported by flumes back to the dewatering station.

A third rock tunnel was driven to the coal at a point almost halfway along the panel. From the seam contact, two dipping slopes were driven in the coal and, from these, the two No. 4 access entries are being driven by two continuous miners. The coal produced is fed by shuttle cars to belt conveyors which carry it to the surface through No. 3 Rock Tunnel.

Monitor production was expected to start from Panel 6 at the end of 1979. The rate of production forecast is 1.2 million raw short tons per year.

Raw coal production from Panel 6 in 1978 amounted to 108,000 short tons.

Remote Monitoring

No. 10 Seam is prone to spontaneous heating. Five incidents of heating have occurred since 1972 during the life of the hydraulic mine and others prior to this, going back to 1966.

To provide early warning of heating, a joint research project by Kaiser Resources Ltd. and Energy, Mines and Resources Canada developed a system to precisely monitor the carbon monoxide in the gob gases.

The system draws continuous gas samples from selected areas of the mine through 1/2-inch-O.D. polyethylene tubes up to a distance of 7000 feet. The actual analyser is installed on the surface. The essential components are: electro-chemical CO analyser; thermal printer; four vacuum pumps; polyethylene tubing; logic unit/valve driver; and mini-computer.

After testing and modification, the unit has operated satisfactorily since September, 1976, except for occasional freezing of the lines at the surface. Freezing has been overcome by heat taping.

The electro-chemical analyser is capable of an accuracy of ±1 ppm over a reasonable period, and the indicator reads CO directly to 0-10 ppm. The system can be operated in either of two ranges. The printer records:

i) day of the year (1-365);
ii) time of the day (24-hour system);
iii) sampling point number);
iv) range selected (0-10 or 0-50 ppm);
v) CO concentration in ppm;
vi) alarm condition due to system fault.

Samples are drawn from each of the four locations, in rotation. Each sample is analyzed for 15 minutes and prints the results. The analysis period can be changed by modification to the logic unit.

The mini-computer calculates the difference in CO values at every four-hour interval for each sample line. The differences are printed separately and are preceded by a (+) or (-) sign, indicating rising of falling values during the last four hours.

Normal readings for the mine range from 3 to 5 ppm. The passage of diesel vehicles near the sample points will locally affect the value of that sample, but a return to normality indicates that the event is an isolated one.

The intake air is also monitored, because the use of air heaters on the surface in winter will produce a reading of 3-7 ppm CO.

The absolute level of CO is not significant in the early detection of underground heating. It is the steady increase in CO concentration that indicates abnormal oxidation.

Major Underground Mining Equipment

Balmer North

1 continuous miner;
2 shuttle cars;
2 supply vehicles;
8000 feet of 36-inch belt conveyor.

Panel 5

1 continuous miner;
4 monitors with feeder-breakers;
1 supply vehicle;
1 pump, 1500 (US)gpm, 2500 hp;
1 pump, 900 (US)gpm, 700 hp.

Panel 6

4 continuous miners;
2 shuttle cars;
6700 feet of 36-in. belt conveyor;
4 supply vehicles;
2 double-deck vibrating screens;
8 slurry pumps, 300 hp each;
1 gland water pump, 100 hp;
2 emergency pumps, 60 hp;
147 feet of chain conveyor.

In addition, dewatering facilities are located on the surface for the two hydraulic mines.

Surface Mines

Mining Procedures

The surface mines so far have been mostly located on mountain slopes, with the coal outcropping near the crest and dipping in the same direction as the surface under gradually in-

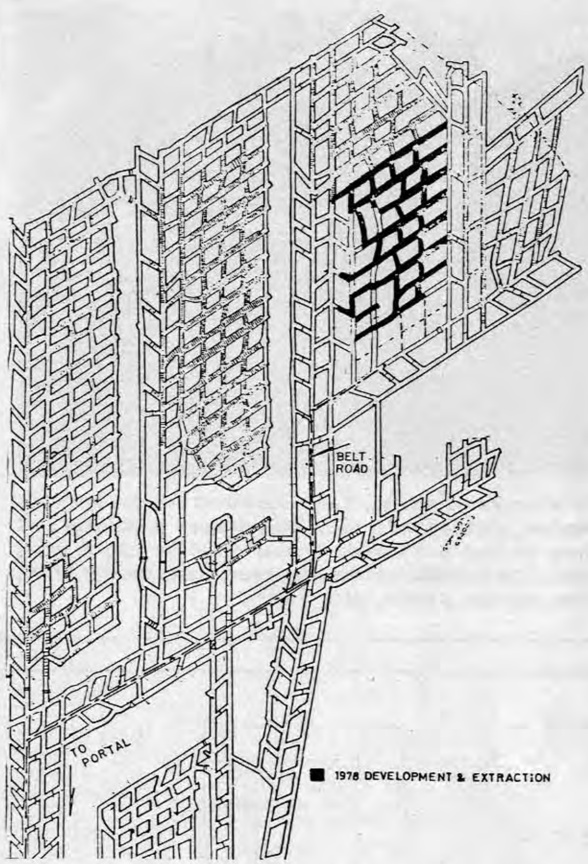


FIGURE 3. Kaiser Resources' Balmer North Mine.

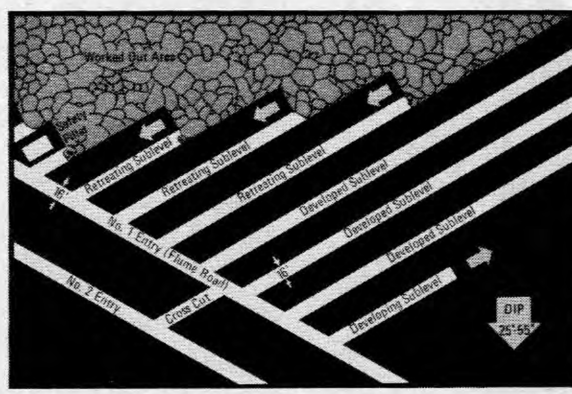


FIGURE 4. The hydraulic mine panel plan.

creasing cover (Fig. 8).

Mining starts at the top and progresses downward in 50-ft-high benches. The limit of the pit is set at the point where the strip ratio, measured linearly along the cutwall (cut-off ratio), reaches its economic limit.

Mining procedure consists of the following chief elements:

(1) drilling and blasting;
(2) rock removal and disposal;
(3) coal recovery.

Drilling and Blasting

Prior to drilling, the ground is prepared for drill sites by levelling with dozers. At the edge of the bench, where the bench intersects the original surface, the ground is sloping. This sloping surface is formed into terraces suitable for drill sites by dozing

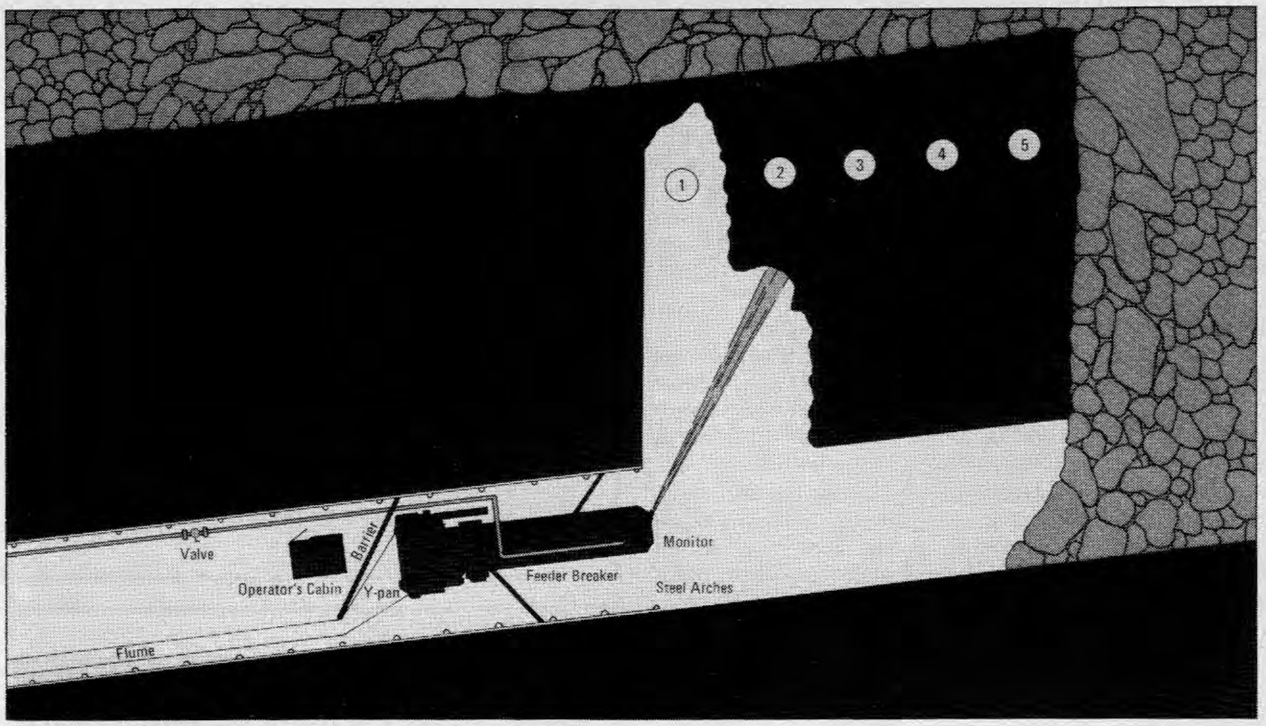


FIGURE 5. Face area plan view at the hydraulic mine.

or, if the ground is too hard, by filling with spoil.

Figure 9 shows a standard 12¼-in. drill hole. The hole is 57 feet deep, which allows for a 50-foot bench and 7 feet of subgrade. If the hole reaches coal, the subgrade is eliminated. Instead, the hole is backfilled 3 feet to minimize dilution of the coal by rock.

Most holes are dry. These, and holes which can be dewatered, are lined with 8-mil plastic liners and loaded with 1300 pounds of straight ANFO. Wet holes which cannot be dewatered, and which are difficult to line, are loaded with water-gel slurry. In areas where hard, massive sandstone is encountered, the holes are loaded with 700 pounds of aluminized ANFO (7% Al) at the bottom and topped with ANFO to normal collar height.

Each hole is primed with a single 1½-pound primer which contains two 150-ms detline delays. The detlines are connected at the surface to the reinforced primacord network.

Figure 10 shows a typical drill pattern. The holes are spaced 28 feet in a row, with 24 feet between rows. Holes are staggered in adjacent rows. The typical blast has 250 holes, consisting of 12 to 15 rows with 20 to 25 holes per row. The volume of rock in a blast is commonly 300,000 bank cubic yards. The powder factor is 1.08 pounds per bank cubic yard.

Holes are fired in successive rows starting from the free face. Delays between rows are 40 ms; the delays in the holes are 150 ms. The result is that when a row fires, three rows ahead are already initiated. This prevents surface cut-offs.

For best results, particularly to reduce overbreak, the rows must be oriented perpendicular to the strike of the strata.

The rock removal fleet includes 22 Lectra-Haul 200-ton trucks and four 25-cubic-yard P & H electric shovels, as shown in the photo. The company also operates 24 Lectra-Haul 100-ton trucks and four 15-cubic-yard P & H shovels. The present production rate calls for removal of approximately 45 million bank cubic yards of overburden a year.

Rock Removal and Disposal

After blasting, the rock is loaded by shovels into trucks. Present shovels are of 25 and 15 cu. yd capacity and the trucks are 100-ton, 170-ton and 200-ton. A Terex 350-ton truck and a Poclain 1000 hydraulic shovel are undergoing tests leading to possible purchase.

The rock is hauled to both ends of a bench and around the side and back of the mountain to form terraces of spoil. As mining progresses to lower benches, these terraces also progress lower, thereby wrapping around each other. This "wrap around" reduces the average slope of the dump and contributes to their stability. As much as possible of the spoil is backfilled on top of the bare footwall in the excavated area. Dumps are constantly monitored for stability. Our experience is that settling and slides can be expected during the initial stages of the "wrap-around" dump, but never from dumps on the footwall.

Bench elevations are also constantly monitored to ensure that benches are kept to grade. The ease with which a bench can be dug to grade has been found to be the best measure of the success of a blast, and indexes of blast efficiency have been developed on this basis.

A shovel does not have sufficient reach to remove all the rock above a pitching coal seam. The remaining rock must be dozed down and is loaded into trucks by front-end loaders or by a shovel if it is free.

Coal Recovery

Prior to actual recovery, drilling is done to determine the exact coal structure and quality. These aspects had been determined during the exploration period, but only in general. Exploration holes are too widely spaced to detect local variations.

For structure, 3-inch holes are drilled by a percussion drill. The holes are in rows parallel to the dip, with the rows spaced 200 feet along the strike. Spacing in a row is 100 feet or less, depending on the complexity of the structure. These holes are particularly useful in fault zones where the seam is split and repeats itself. Determining the exact structure ensures maximum recovery of the coal and avoids needless stripping.

Drilling for quality is done by a 3-1/2-inch auger. The holes are spaced 50 feet along the strike and are located to intercept the full seam. Coal samples are collected in 10-foot increments and tested for ash and FSI. Any variation in quality is thereby determined well in advance so appropriate measures for handling and processing can be taken.

Coal recovery is under the control of a special group. They supervise the final removal of rock from the top of the seam and also the loading of the coal so that recovery losses are minimized. The work of this group has improved coal recovery from below 85% to above 90%.

Surface Mining Equipment

The major mining equipment used in the surface mines, when at full production, consists of the following:

Electric Shovels
Four 25 cu. yd
Four 15 cu. yd
One 8 cu. yd

Front-End Loaders
Four 22 cu. yd, coal bucket
One 10 cu. yd, rock bucket

Production Drills
Seven 12¼-inch hole
One 9⅞-inch hole

Haulage Trucks
Twenty-two 200 ton
Three 170 ton
Twenty-three 100 ton

Dozers
Three Fiat-Allis HD41
Fourteen Cat D9
Two Cat 824
Four Cat 834

In addition, there are graders, water trucks, 35-ton trucks, crusher and various service vehicles.

Operating Statistics, 1978

Payroll	$60,000,000
Taxes paid	$75,000,000

Production

Coal in Raw Short Tons	
Underground Hydraulic Mines	727,000
Underground Conventional Mines	150,000
	877,000
Surface Mines	
10 Seam	6,424,000
8 Seam	573,000
Thermal	249,000
	7,246,000
All Mines	8,123,000
Rock Stripped in Surface Mines (bank cubic yards)	25,789,000

During 1978, the hydraulic mine lost a month's production due to spontaneous heating. Rock stripping during the year was well below mine capacity and some equipment was idle.

The world's largest truck, the 350-ton Terex 33-19, is on trial at the surface coal mining operations of Kaiser Resources at Sparwood, B.C., to determine its performance as an overburden hauler.

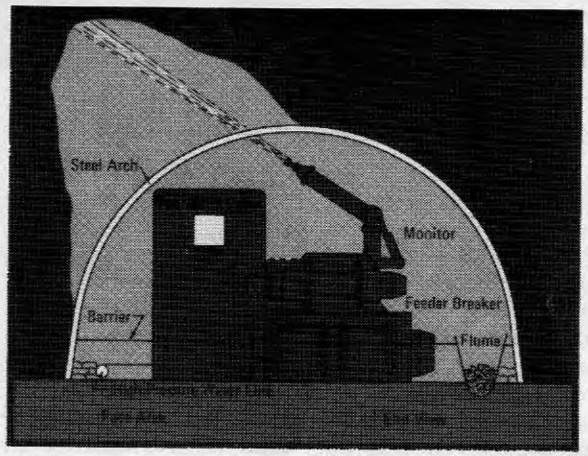


FIGURE 6. Another plan view of the face area at the hydraulic mine.

Stripping is scheduled to increase gradually to full capacity of 44.5 million BCY in 1980.

Productivity

Raw short tons of coal per manshift	21.2
Clean short tons of coal per manshift	16.0

Cost Distribution

	Underground Mines	Surface Mines
Operations		
Labour (wages and salaries)	56.3%	16.8%
Materials and supplies	13.2	20.1
Outside services	2.7	1.8
	72.2	38.7
Maintenance		
Labour (wages and salaries)	9.8	19.8
Materials and supplies	7.3	28.2
Outside services	0.8	3.9
	17.9	51.9
Service Departments warehouse, safety, security, engineering, environmental services, etc.	4.0	8.0
Power & Utilities	5.9	1.4
TOTAL	100.0	100.0

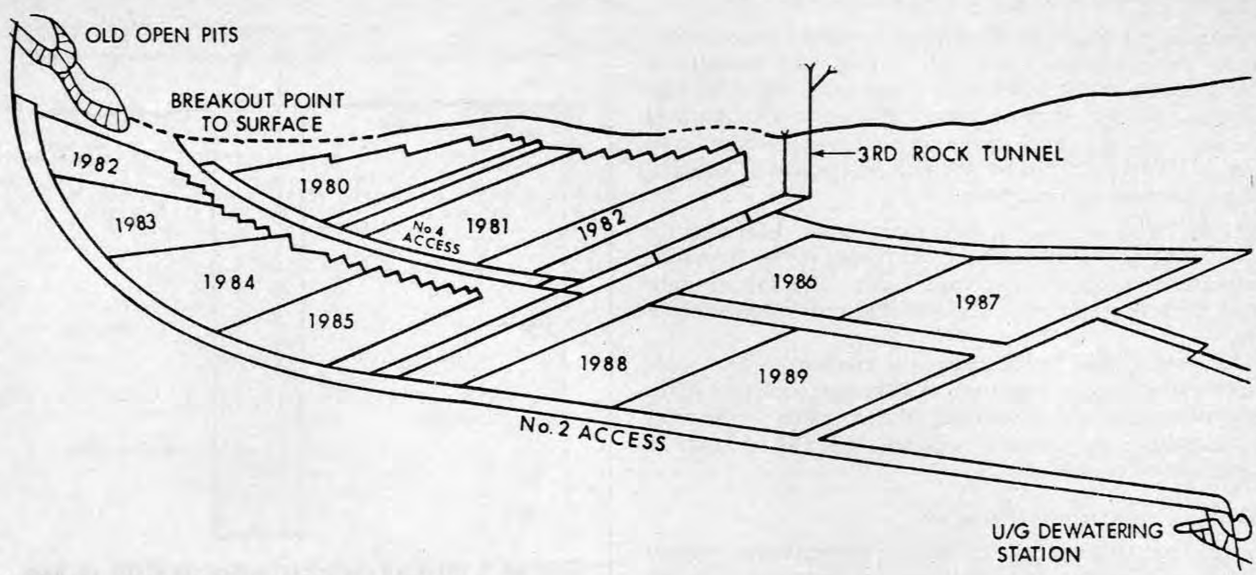


FIGURE 7. Extraction plan of Panel 6, No. 10 Seam.

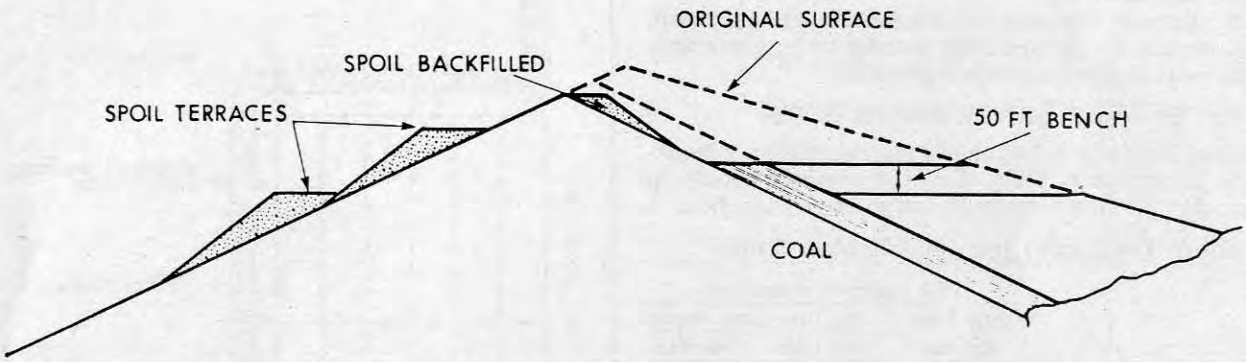


FIGURE 8. Typical cross section of the surface pit.

Safety Practices and Programs

Organization

The safety programs are headed by the safety supervisor. The operation of the programs is divided into three areas, each with its own personnel and equipment. The areas are:

Harmer Pit
1 Safety Coordinator
4 Industrial First-Aid Attendants
1 Fully Equipped First-Aid Station and Ambulance

Elkview Plant
1 Safety Coordinator
4 Industrial First-Aid Attendants
1 Fully Equipped First-Aid Station and Ambulance

Michel Underground
1 Safety Coordinator
4 Industrial First-Aid Attendants
1 Fully Equipped First-Aid Station and Ambulance

Safety Programs and Training

Surface Personnel

Heavy equipment operators undergo special training. First is six to eight hours of classroom training, which includes lectures, films and slide presentation. This is followed by five to ten days of practical operating practice accompanied by an experienced operator. The trainee must pass a written and a practical examination before being allowed to operate the equipment on his own.

Maintenance personnel also receive training in the safety rules and procedures involved in the operation of all haulage trucks, auxilliary equipment, service trucks and cranes. Each employee must demonstrate the ability to perform the basic operating techniques and is subsequently restricted to operating equipment for maintenance purposes only.

Underground Personnel

The safety training of underground personnel initially involves forty hours of classroom instruction covering the following subjects:

Tour of Mine
Basics of Roof Conditions
Basics of Mine Ventilation
Mine Gasses - Hazards, Control, Protection
Protective Equipment—Types of Masks and Use of Gas Detection Instruments
Fire Fighting and Fire Prevention
Reading of Mine Plans
Mine Emergency Procedure
Action if Trapped in Mine

The first week of classroom work is followed by four weeks of underground work on general mine maintenance. During the fifth week, trainees return to the classroom for one day of review and to discuss problems.

Mine Rescue and First-Aid Training

With the cooperation and assistance of government agencies, regular classes in surface and underground mine rescue, industrial first aid and St. John Ambulance first aid are conducted.

A special vehicle has been equipped for mine rescue. It consists of a 4-wheel-drive truck with covered back arranged to carry injured persons. In addition to the usual first-aid equipment and stretchers, it carries breathing apparatus for working in gaseous atmospheres, a power saw for cutting steel and concrete, an hydraulic cutter for opening steel bodies of vehicles, and mountaineering equipment.

During 1978, the underground mine rescue team won the regional and provincial titles and competed in the Dominion competition in Glace Bay, Nova Scotia. The surface mine rescue team won the local, regional and provincial competitions.

The surface mine rescue team was involved in two, non-industrial, emergency situations. In one, they took part in the rescue of an injured man stranded on a mountain; in the other they assisted in the release of a teenage girl pinned inside an overturned pick-up truck.

Hearing Conservation Program

This program tests annually the hearing of employees exposed to high noise levels. Since the program began in 1976, an average of 1300 persons have been tested each year and a total of 48 W.C.B. claims were processed. To date, six employees obtained hearing-loss pensions and thirteen employees were fitted with hearing aids.

The company maintains its own hearing test equipment, which consists of a custom-built, portable trailer with sound-proof booth and an automatic Audiometer.

External Mine Safety Inspections

The Coal Mine Regulations require that the local mine inspector do inspections monthly. This requirement is usually exceeded and the inspections are found to be very beneficial.

Accident Frequency per 100,000 Man Shifts

	1978 Accident Frequency		
	Time Loss	No Time Loss Cases	
	Cases	First Aid	Medical
Harmer Pit	24.63	72.34	55.41
Elkview Plant	16.00	18.29	43.44
Michel Underground	91.73	70.40	46.93
*Other	9.86	5.64	15.50
Total	42.42	55.97	45.31

*Includes main office, environmental control and exploration.
Workmen's Compensation costs are 1.7% of total operation costs.

Absenteeism—1978

Shift Lost		
Accidents	6,106	1.8%
Sickness	17,834	5.3
Leave	3,004	0.9
Absent With Permission	13,886	4.1
Absent Without Permission	6,549	1.9
	47,379	14.0
Shifts Worked	290,654	86.0
Total Shifts Scheduled	338,033	100.0

In addition, there were 21,965 vacation shifts.

Reclamation

The Reclamation Department was established in 1969 and became fully operational in the spring of 1970. Since that time, 1997 acres of disturbed land have been reclaimed.

The first work was on old abandoned surface mine sites, where early techniques and grass species were tested. These sites provided all the problems of slope aspect, type of spoil material; and interrelationships of species, and revealed the

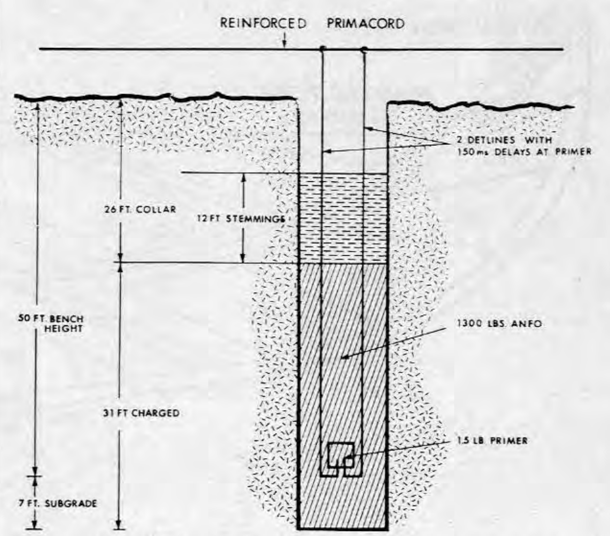


FIGURE 9. Standard explosives loading for a 12¼-in. hole.

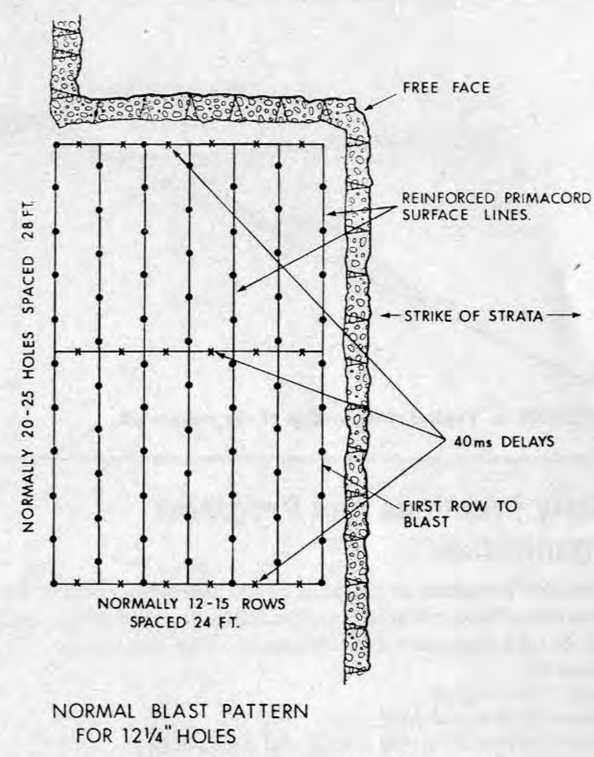


FIGURE 10. Normal blast pattern for 12¼-in. holes.

preferences of animals as to grass and shrub species. The latter is very important, because the whole area is designated as wildlife habitat.

The main mining and exploration areas fall within the following biogeoclimatic zones:

a) The interior Douglas fir zone—from valley bottom to 5000 feet.

b) The Engleman Spruce - Alpine fir zone—at elevations from 4,500 to 7,000 feet.

c) The Alpine zone—at elevations above 6,500 feet.

The steep topography and rugged terrain have broken these biogeoclimatic zones into localized areas which blend into each other. In the early stages, the reclamation program aimed to restore the vegetative cover as designated by the Canada Land

Reclamation of mined land is an integral part of the company's operations and to date approximately 2,000 acres of mined mountain terrain have been rehabilitated for wildlife forage.

Unit trains of 106 cars transport clean coal from Sparwood to the company's port facilities at Roberts Bank, near Vancouver, a 685-mile rail haul.

Inventory - Land Capabilities Analysis. However, practical experience showed that the best approach to reclamation of spoil here is to start a natural succession at the primary level of grasses and shrubs rather than attempt to replace a high-yield forest with similar material. The agronomic grasses provide not only initial ground cover, aid soil development and aid erosion control, but also provide a high-quality forage to replace the feeding areas alienated by the mining operation.

The most important and expensive phase of any reclamation program is site preparation. D8 and D9 dozers fitted with U-blades are used to flatten dump slopes from their original 37-degree angle to 26 degrees. In addition to establishing a suitable surface for vegetation, drainage control and aesthetics are accommodated by resloping the dumps to blend into the contours of the surrounding terrain.

Dumps are normally formed in descending terraces as stripping proceeds to lower levels. These terraces are at least 100 feet wide and occur at vertical intervals varying from 50 to 150 feet.

The incorporation of dump roads into terraces when resloping reduces surface erosion and also retains moisture for establishing vegetation. At first, a maximum slope angle of 26 degrees was maintained following experience gained on earlier fine spoil material. However, as the work progressed, it was felt that this particular spoil material could be left at 30 degrees because of its coarseness and relative lack of fines. After two years, 30-degree slopes have shown no signs of erosion. Steeper angles provide a considerable cost saving.

Seeding follows resloping. On the smaller sites this is still done by hand, but on larger sites helicopter seeding and fertilizing is used. After seeding, heavy harrows are drawn across the slope primarily to cover and protect the seed, but also to create a series of small terraces which aid in erosion control and retention of surface water for vegetation.

The grass and legume species used are all agronomic grasses, and the seed mixture is the result of test plot and annual vegetation assessments of reclaimed sites. The aim is to cover the spoil with vegetation as soon as possible after mining. Ideally, native species will invade from adjacent undisturbed sites and questions have been raised over the suitability of these agronomic grasses to the high elevations here. Three years of experience show that the introduced species are establishing a continuing vegetative cover at all elevations.

On darker soils, the seedlings require protection in their juvenile stages, and this is done by harrowing or applying wood fibre mulch by a hydroseeder. Once an initial cover has been established, the native shrubs and trees, which are grown from seed or cuttings in the company greenhouses and nurseries, are planted on site. These seedlings are held in the nurseries, for at least four years until they are of suitable size for field planting. So far, 350,000 trees and shrubs have been planted. The aim is to plant species which will provide suitable feed and cover for wildlife.

Fertilizer is applied annually to reclaim sites. How many years this will be necessary to make vegetation self sustaining is not yet determined. Research is being done on the use of nutrients and their cycling through the soil. These studies will determine the time necessary to develop a soil type.

Since 1974, Kaiser Resources Ltd. has adopted exploration techniques which appreciably reduce land and water disturbances. Previously, seam tracing and trenching were largely used to provide geological information. Trenching is now combined with road building. This, as well as increased drilling, greatly reduces land disturbance. All exploration proposals are plotted on sensitivity maps and aerial photographs. This helps in the evaluation of possible land disturbance and the alteration or elimination of bad features. In the field, all roads, drill sites and adit sites are flagged and inspected prior to construction. Specific changes can be made to avoid sensitive areas that did not show on the sensitivity maps or aerial photographs. Construction is done by experienced operators, most of whom have attended a Kaiser-sponsored course on environmental awareness and protective techniques in exploration. Whenever accessible merchantible timber is encountered, logging of the road right-of-way is carried out. Merchantible timber is sold to local mills. This technique avoids costly and dangerous slash abatement and wastage of a natural resource.

The Reclamation Department supervises logging, monitors exploration and reclaims past exploration work. The latter includes slash abatement, ripping and seeding of dormant roads, backfilling of trenches, test pits and adits, and re-establishment of watercourses.

Since 1969, the company has found that sites disturbed by mining can be successfully reclaimed by modified agricultural techniques. The success of this program is proven by the extensive use of reclaimed sites by wildlife.

Costs of reclamation differ widely, depending on local conditions, and have ranged from $500 to $5,000 per acre.

Kaiser Resources was awarded, for the year 1976, the first annual trophy presented by the B.C. Department of Mines for outstanding achievement in reclamation. The following year, the company received a citation for continuing leadership in the development and application of reclamation techniques. In 1978, Kaiser Resources won the provincial trophy a second time.

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