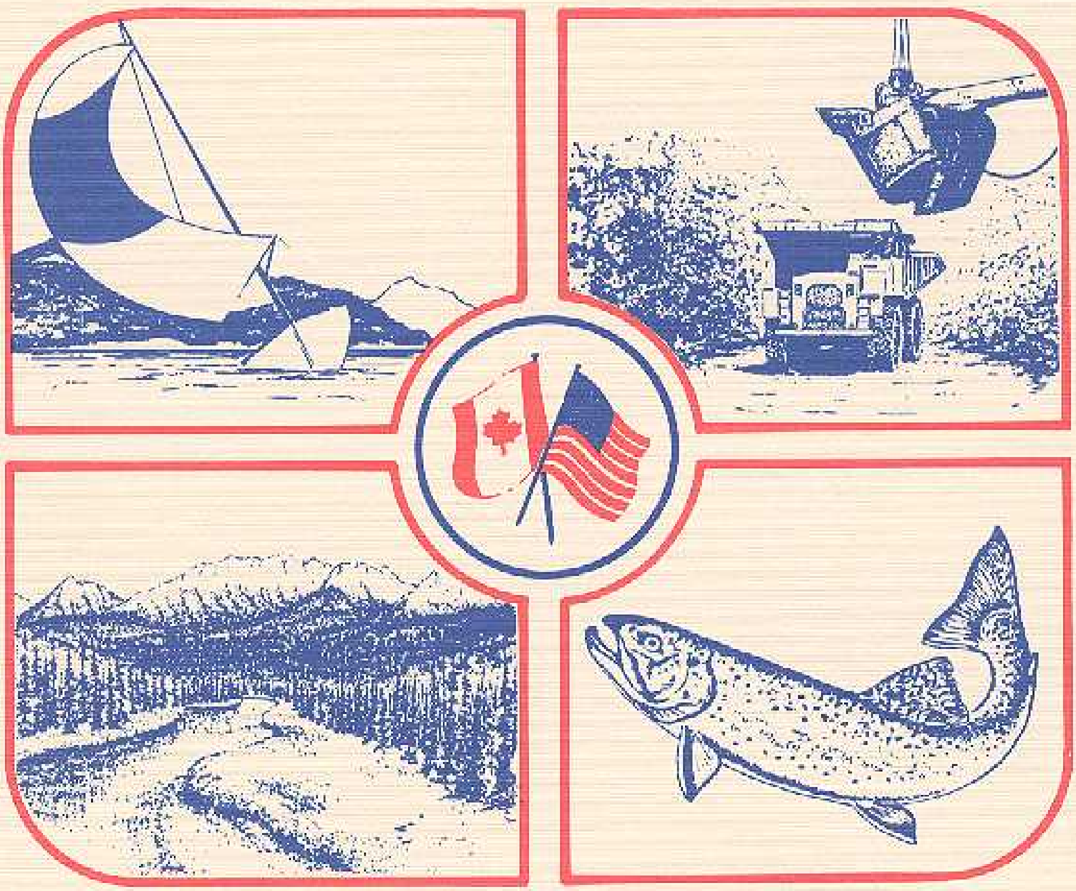
FLATHEAD RIVER
INTERNATIONAL STUDY



MINE DEVELOPMENT COMMITTEE TECHNICAL REPORT

We, the undersigned, members of the Mine Development Committee, appointed by the Flathead River International Study Board, have prepared the following report: "Mine Development Committee Report - Proposed Sage Creek Coal Project" and fully endorse its contents.

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PROPOSED SAGE CREEK LTD. COAL PROJECT

by

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MINE DEVELOPMENT COMMITTEE

Flathead River International Study Board

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EXECUTIVE SUMMARY

INTRODUCTION

This report was written to provide the Flathead River International Study Board and its other technical committees with mine site and design information on the proposed Sage Creek Coal Limited project as a basis for water quantity and quality impact assessment.

Sage Creek Coal Limited proposes to mine 2.2 million tonnes (2.4 million U.S. tons) of thermal coal per year over a 21-year period by open-pit methods. The proposed mine site is located near the confluence of Howell and Cabin Creeks in the Flathead River valley of British Columbia. The proposal includes a water management plan utilizing ditches and ponds on the mine site to control contaminated runoff. The proposal also includes a main haul road and transmission line routed from the north down the Flathead River valley as well as some of the tributaries to the Flathead River.

The British Columbia Government has granted the project Stage II approval-in-principle, which includes a number of water quantity and quality conditions to be met at Stage III. Stage II is the conceptual mine planning stage, whereas Stage III, which has not yet been reached by this proposed mine, is the detailed planning stage during which detailed mine plans are submitted and applications are made for various permits and licences.

In addition to project and area descriptions, the report includes both qualitative and quantitative assessments of the potential effects of the project. Optimal and adverse operational case scenarios are described to allow the evaluation of a range of effects that could potentially result from the proposed project, if developed. The optimal case is based on the Stage II design, as well as the assumption that standards and conditions specified in British Columbia Government regulations and guidelines for coal developments would be met. The adverse case is based on past instances where existing Elk Valley mines do not appear to have met those standards and conditions.

Existing Elk Valley mines were used for this evaluation because of geological and biophysical similarities between the Elk and Flathead

River valleys and because of similarities between the operating Elk River valley mines and the proposed Sage Creek Coal Limited project. In many cases it was not possible to provide precise or detailed quantitative estimates of mining effects because the data base was too weak. Appropriate application of data from the existing mines in the Elk River valley to the proposed mine site required the use of best professional judgement. It is possible that certain conditions or impacts may occur at the proposed Sage Creek Coal Limited mine site that are not adequately depicted by the available data.

QUALITATIVE DESCRIPTION OF POTENTIAL EFFECTS

During the construction phase of the project, the activities would include logging, land clearing, earth moving, and construction of roads, bridges, sediment control structures, transmission line, plant site facilities, and a tailings pond. Not all of these would occur within a discrete time period.

These construction activities could increase sedimentation, nutrient additions, organic debris loadings, and oil and grease contributions to streams, as well as disrupt stream geomorphology. Sediment controls, good "housekeeping" practices, appropriate construction timing, and revegetation have been proposed by the mining company to reduce impacts to water quality in the vicinity of the mine site during this phase.

The mining phase would involve pit and waste and refuse dump development, blasting operations, and coal processing. It would also involve use of mine roads, bridges, tailings pond, sewage disposal facilities, and a water management system. Mining phase activities would potentially result in sediment and/or inorganic nitrogen loadings to surface and groundwater from the pits and dumps, as well as nitrogen and phosphorus loadings from sewage disposal. Surface and groundwater discharges as well as pit dewatering would probably significantly alter surface water temperatures.

A water management plan has been proposed by the company to handle surface water. Any contaminated waters would be collected in ditches and routed to any of four settling ponds. Three of these ponds would discharge to the Flathead River while one would discharge to Cabin Creek. Runoff from the coal processing area would enter the tailings pond. Uncontaminated water diversion ditches would convey upslope water around mine facilities and discharge to Cabin, Howell, and Couldrey Creeks.

Sage Creek Coal Limited has proposed standard reclamation practices for this project. These would involve removal of mine site structures, grading waste dump slopes to approximately 26°, ripping the surface of roads and the plant site, applying salvaged soil materials (topsoil), and revegetation. The water-related impacts during the reclamation phase are expected to be similar to those identified during the mining phase.

Impacts to groundwater flow are expected to commence during construction and to continue through mining and reclamation. The following sequence is anticipated.

1. Initially, increased inflow to underlying aquifers and concomitant increased outflow to areas of groundwater discharge.
2. Leakage of as much as 75% of ditch and pond waters to the ground.
3. Later, local reduction of groundwater upwelling to creeks, decreased flow at springs, and reduced inflow to deep aquifers.
4. After proposed pits extend below creek elevations, there could be loss of Cabin or Howell Creek water to the groundwater system which would later be returned to the Flathead River system from pit dewatering and pond discharges.
5. During reclamation, groundwater flow rates would increase toward former levels, but surface inflow to the ground would remain greater than before initial disturbance.

Contamination of groundwater with various constituents, although low during initial construction, is expected to increase throughout mining and gradually decrease with time after mining. Groundwater temperatures would be affected most where ponds recharge the groundwater system. Conversely, groundwater temperatures would likely influence surface water temperatures in areas of discharge (outflow).

QUANTITATIVE ESTIMATES OF POTENTIAL EFFECTS

The water quality issues of main concern appear to be those related to phosphorus (P), nitrogen (N), total suspended solids (TSS), temperature, and accidental chemical losses.

Particulate P is expected to increase in Howell Creek downstream of its confluence with Cabin Creek by 0.050 mg/L and 0.150 mg/L, respectively, for the optimal and adverse cases (both figures are maximum daily average increases above background concentrations in any given year). Average annual loadings would probably range from 250 to 500 kg (550 to 1100 lbs). About 80% of this loading would occur during freshet.

For soluble reactive phosphorus (SRP), which is considered the most biologically available component of total P, the estimated increases are 0.002 mg/L and 0.004 mg/L (again, both are maximum daily average increases above background in any given year). If both surface water and groundwater discharges are considered, the estimated annual loading of SRP would be about 270 kg (594 lbs). A maximum range of 100 to 500 kg (220 to 1100 lbs) would be anticipated. These figures do not meet the phosphorus objective in the British Columbia Stage II approval-in-principle for the Sage Creek Coal Limited project, which stipulates no phosphorus increase in receiving streams, except for increases in sediment-related P.

The estimates for nitrate-N concentrations, primarily coming from explosive residues, are <5 and <10 mg/L (maximum daily average concentrations in any given year) in Howell Creek downstream of Cabin Creek for the optimal and adverse cases respectively. These would be within the British Columbia Government's approval-in-principle objective of 10 mg/L. Annual nitrate loading is estimated to be 120 tonnes (134.4 U.S. tons). Nitrate would comprise over 95% of the total inorganic nitrogen loading.

Nitrite-N concentrations are estimated to be 0.01 and 0.02 mg/L (maximum daily average concentrations in any given year) in Howell Creek below the confluence with Cabin Creek. These estimates were based on company data which may have over-estimated nitrite-N concentrations. The B.C. Government objective levels for this project are 0.060 mg/L at any time and 0.020 mg/L for prolonged periods.

Maximum daily average concentrations of total ammonia-N in any given year are estimated as 0.05 and 0.15 mg/L in Howell Creek below its confluence with Cabin Creek. These may be underestimates, based on the data used. The calculated total ammonia-N objective for this project is 0.838 mg/L.

For the adverse case, TSS concentrations would probably exceed the Sage Creek Coal Limited objective of a 10 mg/L increase above background levels on four occasions during freshet in an average year and once every four years during late summer or fall due to storm events. The average peak daily increase above background during these occasions is estimated to be 43 mg/L in Cabin or Howell Creeks above their confluence over a three-day period for each occasion. This peak estimate would apply to the construction and mining phases only. Peak concentration data cannot be used for generating loading estimates. The environmental objective of no greater than a 10 mg/L increase above background would be met during the remainder of the year; increases should frequently be much lower than 10 mg/L.

In the optimal case the 10 mg/L objective for TSS would not be exceeded. During non-freshet periods on Cabin Creek and all periods on Howell Creek, TSS increases above background should frequently be much less than 10 mg/L.

Temperature effects on Howell Creek below the confluence would include estimated changes of -1° to +1°C (-1.8° to 1.8°F) and -2° to +3°C (-3.6° to 5.4°F) changes, respectively, for the two scenarios as compared with the objective of a ±1°C (±1.8°F) change.

A variety of other parameters are discussed in the text with respect to receiving or mine effluent water concentrations. These include dissolved oxygen, pH, total dissolved solids, metals, and other cations and anions.

Land disturbance would be expected to increase runoff from the mine site by 20%, and to cause a three-fold increase in groundwater discharge from the mine site at maximum mine development. The average overall increases are estimated to be 0.91×10^6 m^3/yr (2.4×10^8 gal/yr) for surface water and 1.82×10^6 m^3/yr (4.81×10^8 gal/yr) for groundwater.

OTHER EFFECTS

The water-related effects of other mine-related events such as fugitive dust emissions and stream channel encroachment, have not been quantified. Nor have the effects of uncertain events, such as extreme flood flows and waste dump failures, been quantified. Nevertheless, they have been qualitatively evaluated or discussed in Section 6 of this report.

All settling ponds would contain two outflow structures: the normal decant to handle flows up to the 50-year flood, and a free crest spillway capable of passing the peak flow from a 200-year flood. A 50-year flood flow could decrease retention times in settling ponds or cause short circuiting of control structures. Debris could limit peak flows from discharge structures, or could cause a breach of a diversion ditch. Such an event could increase TSS contributions to the receiving waters, but other parameters would likely not be increased significantly due to dilution associated with the increased runoff. However, direct impacts to control structures from a 50-year flood flow should not be severe.

Probability estimates indicate that there is a 40% chance of a flood flow occurring that would equal or exceed the capacity of the normal pond decant (50-year) design, resulting in flow from the emergency spillway during the active project life (25 years). The probability of a flood flow equalling or exceeding the design capacity of the emergency spillway is 12% during the active project life. These probabilities increase when the project life is increased to 35 years to include 10 additional years into the reclamation period.

There had been no failures of settling ponds or tailings pond structures in the existing Elk Valley mining area of British Columbia until settling pond failures occurred at one mine in the spring of 1986. These failures are discussed in Appendix 7. Because of the considerable differences in settling pond design between those that failed and those proposed by Sage Creek Coal Limited, it would be unreasonable, from the standpoint of design, to consider additional risk of failure of the proposed Sage Creek Coal Limited settling ponds in light of the failures at the existing operation.

A number of waste dump failures have occurred in the Elk Valley area. Although visual observations indicated that limited and short-term water quality deterioration occurred as a result of these failures, quantitative data on these effects were not collected. While geotechnical information and dump design data indicate some potential for dump failure at the proposed Sage Creek Coal Limited mine site, proper dump construction and management practices would be expected to significantly decrease the likelihood of a failure. However, if a large enough failure of a proposed dump adjacent to Cabin or Howell Creeks were to occur, it would most likely cause a significant elevation of suspended solids in, as well as altering the geomorphology of, those creeks.

CONCLUSION

Table 6 of the text illustrates a comparison of effects predicted by the MDC with conditions set for approval-in-principle by the British Columbia government. The parameters that will tend to exceed the conditions for approval-in-principle as shown by Table 6 are soluble reactive phosphorus, temperature, and total suspended solids. Reduced nitrogen species may be of concern at locations of groundwater upwellings in Cabin and Howell Creeks.

ACKNOWLEDGEMENTS

The Committee gratefully acknowledges the many individuals and coal companies of the Elk Valley that contributed their information and perspectives.

Government agencies and their staff were very helpful in providing the Committee with technical information, background reports, and available government policy information.

The Committee is indebted to the B.C. Ministry of Energy, Mines and Petroleum Resources, Mineral Resources Division and, in particular, to the Mineral Policy and Evaluation Branch, for supplying office facilities and typing support.

The Committee wishes to thank Vivian Vosberg of the B.C. Ministry of Energy, Mines and Petroleum Resources for the many long hours of typing and re-typing earlier drafts.

Joe Truscott of S.J. Truscott and Associates co-ordinated compilation of this report and also provided assistance in its editing.

1. INTRODUCTION

1.1 RESPONSIBILITIES OF MINE DEVELOPMENT COMMITTEE

As part of the Flathead River International Study, the Mine Development Committee (MDC) was organized to provide other technical study committees with mine site environmental and design information necessary to assess impacts of the proposed Sage Creek Coal Limited project on water quality and quantity in the Flathead Basin.

The following terms of reference were given to the MDC by the Flathead River International Study Board (FRISB).

"The Mine Development Committee will have the following tasks:

1. to establish detailed work plans, including estimated financial requirements, schedules, subcommittee assignments, etc.;
2. to examine the mine and its ancillary facilities as described in the Sage Creek Coal Stage II Report as well as the supplementary conditions attached to the Stage II approval-in-principle required by the Government of British Columbia;
3. to determine the source, magnitude, extent, and duration of all water discharges related to the mine, and stream channel modifications occurring during the construction, operation, and reclamation of the Cabin Creek Coal Mine and its ancillary facilities, that could affect water quality, quantity or stream habitat of the Flathead River or its tributaries (especially Cabin and Howell Creeks). In its determinations, the committee shall consider, but not be limited to, plans for:
   - construction of powerlines and roads,
   - mine site water management,
   - construction camps,
   - sewage treatment,
   - blasting procedures,
   - mine waste disposal,
   - coal handling and dust suppression,
   - reclamation; and,

4. to prepare a report detailing the results of the above tasks, to be used by both the other committees and the Board." (FRISB Revised Plan of Study, January 1986).

In the early phase of the study a representative of Sage Creek Coal Limited was available as a technical advisor to the MDC. Following the reassignment of the company representative, Sage Creek Coal Limited was not represented on the committee. The company offered to provide further technical advice if required.

1.2 GENERAL PROJECT DESCRIPTION

Sage Creek Coal Limited proposes to develop a thermal coal mining operation consisting of two open pits near the confluence of Howell and Cabin Creeks in the Flathead River valley in British Columbia (Figures 1 and 2). The mining program is proposed to produce 2.2 million tonnes annually (Mt/yr) of medium volatile clean thermal coal over a period of 21 years (one tonne equals 1000 kilograms or 1.1 U.S. tons). Reserves in the immediate area are approximately 152 Mt of in-place coal of which 55.6 Mt would be mined, producing 46.6 Mt of clean coal (B.C. Research and Norecol 1982, [from here on, for clarity and expediency, this source will also be referred to as Stage II Environmental Assessment or Stage II EA]). More precisely, an annual clean coal production of 2.22 Mt would be necessary to produce a total of 46.6 Mt for 21 years of mining.

Open pits would be developed (see Subsection 2.1 for details) and overburden wastes would be placed onto waste dumps adjacent to the pits. A processing plant, coal drier, tailings pond, refuse dump, emergency stockpiles, and ancillary facilities would be located west of Howell Creek and south of Cabin Creek (See Subsection 2.6 for details). Coal would be processed at the mine site and transported by truck over an upgraded road to a load-out facility at Morrissey. Coal would then be transported from Morrissey along the existing C.P.R. rail line to the Roberts Bank Coal Port in Tsawwassen, near Vancouver.

A new 230 kilovolt (kV) transmission line would supply power for the project. This line would extend south 87 km (54 mi) from Natal to the mine site.

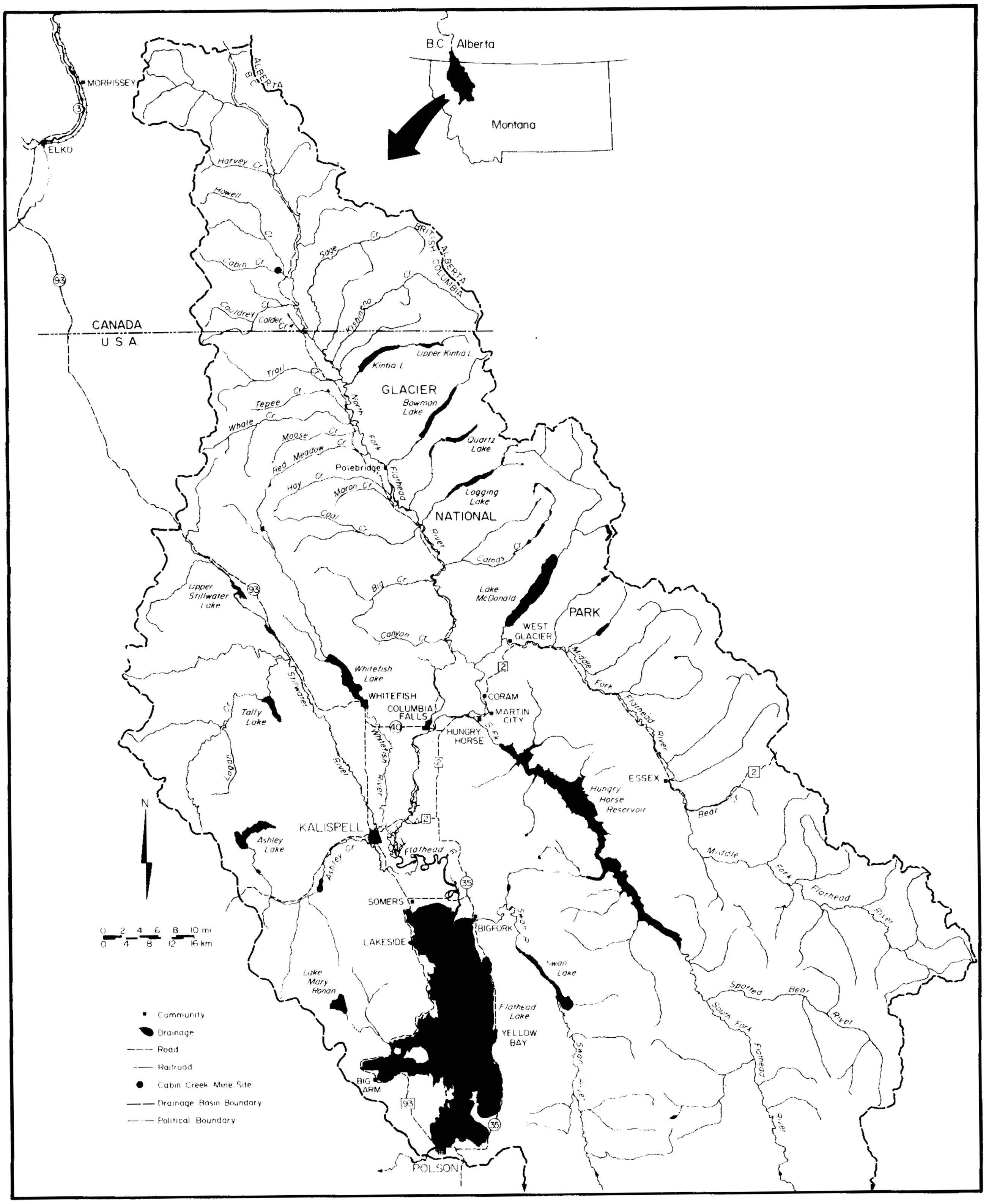

Figure 1. Flathead River drainage basin.

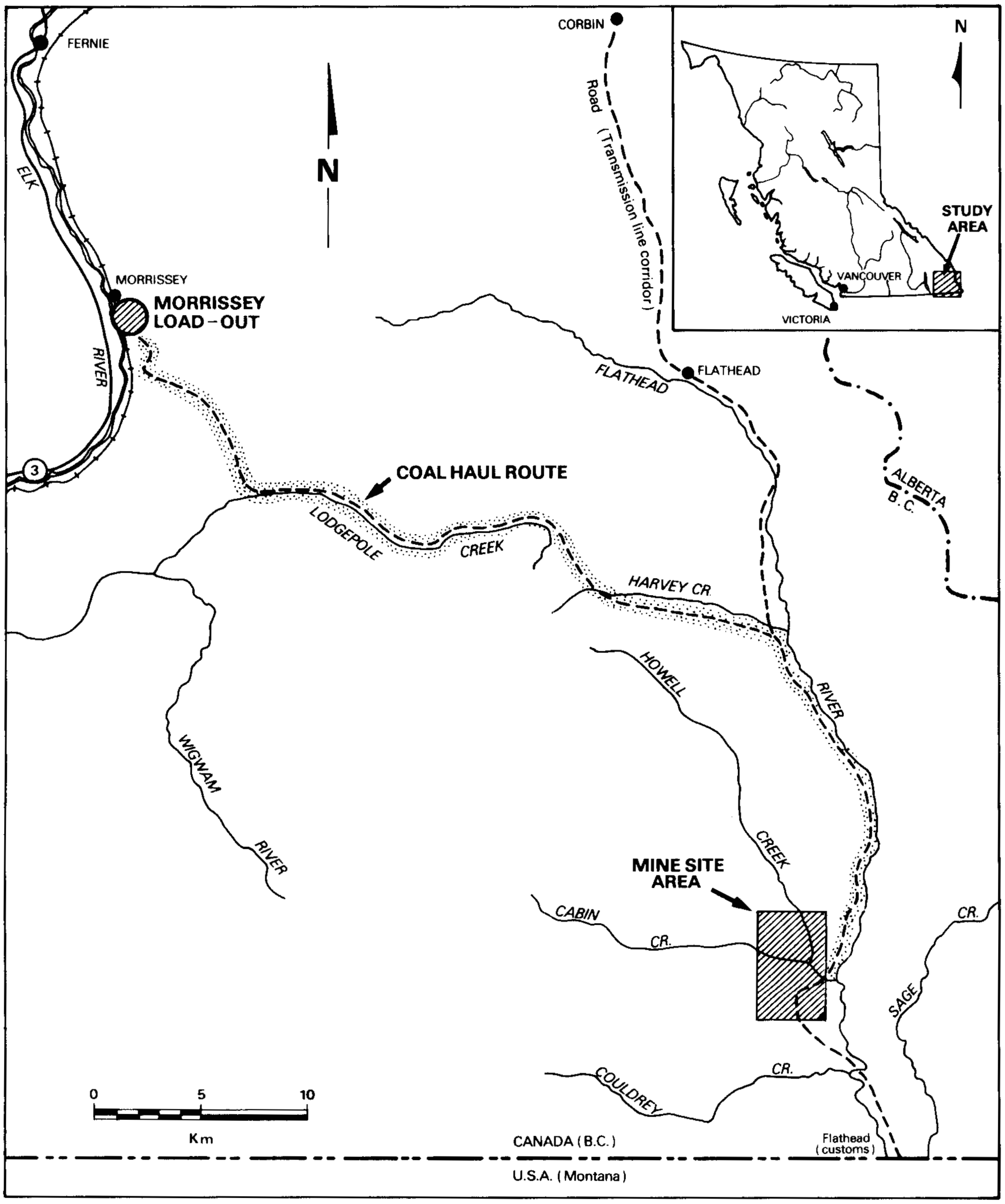

Figure 2. Location of the proposed project.

A 400-worker construction camp would be located near the mine site for the duration of the construction period, and would be dismantled after the construction has been completed.

Table 1 provides general technical project information. To achieve the proposed coal production levels, the mine would operate three eight-hour shifts per day for 355 days per year.

Water supply for the plant operation is proposed to be mainly recycled water from the cyclone and thickeners, as well as a small contribution from the tailings pond. Make-up water would be obtained from the settling ponds.

Four settling ponds at the mine site have been designed to reduce potential sediment loading to natural streams. Mine site drainage from roads, mine facilities, open pits, and waste dumps is designed to be controlled by drainage ditches and culverts, and then directed into settling ponds.

Three mine site bridges have been proposed: two crossings over Howell Creek and one over Cabin Creek.

1.3 SCOPE OF THE MDC STUDY

The Flathead River International Study Board (FRISB) recognized that because the mine development plan is still in the conceptual design phase (Stage II) the MDC would not be able to precisely estimate the off-site water quantity and quality changes without making specific assumptions regarding final design. Accordingly, it directed the MDC to develop two mine site design scenarios to allow evaluation of a range of potential effects on water based resources from the construction, mining, and reclamation phases of the project (see Appendix 1).

The two scenarios developed included an "Optimal Operational Case" formerly called "Most Desirable Case" by the FRISB and an "Adverse Operational Case" formerly called "Operational Case" by FRISB.

1.3.1 Optimal Operational Case

In this case the MDC has assumed that all mine site design components would involve the use of state-of-the-art mine technology and would also achieve design standards specified in various mining regulations and guidelines in the Province of British Columbia, including:

Table 1. Key technical data for the Sage Creek Coal Limited mine project.

Nominal clean coal production rate	2.2 Mt/yr
Nominal raw coal production rate	2.6 Mt/yr
Average stripping ratio	4.7 bank cubic metres[a]/per 1 tonne of raw coal
Average volume of overburden excavated annually	13 million bank cubic metres
Project life	21 years
Average wash plant recovery	
Years 1 to 5	82%
Years 6 to 10	74%
Years 11 to 21	69%
Mine operating days per year	355
Mine operating shifts per week	21
Plant operating days per year	313
Plant operating shifts per week	18
Plant maintenance shifts per week	3
Total number of mine employees	455 to 530[b]
Average hourly plant feed	
Years 1 to 5	444 t
Years 6 to 21	496 t
Washplant availability	82%
Power demand	15 Megawatts
Total *in situ* reserves	152 Mt
Total *in situ* coal reserves to be mined	55.6 Mt
Total clean coal to be produced (16% ash, 8% moisture)	46.6 Mt

a One bank cubic metre is one cubic metre in place before extraction, and therefore before swelling due to fracturing and bulking.

b Indirect employees added.

- Guidelines for Design, Construction, Operation, and Abandonment of Tailings Impoundments (Ministry of Energy, Mines, and Petroleum Resources [MEMPR]);
- Guidelines for Mine Dumps (MEMPR);
- Guidelines for Approval of Main Surface Haul Roads Regularly Used for the Transportation of Minerals or Waste at Mines (MEMPR);
- Mine Reclamation Guidelines (MEMPR);
- Pollution Control Objectives for the Mining, Smelting, and Related Industries of B.C. (governing air, solid, and liquid waste discharges at mine sites, preparation plants, and construction camps) (Ministry of Environment [MOE]);
- Water Licences and Approvals governing all surface water diversion and settling ponds (MOE);
- Guidelines for Stream Crossings (MOE); and
- Conditions for Stage II Approval-in-Principle.

1.3.2 Adverse Operational Case

In developing an adverse operational case, the MDC has considered actual operational data based on experience with existing mining operations in the Elk River drainage as well as specific conditions of the proposed Sage Creek Coal Limited project site. This includes allowance for variances due to problems with environmental control structures experienced at mines operating in the Elk River drainage.

The operating mines have been used to establish a range of observed effects. However, it cannot be assumed from this that operating mines generally represent the adverse case. Rather, different facets of each existing operation may reflect either adverse or optimal operational cases under different conditions and at different times.

This case includes the assumption that events would occur that would result in point and non-point source discharges which exceed water quantity and quality standards specified in the above regulations and guidelines. While the contributions of some such events, such as chemical spills, are implicitly included in quantitative projections in

Section 5, contributions of "extreme events", such as high flood flows, were not quantifiable and are discussed in Section 6.

1.4 THE MINE DEVELOPMENT COMMITTEE REPORT

The FRISB directed the MDC to prepare a statement which covers all phases of the project and which is based on preliminary design specifications outlined in the Stage II EA for:

- mine site water management measures;
- waste treatment at processing plant and construction camps;
- blasting procedures;
- mine waste disposal and dump stability;
- coal handling and dust suppression;
- reclamation measures; and
- construction of powerlines and roads.

In several cases the MDC has not been able to assess the Stage II design conditions to effectively quantify water quantity or quality emanating from potential point and non-point contaminant sources. In those cases, the uncertainties and means of addressing them are outlined.

The MDC has limited its detailed evaluations (Sections 4 to 6) to a 21-year mine life plus an initial two-year construction period. The mining plan in the Stage II reports of the company is based upon that period. However, considerable coal reserves would remain at the mine site at the end of its 21-year life (see Table 1). Moreover, there are aspects of design that are built into or are a natural part of various mine site structures that would accommodate continued mining past the 21-year horizon (Subsection 2.5).

Reclamation activities would continue for some unknown period of time after completion of mining (see Subsection 4.3).

1.5 STUDY METHODS

In most cases, the analysis involved collection, review, and evaluation of existing data, reports, and file information from both the proposed mine site and existing mines in the Elk River drainage. Some chemical analyses were performed on coal-waste refuse samples from an Elk River valley operation (see Appendix 2) to provide worst case-type data for waste and refuse dumps groundwater quality assessment purposes.

Effluent and receiving water data from mining activities in the Elk River valley were used because of geological, biophysical, and mining method similarities between the operating mines and the proposed Sage Creek Coal Limited project.

There are five open pit-coal mines in the Elk River drainage in southeastern British Columbia upstream of Lake Koocanusa.

	First Coal Shipped	Annual Production Capacity (million tonnes) Metallurgical	Thermal
Westar Mines Ltd. (formerly B.C. Coal Ltd., Kaiser Resources Ltd.)	1968	7.0	1.0
Fording Coal Limited	1972	5.0	1.0
Byron Creek Collieries	1974	-	1.3
Greenhills Mine (Westar)	1982	1.8	1.1
Line Creek Mine (Crows Nest Resources)	1982	1.3	1.7
TOTAL		15.1	6.1

Since 1970, substantial improvements have been made in the state-of-the-art of all aspects of open-pit coal mining, settling ponds, tailings ponds, plant efficiency, waste dump control, coal refuse disposal, environmental control, and reclamation.

In view of the limitations of the data base at the proposed mine site as well as at similar open-pit coal mines in the Fording and Elk River valleys, the MDC found it necessary to make a number of assumptions in order to estimate impacts to water quantity and quality. Major data deficiencies consist of an inadequate understanding of mine site and regional hydrogeology, dewatering practices to be used in preparation for the use of explosives, pit dewatering, hydraulic conductivities of surficial geological deposits, chemistry of discharges, detailed engineering design information, and reclamation. Attempts have been made to outline where major assumptions were made and to caution the reader where interpretations were based more on professional judgement than actual data.

1.6 PROJECT HISTORY

The company proposing the development, Sage Creek Coal Limited, was formed as a partnership of Rio Algom Ltd. and Pan Ocean Oil Ltd.

The Sage Creek Coal Limited project has been under review by the British Columbia Government since 1970 (see Appendix 3 for a description of legal and administrative arrangements for reviewing, regulating, and monitoring coal developments in British Columbia). Key dates in the evolution of project planning are:

1970-75:	Exploration Phase.
July 1975:	Prospectus Submitted.
August 1975:	Project designated for review pursuant to Environment and Land Use Committee Guidelines for Coal Development.
July 1976:	Stage I Environmental Assessment Submitted.
October 1976:	Stage I Approved.
December 1979:	Stage II Reports Submitted, Screened by Mine Guidelines Steering Committee (MGSC) (see Appendix 3 for description of this committee).
July 1980:	Stage II withdrawn by company for revision.
August 12, 1980:	MGSC review comments forwarded to company with letter confirming withdrawal of the report.
August 17, 1980:	Provincial Ministries (MOE and MEMPR) approach Sage Creek Coal Limited to clarify continuing Provincial requirements.
March 1982:	Revised Stage II Reports submitted by Sage Creek Coal Limited to Coal Guidelines Steering Committee.
February 1984:	B.C. Cabinet issues Stage II approval-in-principle with Stage III conditions imposed.
January 1985:	Provincial/Federal Stage II review comments submitted to Sage Creek Coal Limited.

1.6.1 Stage II Approval-in-Principle Conditions

In a letter dated 1984-02-21, the Honourable A.J. Brummet, then Chairman of the Environment and Land Use Committee (ELUC), granted Sage

Creek Coal Limited Stage II approval-in-principle. The letter also summarized and confirmed several past commitments the company had made and required the company to adhere to a number of conditions and environmental objectives, as outlined below.

1.6.1.1 Company water quantity/quality-related commitments.

- Establishment of an environmental surveillance program at the start of the construction period.
- To avoid potential impacts of nitrogen enriched waters on critical spawning areas by relocating settling pond discharges below sensitive reaches or directly into the Flathead River.
- Containment of coal during storage and transport.
- Careful timing of bridge construction at the mine site to minimize fisheries impacts.
- Identification of potential problems concerning pollutant accumulation which could occur at the mine site within flood plain micro-environments.
- To locate and design contour ditches above the mine site in accordance with water licence requirements.
- To support an air emission permit at Stage III, by undertaking a baseline air quality monitoring program for total suspended particulates.

1.6.1.2 Additional requirements.

- "A completely undisturbed buffer strip of land must be preserved adjacent to both Howell and Cabin Creeks, extending a minimum of 90 m [295 ft] from the high-water mark of these streams. Minor variations to this set-back distance may be allowed if the net result would be improved waste dump stability in particular, and improved environmental protection in general. Such variations would have to be approved by both the Ministry of Environment and the Ministry of Energy, Mines and Petroleum Resources". The MDC assumes that the buffer strip would include bridges and, to some extent, contaminated water ditches, a sewage line across Howell Creek, and rip-rapping of Howell Creek banks (see Sections 4 and 6). The MDC also assumes that protective berms proposed around the bases of some of the waste dumps would generally be outside the buffer strip because they would be incorporated into the toes of the dumps when they are graded during reclamation. A final MDC assumption is that logging would not be allowed in the buffer strip.

- "A major concern of the Ministry of Environment is the potential dewatering of Howell Creek, as the mine pit extends below the valley floor. The company will be required to carry out further groundwater studies at Stage III in order to determine the likelihood of this occurrence, and to propose preventative measures. This information will be required in support of the application for a land-improvement water licence covering diversion ditch construction.
- "A quantitative assessment of potential fisheries impacts along the proposed transmission line and route alternatives, [must be undertaken] identifying both mitigatable and non-mitigatable impacts.
- "The inventory of cutthroat trout spawning areas in Howell and Cabin Creeks [must be completed along with a] determination of mitigatable and non-mitigatable losses.
- "The results of wildlife and fisheries studies must be used to develop a comprehensive mitigation plan that lays out clear implementation strategies" (Attachment 3, letter from Honourable A.J. Brummet, Chairman ELUC, to Mr. L.H. Hunter, President, Sage Creek Coal Limited, 1984 February 21).

1.6.1.3 Environmental quality objectives. "The following ambient water quality objectives shall apply in those reaches of Howell Creek that are important for Dolly Varden spawning, and in the Flathead River at [the confluence with] Couldrey Creek:-

"(a) The maximum permissible increase in suspended solids above background levels shall be 10 mg/L when background concentrations are less than 100 mg/L, or 10% [of background] when background concentrations exceed 100 mg/L.

"(b) Concentrations of nitrogen compounds [as N] shall not exceed the following:

NO_3 [Nitrate] - 10 mg/L at any time;

Un-ionized NH_3 - 7 [micrograms per litre] μg/L for prolonged periods and 30 μg/L at any time.

NO_2 [Nitrite] - 20 μg/L for prolonged periods and 60 μg/L at any time.

"(c) No increase in phosphorus concentrations will be permitted, except that contained in allowable increases in suspended solids concentrations.

"(d) Barium concentrations shall not exceed 1.0 mg/L".

(Attachment 2, letter from the Honourable A.J. Brummet, Chairman, ELUC, to Mr. L.H. Hunter, President, Sage Creek Coal Limited, 1984 February 21).

1.6.1.4 Clarification of approval-in-principle conditions. In a letter dated 1984-06-12, to Mr. Lorne Hunter, President, Sage Creek Coal Limited, the Honourable A.J. Brummet clarified these requirements as follows in these excerpts.

"These water quality objectives are a general statement of Ministry of Environment policy on the levels of water quality that must be maintained over time if important water uses are to be protected. They are considered provisional, reflecting current [June 1984] information on the effects of water-borne contaminants on the aquatic environment and, therefore, are subject to refinement as new information becomes available. The objectives have no legal standing since their direct enforcement would not be practical because of the difficulty of accurately measuring contaminants in streams, and thus of proving violations and their cause. The objectives will assist in determining the allowable loadings of specific contaminants in permitted waste discharges and ... discharge objectives set by [waste management] permit will continue to be the basis for assessment and review of waste water control facilities. The receiving-water objectives become a goal to be maintained or reached over time and, as such, provide a context for both the discharge objectives and any improvement in abatement facilities that may be required. It has not generally been the policy of the Ministry of Environment to allow specific effluent discharges to saturate the capacity of the receiving environment, a practice that would be neither desirable nor conservative given that the long-term effects of many pollutants on aquatic life are inadequately understood. In short, the existence of receiving-water objectives must not be construed as a reason not to provide basic levels of waste treatment."

"...The ambient water quality objectives will apply everywhere in Howell and Cabin Creeks and the Flathead River except for yet to be specified initial dilution zones downstream from waste discharges. On the basis of present information, [it can be said] with certainty that the objectives must be met in two locations; Howell Creek, to protect Dolly Varden spawning; and the Flathead River upstream of Couldrey Creek, in order to minimize transboundary water quality degradation. Where else the objectives will be applied, and the site-specific variances that may be allowed, will depend upon the siting of initial dilution zones, which in turn will depend upon information, such as the inventory of cutthroat spawning areas, that [the] Company has committed to provide at Stage III. The actual selection of monitoring sites, sampling frequencies, and sampling periods, will depend upon a detailed assessment of the locations of waste discharges, mixing patterns, and the distribution of significant aquatic resources. It would be desirable for the Ministry [of Environment] and Sage Creek Coal Ltd. to agree on all aspects of the monitoring program, but if they cannot, the Ministry would exercise its environmental management mandate and set the conditions itself."

"The objectives for phosphorus should be viewed simply as [an MOE] policy statement rather than a quantifiable objective; in short, the Ministry wishes to minimize the discharge of phosphorus into any stream susceptible to algal growth, particularly if those streams are also subjected to increased nitrogen loadings. We may, in the future, set a numerical objective based on algal growth, but considerably further work would be necessary to develop such an objective. For the time being, it is more practical simply to closely manage phosphorus sources, such as sewage and fertilizers, to minimize their loss to surface water.

"We acknowledge that barium levels have infrequently exceeded the 1.0 mg/L objective under natural conditions. In such circumstances, as indicated by monitoring sites upstream of the project, the objective would not apply".

1.6.2 Other Company Commitments

Sage Creek Coal Limited proposed to conduct more field investigations and detailed analyses of certain mine site features once approval-in-principle was granted. These features include:

- bridges on Cabin and Howell Creeks;
- Settling Ponds 2 and 4 because of their infringement on the Howell Creek floodplain; and
- ditches in the vicinity of the upper Howell Creek bridge and Settling Pond 4 for the same reason.

The company has also indicated that the following studies would be conducted during the Stage III process for engineering design purposes.

- Groundwater studies, although it is not clear what these would entail (letter dated March 15, 1984, from Mr. Lorne Hunter, President, Sage Creek Coal Limited, to the Honourable A.J. Brummet, Chairman, ELUC).
- Detailed engineering studies and environmental assessment of the transmission line. Further investigations of surficial materials to identify areas of potential stability problems along the proposed route would also be undertaken.
- 200-year floodplain studies.
- Detailed studies of the proposed route and costs of the main haul road.
- Geotechnical studies of the tailings pond and the settling ponds.

The reader is referred to Sections 4 and 6 where the above features of the mine and mine site are discussed. Subsection 4.2.3 includes discussion of alternative routing of the transmission line.

2. MINE PLAN

Much of the material in this section is available in the Stage II proposal reports (B.C. Research and Norecol 1982) but general information related to the proposed mine plan, and waste discharges and management, has been reproduced here for the convenience of the reader. The reader is referred to Section 4 for a detailed description of possible environmental effects of the project.

2.1 GENERAL

The Sage Creek Coal Limited project would employ truck and shovel open-pit mining methods similar to those used at Elk River valley coal mines. After the overburden is blasted, it would be loaded by 19 m^3 (24.8 yd^3) electric shovels into 154-tonne, electric-wheel, end-dump trucks. This overburden material would be hauled to waste dumps located adjacent to the pit areas.

Mining would be carried out in two areas described as North Hill and South Hill (Figure 3). Three development stages are planned for the North Hill area and two stages for the South Hill area, excluding pre-development.

The following schedule of activities is reproduced from information existing in or implied by the Stage II EA. This schedule is probably tentative and subject to change during Stage III, which involves permit and licence application, and during project operation.

2.1.1 North Hill Preproduction

During an initial two-year period, the following construction work would be required (a chronological sequence is not implied):

- development of 400-employee construction camp at the mine site;
- logging, grubbing, and stripping;
- levelling of the plant site to grade and construction of mine site access, haul, and service roads, including the bridge across Cabin Creek;
- development of the North Hill pit to a stage where mine production could begin;

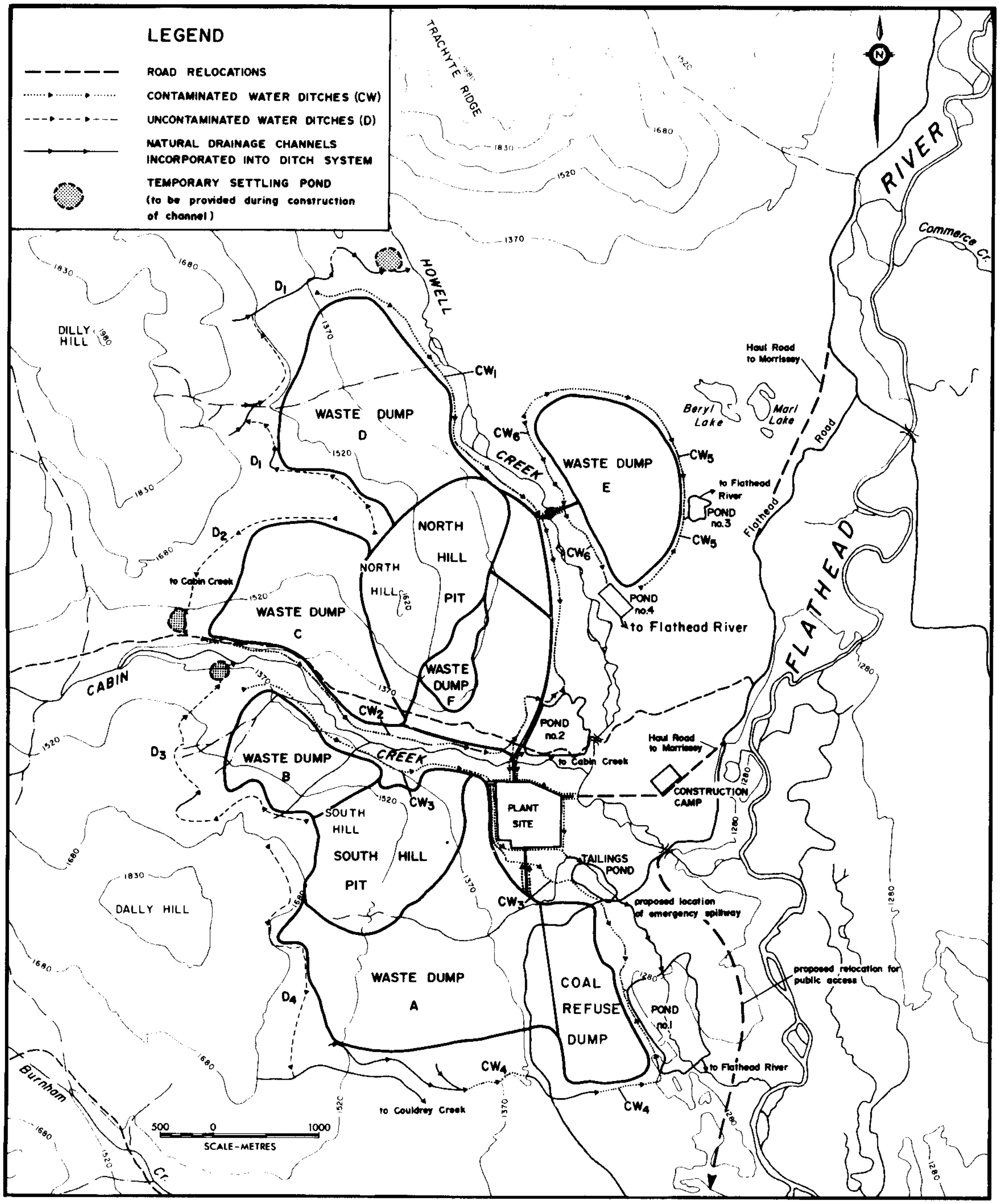

Figure 3. Project development plan.

- road upgrading from Morrissey to the mine site for use as a haul road, including building one of the bridges across Howell Creek;
- construction of all required buildings and facilities (including that for sewage treatment);
- construction of the 230-kV transmission line from Natal to the mine site, including access roads;
- building of the Morrissey coal load-out railroad facility;
- installation of Settling Ponds 1 and 2 and the tailings pond;
- construction of Contaminated Water Ditches CW1 (partial) and CW2 around North Hill and at least a portion of CW3 around the coal refuse dump (see Figure 3);
- construction of Clean Water Diversion Ditches D1 and D2; and
- begin construction of Waste Dumps C and D (and associated protective berms).

2.1.2 North Hill Stage 1 (Years 1 to 4)

- construction of Settling Ponds 3 and 4;
- construction of Contaminated Water Ditches CW5 and CW6 around site of Waste Dump E;
- additional road building;
- building of bridge across Howell Creek to access site of Waste Dump E;
- stage 1 mining (to the approximate elevation of adjacent valley floor);
- expansion of Waste Dump D and berm;
- begin construction of Waste Dumps E and F; and
- begin construction of coal refuse dump (near plant site) and construct associated protective berm.

2.1.3 North Hill Stage 2 (Years 5 to 6)

- stage 2 mining;
- expansion of Waste Dump C and berm;
- expansion of coal refuse dump; and
- additional road building.

2.1.4 South Hill Preproduction (Year 5)

- logging (assumed to be no later than year 5), grubbing, and stripping;
- construction of Settling Pond 1;
- construction of Contaminated Water Ditches CW3 (additional segment) and CW4;
- additional road building;
- begin overburden excavation and Waste Dump A construction; and
- construction of Clean Water Diversion Ditch D4.

2.1.5 South Hill Stage 1 (Years 7 to 11)

- stage 1 mining (to an elevation somewhat below that of adjacent valley floor);
- expansion of Waste Dump A and building of Waste Dump B;
- complete westward extension of Contaminated Water Ditch CW3;
- construction of Clean Water Diversion Ditch D3;
- expansion of coal refuse dump; and
- additional road building.

2.1.6 North Hill Stage 3 (Years 12 to 16)

- stage 3 mining (to pit limits below adjacent valley floor);
- expansion and completion of Waste Dumps C, D, E, and F and berms associated with C and D;
- continued building of coal refuse dump; and
- additional road building.

2.1.7 South Hill Stage 2 (Years 17 to 21)

- stage 2 mining (to pit limits below adjacent valley floor);
- expansion and completion of Waste Dump A and coal refuse dump; and
- additional road building.

This sequence of stages is designed to give the best overburden to clean coal ratios during the early years of production. In the early years the clean coal stripping ratio would be 6.35:1 and over the life of the mine would average 7.91:1.

2.2 MINE HAUL ROAD DEVELOPMENT

The mine haul roads at the Sage Creek Coal Limited property are designed to accommodate 154-tonne trucks. They would be constructed using cut and fill construction techniques. Steel and concrete bridges would be built for the roads to cross the various creeks. Each stage of mining described above would be associated with a distinct access road.

2.3 BLAST HOLE DRILLING

Since the proposed mine site contains stratigraphic units similar to those found at Elk Valley coal mines, similar operational techniques would be used in blast hole drilling at the mine. Only the overburden is blasted.

2.4 WASTE DUMPS

Discussed at length in Subsection 4.2.6.

2.5 POTENTIAL FOR FUTURE MINE PRODUCTION

The proposed mine plan is based on a 21-year mine life, but substantial additional reserves of coal exist and adequate space is available for dumping wastes well beyond this period.

Coal reserves proposed to be mined during the 21-year mine life are 55.6 Mt, while total reserves are estimated at 152 Mt (Table 1). The areas for mine expansion would be the deep coal reserves on the North Hill and Seam 5 on South Hill. However, development of these areas in the future would depend on the ability to secure sales contracts and on the economics of mining at the time. The economics of future mining could also be influenced by advances in mining technology and changes in government legislation or taxation.

Sage Creek Coal Limited has indicated that the proposed mine plan has been developed to permit a smooth continuation of operations beyond the present 21-year mining horizon. Of the proposed waste storage areas, Waste Dumps A, D, and E (Figure 3) are designed to accommodate future expansion. Dump A could expand southwards, Dump D could expand northwards, and Dump E could be extended northwards, eastwards, and southwards, if required. Such expansion would result in more land disturbance than is now shown for the 21-year mine life. The extent of additional disturbance would increase with continued mining.

Since no backfilling of the pit areas would occur during the proposed 21-year mine plan, remaining coal reserves would be protected for possible future underground development.

The tailings pond was also designed for an operating life longer than 21 years (Klohn Leonoff 1981b). Its present design capacity is planned to store the tailings from 40 years of mine production, at a rate 20% higher than the 2.2 Mt/yr currently planned. The tailings pond could also be enlarged in stages if increased capacities are needed beyond a 40-year period.

Similarly, the settling ponds shown in Figure 3 could be utilized beyond the 21-year mine plan. Should additional storage capacities of the two larger ponds be required, their dike walls could be raised, or sediment could be removed from the ponds.

2.6 COAL PREPARATION

2.6.1 Plant Process

The coal preparation plant (Figure 4) is designed to treat 2.6 Mt/yr of raw coal. On the basis of 5500 operating hours per year, the average throughput would be about 465 t/h.

Basically, the coal processing plant technology would be similar to that of other Elk River valley coal producers. Water-only cyclones would be employed as a primary coal beneficiating technique.

2.6.2 Mine Coal Handling

The raw coal from each seam would be stored separately in raw coal piles to facilitate quality control of plant production. Coal would be reclaimed by a front end loader feeding a pre-determined mix of the seam coal into a hopper.

Coal handling would consist of a fines circuit, coarse circuit, and medium recovery and handling circuit. The reader is advised to consult B.C. Research and Norecol (1982) for detailed descriptions of these circuits.

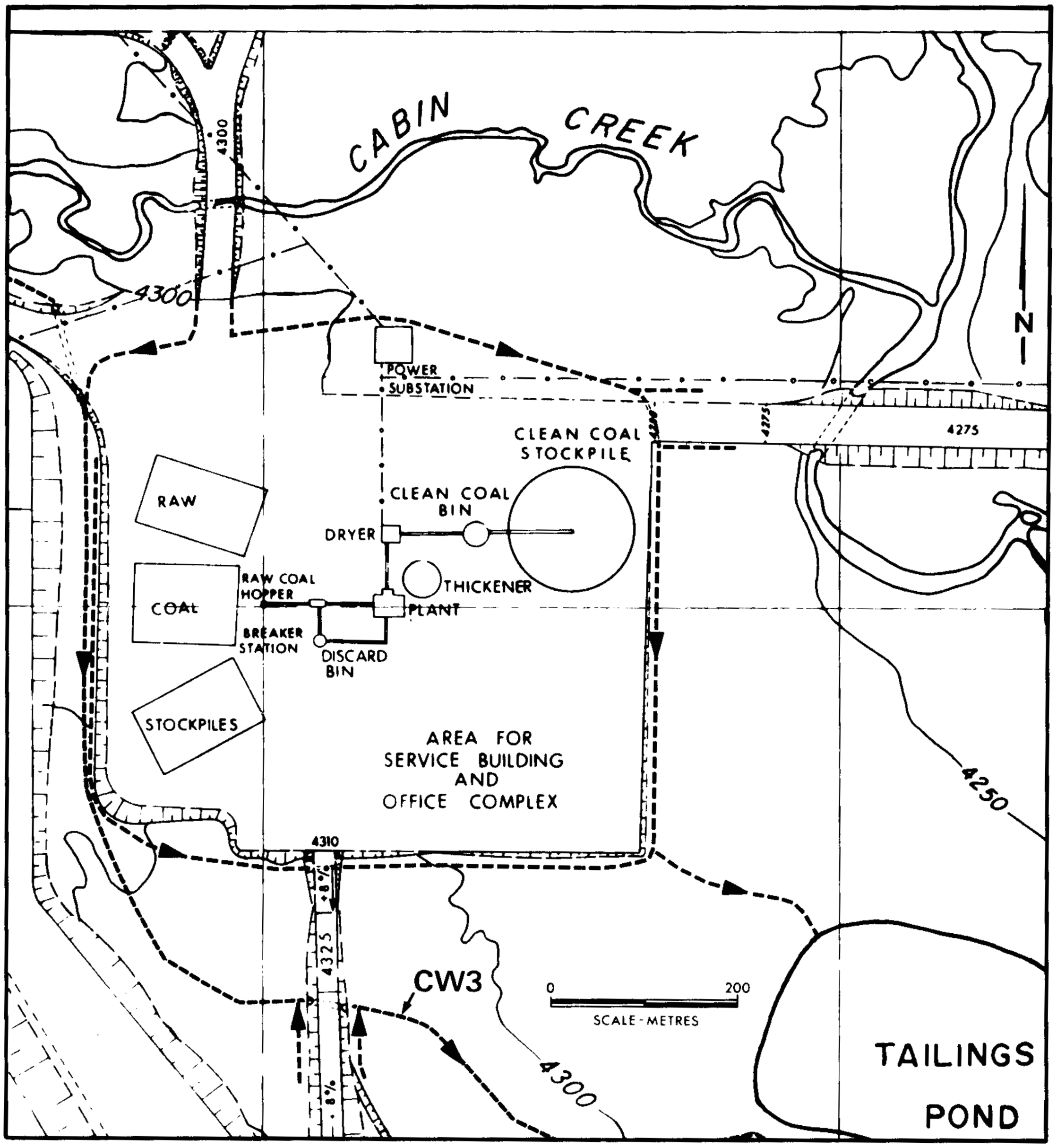

Figure 4. Plant site layout.

Generally, the fines circuit would have a discharge of centrate from the centrifuge to the tailings pond at a rate of about 2.5 L/s (39.6 gal/min). The coarse circuit would result in a discharge of centrates and rinse screen underflow which would be fed to the medium recovery and handling circuit to be recycled.

The thermal dryer would be a coal-fired, fluidized-bed dryer with no internal moving parts. All the coal mines in the Elk River valley have gas-fired dryers, except for one which has been converted to a coal-fired dryer. Two others will be converting in the future. The incoming feed would be spread across an air distributor and be fluidized by the upward stream of hot gases from the furnace. The air distributor would be sized for the proper pressure drop and flow of the hot gases to fluidize and to mix the coal. The water vapours would be carried out of the dryer in the exhaust gases.

A small percentage of the fine particles in the drying chamber would be carried out with the exhaust gases. These fines, down to about 10 micrometres in size, would be separated from the gas stream in cyclone dust collectors. The collected fines would subsequently be discharged through discharge gates into the dust screws which would convey the fines to the product conveyor.

The fraction less than 10 micrometres in size was not addressed by the company in the Stage II EA. However, Mr. Brummet, Chairman of the Environment and Land Use Committee at the time of approval-in-principle, charged the Company to do additional air emission work (see Subsection 1.6.1.1).

2.6.3 Clean Coal Handling

The dried clean coal, as discharged from the dryer, would be conveyed to a storage bin from which trucks would be loaded for trucking to the load-out station at Morrissey. The storage bin would have capacity for one day's mine production or approximately 7600 t.

An emergency ground stockpile of 50,000-tonne capacity would also be provided. Should the storage bin become full, a bypass chute on the top of the storage bin would be opened to divert the clean coal to the emergency stockpile. This coal would be loaded on the haul trucks by front-end loaders.

2.6.4 Refuse Disposal

Refuse from the coarse and fine circuits plus rejects from the rotary breaker would be conveyed to a 508-tonne capacity storage bin at the plant site. It would be hauled approximately 2.0 km (1.2 mi) from the bin to the coal refuse dump area by a 154-tonne, end-dump truck.

The coal refuse dump area would be located approximately 1.6 km (1 mi) south of the plant site and immediately to the west of Settling Pond 1 (Figure 3). The refuse dump is planned to hold 11 Mt of refuse material and cover about 67 ha (166 acres). Overburden berms would be built around the periphery of this dump area and would be progressively raised above the refuse material. At completion of operations, this refuse dump may be covered with overburden as part of the reclamation process.

2.6.5 Effluent Disposal

The plant effluent discharged to the tailings pond is expected to contain about 5% solids. The flow rate would be about 2.5 L/s (39.6 gal/min) while the plant is operating. The yearly effluent volume would be 50 x 10^6 L (13.2 x 10^6 gal). The company states that the suspended solids in the effluent would settle in the tailings lagoon as semi-consolidated sludge containing about 50% moisture (Stage II EA). It is estimated that the sludge would occupy about 4750 m^3 (6212 yd^3) per year. A 20% contingency has been added for the design of the pond to allow for abnormal conditions that may occur. The clarified water would be recycled to the wash plant for reuse.

2.7 ANCILLARY FACILITIES

2.7.1 Electrical Power Supply

Electrical power would be supplied by B.C. Hydro from the Natal No. 2 Substation via a 230-kV transmission line. Power at the mine site would be transformed to 13.8 kV for on-site distribution. The main plant substation would be located on the north edge of the plant site area. Auxillary power distribution centres would be provided for pumping and other ancillary power requirements at the mine.

2.7.2 Water Supply

The plant will need a process water supply and "domestic" water for staff needs. Water requirements for the plant operation are about 30,900 L/min (18.2 cfs) (Stage II EA, Appendix 2.6.1). This would consist mainly of recycled water from the thickeners (27,000 L/min [16 cfs] or about 87% of the total) with a make-up water requirement of 3600 L/min (2.12 cfs) or about 12% of the total. All or most of the make-up water would come from the settling ponds. The tailings pond contribution to recycled water is only about 0.5% of the plant requirements.

A separate water system would supply domestic water for use in the mine site, office, and plant areas. This requirement of about 909 L/min (0.54 cfs) would be from wells drilled on the site. If a sufficient well water supply could be developed, it would also be used as a back-up to the make-up water system. A more detailed assessment of water sources would be required for a Water Improvement Licence application during Stage III.

2.7.3 Garbage Disposal

During the construction period, garbage would be incinerated and disposed of daily at an appropriate waste disposal site approved by the Ministry of Environment (MOE).

2.7.4 Fuel Storage

A properly designed fuel storage tank would be located near the shop and dry complex in the plant site area. The fuel storage depot would have a capacity of about 500,000 L (132,000 gal) of diesel fuel. Potential spillage from the fuel tanks would be contained within an impermeable berm around the tanks.

Sealed sumps would also be constructed for fuel storage areas. All runoff from the plant site would be directed to the tailings pond.

Fuel supplies would be trucked to the site daily by a fuel supply company. The estimated daily fuel requirements are 40,000 L (10,568 gal).

2.7.5 Explosives Storage and Handling

The primary explosives for the mining operation would be AN/FO (dry ammonium nitrate and fuel oil and sometimes powdered aluminum) and a slurry/water gel. Slurry/water gel is composed of a mixture of sodium and calcium nitrates and fuels (such as fuel oil, sulfur, and other reagents) in an aqueous medium which is thickened with guar gum and commonly gelled with chromates (Pommen 1983). These would be supplied to Sage Creek Coal Limited by an explosives supply contractor.

Bulk storage of ammonium nitrate would be accommodated at the mine site. Slurry/water gel explosive requires a slurry preparation plant, which may be built on the site, or, if quantities do not justify it, the slurry would be trucked from a plant located in the Elk River valley.

2.7.6 Additional Chemicals

Other chemicals would be expected to be stored on-site, including greases, antifreeze, dust suppressants, flocculents, solvents, and other substances. A list of chemicals and their quantities stored and used annually at an existing operation in the Elk River valley is presented in Appendix 4.

The Stage II EA refers briefly to an organic polymer which would be used as a settling agent in the thickener for the coal processing operation. This chemical would be contained in the effluent to the tailings pond (see Subsection 2.6.5). The composition of this chemical is unknown to the MDC.

3. PROJECT AREA PHYSICAL ENVIRONMENT

3.1 LANDFORMS

The Sage Creek Coal Limited project area is located in the Rocky Mountains, within the Flathead Provincial Forest of the South Kootenay Land District (Figure 1). A major physiographic feature of this area is the Flathead River which flows from north to south across the International Boundary into the State of Montana. The Upper Flathead River basin in Canada is approximately 1110 km^2 (429 mi^2) in area, constituting 6% of the Flathead River drainage upstream of Polson, Montana. The Flathead River is the northern component of what is termed the North Fork Flathead River in the U.S. Its headwaters are about 55 km (34 mi) to the north of the project area in McEvoy Creek, which is approximately 65 km (40 mi) north of the U.S. border. Cabin and Howell Creeks, with a combined drainage area of about 238 km^2 (91.9 mi^2), are among the primary tributaries of the Flathead River. The Flathead River Valley is approximately 1300 m (4265 ft) in elevation and is about 4 to 5 km (2.5 to 3.1 mi) wide in the vicinity of the project site. The valley is about 6 km (4 mi) wide at the U.S. border.

East of the Flathead River the Clark Range rises rapidly to create the continental divide. The mountains immediately to the east (Commerce Peak, Langemarck Mountain, Kenow Mountain, and Miskwasini Peak) are steep, generally barren of timber above 1800 m (5906 ft), and have summits at about 2600 m (8531 ft). West of the Flathead River, the hills, ridges, and mountains are topographically more subdued, generally have lower summits, and are commonly forested to the summit.

Mining has been proposed on the east sides of Dilly and Dally Hills (North and South Hills of the Stage II EA report) which rise to elevations of 1980 and 1935 m (6500 and 6350 ft), respectively. These hills are topographically subdued for this area, but locally have slopes in excess of 30 degrees up to a maximum of about 40 degrees. Elevation at the mine site varies from 1250 to 1621 m (4100 to 5315 ft). Two small lakes (Beryl and Marl) are present south of Trachyte Ridge and north of the proposed mine site.

Cabin Creek originates on the northeast side of Inverted Ridge near Cabin Pass and generally flows in an easterly direction. The lower reach of Cabin Creek has an average gradient of 14 m/km (74 ft/mi) between the bridge just below its junction with Storm Creek to where it joins Howell Creek. In the vicinity of the proposed mine site Cabin Creek has a more gentle average gradient of about 6.6 m/km (35 ft/mi).

3.2 GEOLOGY AND SOILS

3.2.1 Regional Bedrock Geology

Numerous geological investigations have been carried out on the economically rich coal strata of the Kootenay Group located in southwestern Alberta and southeastern British Columbia. Many of the reports are of a specialized interest dealing with such topics as regional geology, detailed stratigraphy, coal petrology, coal ranking, structural geology, sedimentology, and others. The reader is directed to Gibson (1985) for a detailed description of previous geological investigations of the Kootenay Group and also for a well documented report on regional geological setting. In a recent paper Grieve (1985) describes the coal fields in the East Kootenays.

A brief summary of Gibson's work is as follows:

1. Strata within the Kootenay Group have long been of economic interest as a readily accessible source of thermal and metallurgical coal.
2. The Kootenay Group is up to 1112 m (3648 ft) thick and comprises formations which include (in ascending order):
   a. Morrissey Formation which ranges in measured thickness between 20 and 80 m (66 and 260 ft) and is composed of fine- to medium- grained sandstone;
   b. Mist Mountain Formation which ranges in measured thickness between 25 and 665 m (82 and 2180 ft) and is composed of predominantly nonmarine sandstone, siltstone, mudstone, and economically important thin to thick seams of coal; and
   c. Elk Formation which ranges in measured thickness between 0 and 590 m (0 and 1936 ft) and consists of an interbedded sequence of nonmarine sandstone, siltstone,

mudstone, shale, and locally, chert-pebble conglomerate and thin seams of coal.

3. The Mist Mountain Formation is the most economically important formation containing coal seams up to 18 m (59 ft) thick.
4. Coals in the Mist Mountain Formation range from medium to high volatile bituminous in the south, to low volatile bituminous to semianthracite coals in the north.
5. Coal seams are thicker and more numerous in the Fernie and upper Elk River valley areas.
6. Cementing agents of the clastic sediments consist predominantly of quartz and chert, and less commonly phosphate, dolomite, calcite, and clay minerals.
7. Analyses of sedimentary and fossil assemblages indicate that the Mist Mountain Formation was deposited in a fluvial, deltaic, and interdeltaic clastic succession in an environment largely unaffected by marine or brackish water inundations.

A brief summary of Grieve's work follows:

1. Three structurally separate coal fields (Crowsnest, Elk Valley and Flathead) are recognized in southeastern British Columbia. All are characterized by compressional tectonic features such as folding and thrust faulting, and by late stage normal faulting. The coal fields are in the Macdonald Ranges of the Rocky Mountains, within 30 km (19 mi) of the Alberta-British Columbia border, and extend north 175 km (109 mi) from the proposed Sage Creek Coal Limited mine.
2. Coal ranks range from low to high volatile bituminous and have a wide range of metallurgical and thermal qualities.
3. Measured reserves (1981) include 1.03 billion tonnes of metallurgical coal and 165 Mt of thermal coal.
4. The Flathead coal field is composed of four isolated outcroppings of the Kootenay Group, all of which are in the down-dropped west block of the Flathead Normal Fault.

3.2.2 Local Bedrock Geology

A number of geological investigations have been carried out within the Flathead drainage basin and at the proposed coal mine (Stage II EA).

A brief summary of local bedrock geology as described in the Stage II EA report is as follows.

1. The coal deposits occur in a local remnant of the Mist Mountain Formation of the Kootenay Group (formerly termed the Kootenay Formation), occupying the upper plate of the Lewis Thrust Fault (Figure 3.1.2-1, Stage II EA). Drill hole data indicate that thickness of this unit at the proposed mine site varies from 220 to 300 m (722 to 984 ft).
2. The strata locally strike north to northeast and dip east at an average of 30° in the shape of a monocline.
3. The downdip extension of the Formation passes underneath the floor of the Flathead Valley and is truncated against the Flathead Fault.
4. Three economically accessible coal seams would be developed on the property (Figure 5). The thickness of the seams proposed to be mined are outlined below:

Coal Seam No.	Overall Thickness	Bench Thicknesses
Seam 2	4.6 m	single bench
Seam 4	14.6 m	9.1 m upper bench 5.5 m lower bench
Seam 5	10.7 m	4.9 m upper bench 5.8 m lower bench

5. Coal quality testing indicates that the coal has a high calorific value and has been rated as excellent quality thermal coal.

The following are observations made by an MDC member during a field trip to the Flathead area:

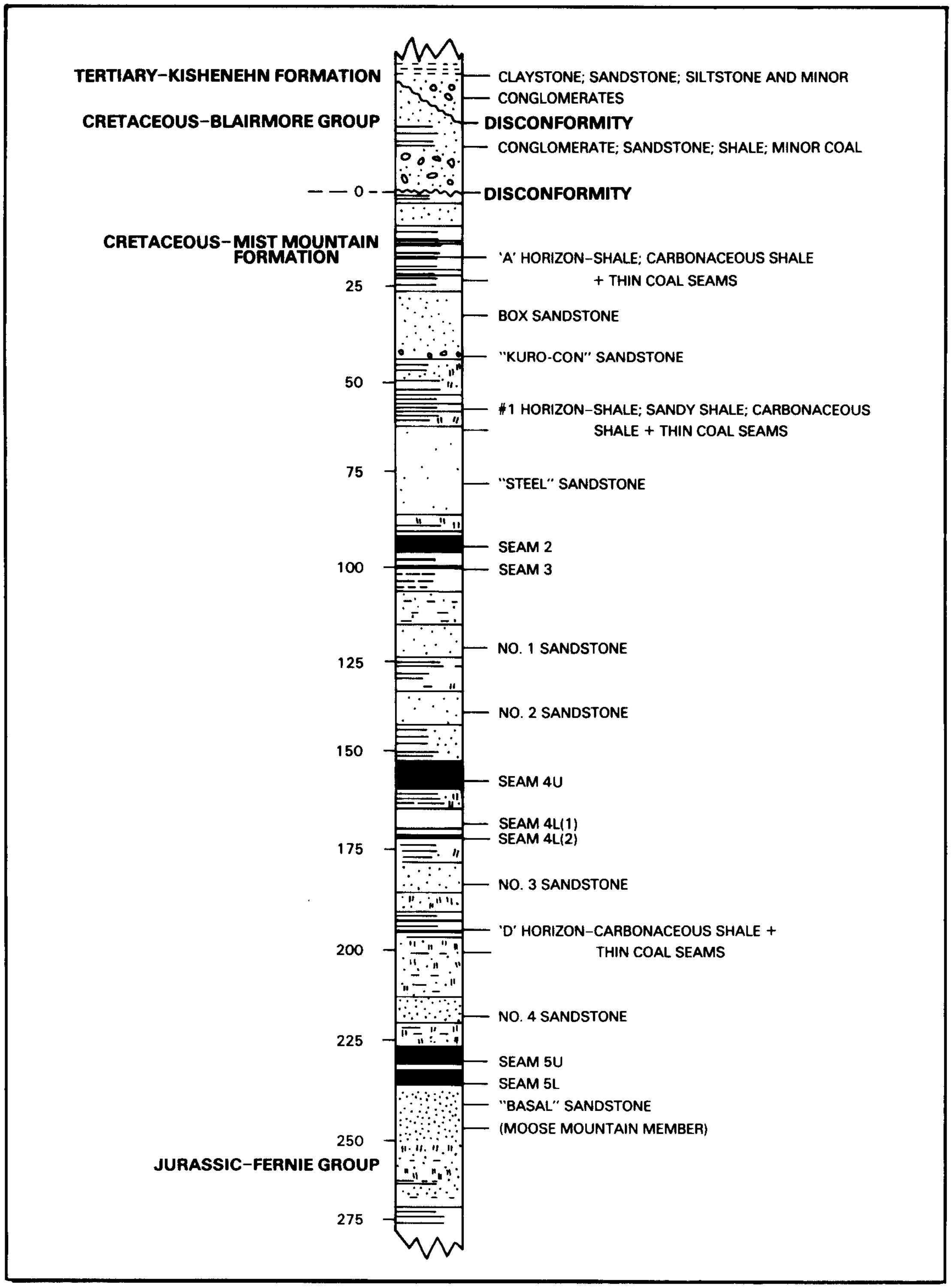

Figure 5. Generalized stratigraphic section at the proposed mine site. Vertical scale in metres.

1. Exposures along the Flathead River valley floor below the confluence of Howell Creek and the Flathead River indicate that all bedrock consists of poorly to moderately well-consolidated Tertiary materials. The Tertiary units are primarily composed of thin beds of siltstones, sandstones, marls, and claystones locally rich with fossils and locally dipping south and east. These units are exposed at a number of locations along the lower reaches of the river. At two separate reaches of the river bedrock is exposed on both banks and forms the streambed. The Tertiary units are relatively well-cemented and fine-grained and appear to have low porosity.
2. Older bedrock units are exposed on the lower and upper flanks of the Flathead Valley - including the mine site.
3. Thrust and normal faulting of the older units have been reported and were observed along the upper reaches of Howell Creek and on the north wall of Cabin Creek. A major fault is exposed approximately 1 km (0.6 mi) upstream of the proposed mine site on the north wall of Cabin Creek.
4. Large groundwater springs are discharging at the top of the Tertiary bedrock exposed on the east bank of the Flathead River at the International Boundary, supporting earlier observations that these units have low permeability.

3.2.3 Surficial Geology

A complex assortment of surficial geological materials on the Flathead River valley floor locally overlies Tertiary units. The areal extent of these units remains largely unknown. Surficial materials observed in the Flathead River valley during the previously mentioned field trip consist of the following.

1. A discontinuous veneer of grey silts (aeolian and/or floodplain) overlying valley floor sediments is evident. This unit is extensive and is exposed along the Flathead River primarily on the east bank below the confluence with Howell Creek and above the confluence with Couldrey Creek. The maximum observed thickness is 2 m (6.6 ft).

2. Coarse clean sands and gravels appear to be extensive in the Howell Creek streambed from its headwaters to its confluence with the Flathead River. There are minor exposures of this unit along the river. Thicknesses of these units are unknown.
3. "Dirty" sands and gravels with a silt and/or clay matrix are extensive above the Couldrey Creek/Flathead River confluence and appear more extensive than the clean sands and gravels along both the Flathead River and observed road cut exposures.
4. Boulder pavements are localized on Howell Creek and Flathead River streambeds. Average boulder sizes are roughly 40 cm (15.6 in) on the long axis. A number of boulders exceed 1 m (3.3 ft) in diameter suggesting either the presence of nearby glacial till or a very high energy flow regime during freshet stage.
5. Glacial till is locally exposed along the lower reaches of the Flathead River generally overlying Tertiary sediments. The till is primarily a light grey color and has a high silt-clay matrix. Thickness is unknown.
6. Silty clays and clayey silts are extensive in the Couldrey Creek valley. The unit appears massive with rare bedding structures. Observed thickness was approximately 30 m (100 ft). Areal extent of the unit is unknown. Two large slump blocks are located near the mouth of Couldrey Creek and are being eroded actively by the Flathead River. The resulting siltation of the Flathead River was significant and was observed downstream south of the International Boundary.

Alluvial fans generally consist of coarse sand and gravel deposits located along the flanks of major river valleys where tributary creeks flow into them. Topographic maps and aerial photos indicate that alluvial fans are located downgradient of the proposed mine site. Because of their recent deposition and young age these units overlie most of the glacial till and glacial outwash deposits.

Coarse-grained alluvium was observed in Howell and Cabin Creeks' stream channels. This unit is believed to be part of the Howell Creek alluvial fan, but its thickness is unknown. Alluvial deposits commonly exhibit high hydraulic conductivity. Consequently, if they are as extensive as believed, they would be expected to provide rapid infiltration of settling and tailings pond waters as well as sewage effluent from both the construction camp and plant facilities.

3.2.4 Soil Types

Soils in the area are complex (Stage II EA). Table 2 summarizes soil types in association with various landforms as parent materials. Soil names used were those employed in the Canadian System of Nomenclature and Classification. A discussion of soil salvage during the operation is included in Subsection 4.2.8.2 of this report.

3.3 GROUNDWATER AND SURFACE WATER HYDROLOGY

3.3.1 Groundwater

The groundwater regime is a dynamic system in which most water is continuously in motion from areas of recharge to areas of discharge. The dynamics of the system are controlled by a large number of variables including soil and subsurface infiltration capacities, fracture flow permeabilities, intergranular permeabilities, length and direction of flow paths, geological settings, and climate. In a typical groundwater flow system this movement occurs through an extensive heterogeneous and interconnecting geologic framework. This framework is composed of geological materials of diverse permeabilities which transmit groundwaters at highly variable flow rates along different flow paths.

At the proposed mine site, the groundwater flows through fractures, faults, intergranular voids, and joint systems in the bedrock units. A hydrogeological investigation carried out by Pacific Hydrology Consultants Ltd. (1982) noted that groundwater in bedrock at the proposed mine site is close to the surface and discharges via springs at lower elevations. This observation, together with local stratigraphic information (Stage II EA), suggests that lateral bedrock permeabilities are greater than vertical permeabilities. Pumping tests carried out on exploration boreholes indicate that groundwaters in the bedrock units

Table 2. Soil types in association with various landforms in the mine site vicinity (compiled from Stage II Environmental Assessment Reports).

Areas	Parent Material	Soils
Flathead River, Valley bottoms	Deep coarse-textured floodplain	Cumulic regosols
	High, stable, deep sandy/gravelly fluvial deposits	Orthic eutric brunisols Orthic dystric brunisols Brunisolic grey luvisols
Lower Elevation (1360 to 1825 m)	Deep, medium fine to medium-textured glacial till deposits	Brunisolic grey luvisols
	Coarse-textured glacial till deposits	Orthic dystric brunisols
Lower Elevation (1360 to 1825 m)	Fine and medium-textured colluvial deposits	Orthic dystric brunisols
	Coarse-textured shallow and deep colluvial deposits of calcareous parent material	Orthic eutric brunisols
Higher Elevation (1525 to 2100 m)	Shallow and deep, medium to coarse-textured colluvium	Orthic humo-ferric podzols
Higher Elevation (1525 to 2100 m)	Coarse-textured glacial till deposits	Orthic humo-ferric podzols
	Medium to fine-textured glacial till deposits	Luvisolic humo-ferric podzols; podzolic grey luvisols

move relatively slowly because of low fracture permeabilities. This could lead to dewatering problems and possible release of nitrogen compounds to groundwater. This will be discussed further in Sections 4 and 5.

Perched groundwater conditions may exist at the proposed mine site where a geological unit of low permeability impedes downward vertical groundwater movement. It is understood that some coal beds in the Elk River valley have low vertical permeabilities resulting in perched groundwater conditions which have led to ensuing dewatering problems at some existing and abandoned mine sites.

Groundwater in the area of the proposed mine also flows through surficial geological materials including glacial till, glacial outwash, alluvial fans, and other materials. The quantity, quality, rate of flow, and groundwater flow directions in the surfical geological materials are controlled by recharge area, hydraulic conductivities of the materials, distribution of the materials, vegetation, and other variables.

Natural groundwater chemistry is controlled primarily by the original water chemistry prior to infiltration, mineralogical constituents of host rock, and residence time of the water in contact with these materials. Chemical analyses of groundwater collected from exploration boreholes are presented in Appendix 5 and depicted graphically in Figure 6. Note that the water chemistry of the one sample from a well in Tertiary-aged sediments (Kishenehn Formation) is distinctly different from the surface waters and groundwater in the coal-bearing strata. Groundwater chemical changes are expected to occur as site development and mining activities progress. The resulting changes in groundwater flow and chemistry would cause impacts on surface waters and interconnecting groundwater aquifers. This will be discussed in Section 4.

3.3.2 Surface Water

The MDC examined site surface water in terms of the effects of mining on the relationship between hydrology and hydrogeology during project development, operation, and abandonment. Surface water hydrology is discussed in those contexts in Section 5 of this report.

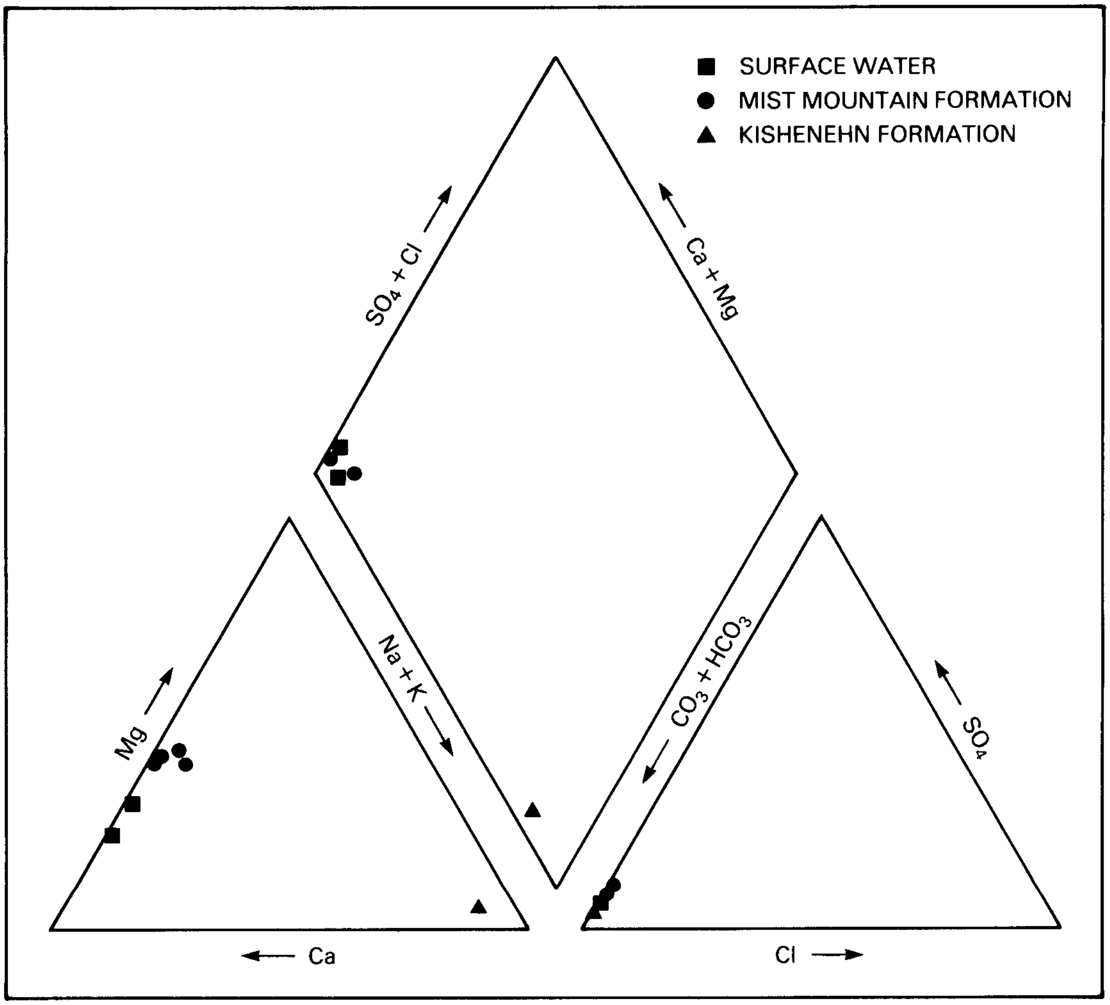

Figure 6. Piper plot of major element chemistry for waters sampled from exploration bore holes (results in Appendix 5).

3.4 CLIMATE

The climate of the project area can be broadly classified as a humid microthermal (snow) continental climate. Summers are hot to warm depending upon elevation. Winters are cold, being dominated by continental polar air (Stage II EA).

Temperatures can vary at any time within the site due to varying aspect and elevation. Significant variations can occur seasonally. Strong and persistent inversions can occur in the project area, although supporting data on these are sparse.

Data from nearby areas at Fernie and Aberfeld (59 and 74 km away) (36.7 and 46 mi) indicate that peak temperatures occur in July with temperatures of over 27°C (81°F) being possible from April through October. Temperature minima occur in January and are generally below freezing from October through April at lower elevations.

Long-term precipitation data for the project area do not exist. The Stage II EA report indicates that the annual precipitation range at Elko and Fernie, averaging 580 and 1082 mm respectively (22.9 and 42.6 in), is representative of the mine site. Ten years of data (1976 to 1986) collected by the Ministry of Environment (MOE) at Butts, B.C. in the Flathead Valley near Howell Creek, yield a mean annual precipitation of 627 mm (24.7 in) (letter dated 1986 June 27, R.J. Crozier, Head of Environmental Section, Waste Management Branch, Nelson, British Columbia). Data from Polebridge, Montana located about 40 km (25 mi) south of the proposed mine site in the Flathead Valley indicate a 42-year annual mean of 593 mm (23.3 in) for that location (U.S. National Oceanic and Atmospheric Administration 1985). Maximum observed 24-hour precipitation based on very short term records at the proposed Sage Creek Coal Limited mine site is 79.5 mm (3.13 in) (Stage II EA).

The average annual precipitation for the mine site was estimated by the MDC to be 762 mm (30 in) (see Subsection 5.1.1.1). This is less precipitation than would be expected for the Canadian portion of the Flathead drainage as a whole, because the proposed mine site is located at a lower elevation than the average elevation of the Flathead River basin in Canada.

3.5 VEGETATION

The Sage Creek Coal Limited mine site falls mainly within the Englemann Spruce-Subalpine Fir Zone. The valley bottoms along Cabin and Howell Creeks as well as the Flathead River floodplain fall within the Montane Spruce Zone (Stage II EA).

The climax tree species in the first of these two zones are Englemann spruce and subalpine fir in mature stands with black cottonwood and trembling aspen characterizing alluvial floodplain areas subject to frequent flooding. Lodgepole pine is the major seral species, with some whitebark pine at higher elevations. Douglas fir, sometimes in association with lodgepole pine, forms seral stands on dry southern slopes.

A wide diversity of plant communities is found in the mine site area. Elevational gradients are the major cause of zonal and subzonal transitions. Past fires have resulted in the formation of seral lodgepole pine stands with some admixture of western larch and aspen.

4. DESIGN AND POTENTIAL QUALITATIVE EFFECTS OF THE PROPOSED OPERATION

Potential sources of impact to consider in the proposed construction, mining, and reclamation phases are listed and discussed in this section. Reference is made to the source, description, and location as well as to the design criteria applicable for impact control. The phase where impact is expected is also discussed. Appendix 3 deals with the review of project proposals and regulation of projects.

4.1 STAGE OF PROJECT PROPOSAL

As indicated in Subsection 1.6, the project has received Provincial Stage II approval-in-principle. This marks the end of the environmental impact assessment and conceptual design stage. The majority of the analysis in this and the following sections of this report was based on information in the Stage II reports (B.C. Research and Norecol 1982). Detailed design plans are usually submitted at Stage III during application for permits and licences. Sage Creek Coal Limited has not yet reached this level of mine planning.

Assuming successful completion of Stage III and following the proposed 21 years of mine development, if the company wished to proceed with further development, it would be required to seek approval for an expansion. This would require the same Provincial review process as the initial proposal.

4.2 CONSTRUCTION AND MINING PHASES

4.2.1 Construction Camps

A temporary construction camp capable of housing 400 workers would be built east of Howell Creek (Figure 3). This camp site is proposed to have ditches and a temporary settling pond of unspecified size designed to control runoff and sedimentation. The camp site and its sediment control facilities would be reclaimed following the construction period.

A second construction camp has been recommended by a consultant to the company just southwest of the confluence of Harvey Creek and the

Flathead River (Crippen Consultants 1981). This camp would be associated with the upgrading and paving of the Flathead road from the mine site to Morrissey for use as a haul road (Figure 1). No mention or details of this camp, including its size, or any sediment or drainage control practices, have been provided by the company in the Stage II EA.

Construction of the camps would be expected to affect adjacent receiving waters primarily with loading of sediment (and associated phosphorus), organic materials, nitrogen, and oil and grease. This would result from vegetation clearing, land levelling, and excavation (which would render the surface more susceptible to runoff and erosion) and from the use of heavy equipment. During operation of the camps, the impacts would again be expected to be associated with sediment as well as oil and grease as a result of present and future use of vehicles around the camps. The second camp located along the haul road route may also be subjected to flooding since it appears to infringe on the floodplain (Crippen Consultants 1981).

4.2.2 Sewage Treatment Facilities

A sewage treatment plant would be built in an unspecified location southeast of the plant site at the mine; this is interpreted as south of Howell Creek. The treatment facility would be sized to service the construction and plant site work force during mining operations. Effluent would be piped to a drainfield location northeast of the tailings pond (Stage II EA). Specific location of the drainfield would be determined during Stage III. Sewage generated at the construction camp would be piped across Howell Creek to the treatment facility. Installation of these sewer lines would necessitate some disturbance and perhaps excavation in or adjacent to Howell Creek.

Another sewage treatment or collection facility would likely be needed for the construction camp designated along the haul road to Morrissey. However, no discussion of such a facility or of the camp itself has been provided by the company.

Discussion of runoff and sediment control practices during land clearing, levelling, and excavation, and for installation and operation of the sewage facilities, has not been provided by the company. Primary impacts to water during construction and operation of sewage treatment facilities would likely be increased contributions of phosphorus and nitrogen and, to a minor extent, sediment and organic debris. During construction there are also likely to be contributions of oil and grease. The company has estimated effluent flows to the ground at the proposed mine site to be 190,900 L/d (50,000 gal/d) during the pre-mining construction phase and 68,200 L/d (18,000 gal/d) during the mining phase (Stage II EA).

Discharge quality to the subsurface materials would be regulated by Waste Management permits. Set back distance from streams would be considered in conjunction with permeability rates. Phosphorus and nitrogen inputs are quantified in Section 5 of this report.

4.2.3 Transmission Line Corridor

The electrical supply for the operation would be provided by a 230-kV line along a route proposed by B.C. Hydro from a substation at Natal, or from a proposed substation at Alexander Creek near Crowsnest, to the mine site. This route would follow Michel Creek upstream to Flathead Pass, thence down Squaw Creek and the Flathead Valley to the mine site.

The line would be 87 km (54 mi) long (roughly 60% of which would be in the Flathead drainage) and have a standard right-of-way of 30 m (100 ft). The total right-of-way area would encompass about 260 ha (1 mi^2). The route would follow an existing transportation corridor for much of this length in the Flathead drainage, thereby considerably reducing the disturbed land area required for the transmission line and roads (Norecol 1982). Additional area would still be required for constructing access roads. A detailed center line survey of the proposed route has not been done.

Stream crossings during construction could provide point sources for discharge of sediment and organic debris to the streams. The same potential impacts to receiving water quality would exist during construction of the transmission line as would occur from construction of the camps for similar reasons (see previous discussion). After vegetation removal, fine-textured glacial tills encountered along the route may be particularly susceptible to erosion and slope failure. In

Stage III the company will undertake additional studies of soils and surficial materials along the corridor route to identify specific problem areas (see Subsection 1.6.2).

Following construction of the transmission line, disturbed lands would be seeded. During the operation of the line, vegetative growth in the right-of-way would be controlled mechanically or chemically. Herbicides would be used in accordance with regulations of the federal and provincial governments, and B.C. Hydro weed control policy (Stage II EA).

Development of an environmental management plan is anticipated for use by the construction work force. The design, construction, and maintenance of the transmission line would be undertaken by B.C. Hydro utilizing practices and standards employed on similar transmission lines.

In his letter of 1984 February 21 granting Stage II approval-in-principle to Sage Creek Coal Limited, Mr. A.J. Brummett stated that a final decision on routing of the transmission line would be deferred until Stage III. He indicated that, while the route described above was acceptable in principle, there was a clear preference by provincial resource ministries for an alternative route that would tap into a 500-kV line proposed to be constructed from Cranbrook, B.C. to Alberta. Mr. Brummett further stated that this preferred alternative involved less environmental impact.

4.2.4 Haul Road to Morrissey

The existing road from the mine site to Morrissey on the Elk River (see Figure 1) would be significantly improved and relocated in order to accommodate 59-tonne payload trucks. The entire 66 km (41 mi) length would be paved and would be 9.8 m (32 ft) wide with a 1 m (3.3 ft) wide gravel shoulder on each side. Portions of the road may be left in a gravelled condition for a while to allow settling (Stage II EA).

Approximately half of the road length would be in the Flathead drainage, paralleling Harvey Creek and the Flathead River (Figure 2). The existing road lies close to Harvey Creek at some places due to the narrowness of the valley. The new road may encroach on some of the side channels of Harvey Creek. Eleven kilometres (6.8 mi) of relocated haul road are proposed in the Flathead Basin.

Sixteen culverts have been proposed where the haul road crosses streams in the Flathead River basin. The culverts are proposed to be sized to allow passage of a 50-year return event. Major tributaries crossed by the road would include Gumbo and Parker Creeks (Crippen Consultants 1981).

One bridge on this road is proposed to cross Howell Creek just south of its confluence with Cabin Creek on the mine site. This bridge would be a single span structure and would provide free-board above water level for a 200-year design flood to permit through-flow of debris. Rip-rap would be used on embankments and foundations to resist erosion and scour of a 200-year flood. Disturbance to riparian vegetation and surficial materials adjacent to Howell Creek would present a potential point source of sediment and organic debris. Some concern has also been expressed regarding the approach to the bridge which would cut through an unstable gravel bank. The company has proposed to eliminate the potential for bank failure in the final design.

The kinds of impacts associated with construction of the haul road would be similar to those identified for the transmission line. Land clearing and the creation of exposed soils and surficial materials (especially fine-textured tills) would render these materials susceptible to erosion and stability problems with consequent sediment-related impacts to adjacent streams. The company has proposed to control these impacts by prompt revegetation of exposed materials and "good construction practices" (Stage II EA). It has also been suggested that major cut slopes in shale bedrock may need an application of shotcrete to maintain stability (Crippen Consultants 1981).

During construction and prior to vegetation establishment, the company has proposed to conduct a monitoring program of adjacent waters that would be affected by the operation (Stage II EA).

Potential sediment-related impacts would also occur during operation of the haul road. However, various conditions and management practices would affect the relative quantities involved. These are discussed further in Section 6 of this report.

4.2.5 Mine Site Roads and Bridges

Mine site haul roads would be 33.5 m (110 ft) wide, constructed to a maximum road grade of 8%, and would include allowance for roadside ditches and safety berms (Stage II EA). Roadside ditches would all be directed to the contaminated water interceptor ditches and directed to settling ponds. Stream crossings planned in the mine area include one on Howell Creek upstream of Cabin Creek to access Waste Dump E, one on Cabin Creek to connect the North and South Hill areas, and a third one on Howell Creek downstream of Cabin Creek to connect the plant site with the main haul road to Morrissey (Figure 3).

The Howell Creek bridge accessing Waste Dump E would consist of a clear span across the active channel plus an additional increment equal in length to the width of the channel across a portion of the floodplain (Stage II EA). It would be high enough to pass a 200-year flood with further allowance for debris. The movement of a meander of the creek above the bridge would be controlled by the use of "guide banks" (rip-rap) along the banks of the creek. Culverts would be used for both approaches to the bridge in back channels of Howell Creek to prevent siltation of the back channel and to minimize stress on the bridge during high flow. These construction activities would occur during the initial three years of coal production from the North Pit (Appendix 2.5.1-1, Stage II EA).

The use of "training works" (or rip-rap) on Howell Creek near the bridge and near Settling Pond 4 are proposed to provide increased protection against flood waters becoming entrained within the adjacent ditches.

The bridge across Cabin Creek would also be designed to pass a 200-year flood plus debris. The lower bridge across Howell Creek was discussed previously.

Under the Water Act, timing and type of instream activity can be regulated, as well as control of unconsolidated material on or adjacent to the bridge deck in order to minimize impact to the stream (verbal communication, 1985, R. Boyer, Water Management Engineer, MOE, Cranbrook, British Columbia). Impacts would be evident for both the construction phase and mining phase but would be under greater control during the mining phase due to the settling pond and ditch systems.

4.2.6 Pits and Waste and Coal Refuse Dumps

The relative location of these features is shown in Figure 3. The North Hill pit and associated Waste Dumps C, D, E, and F, and the refuse dump south of Cabin Creek would be the first areas of development. The remaining site development, including the South Hill pit development and construction of Waste Dumps A and B, would be scheduled as required during the production years (See Subsection 2.1.4). The four North Hill dumps would occupy 634 ha (2.4 mi^2) while the two South Hill dumps would cover approximately 563 ha (2.2 mi^2) (Stage II EA). The maximum elevation difference between the crest and toe of any developing waste rock dump bench would be 122 m (400 ft) (Stage II EA, Golder Associates 1981). Generally, after dump completion, the difference in elevation between any two consecutive benches would be 30 m (100 ft).

Waste dumps are developed under B.C. government authority, with consideration of the geotechnical stability of the structure, suitability for reclamation, and economics of moving material from pits to dump locations.

The dumps would be developed adjacent to the two mining areas (North Hill pit and South Hill pit) by constructing wrap-around type dumps at progressively decreasing elevations. This would involve end-dumping waste rock at the crest of the advancing waste pile. Each dump would be developed in a series of level benches. Dump construction timing is linked to sequenced mine development and access road construction.

Proposed construction of Waste Dump E, east of Howell Creek (Figure 3), would be different from the above approach, because it would be built from the bottom up. This dump would receive material originally planned for North Hill dumps to avoid the need for diversion of Howell Creek. Movement of waste rock to Dump E, away from the east side of the North Hill pit west of Howell Creek, was designed primarily at the request of MEMPR to avoid burying deep coal at that location. This new location was also chosen to allow a larger greenbelt zone from the toe of the North Hill dumps to the creek channels (Stage II EA). Waste Dump E would not be started until year five after initiation of production.

The toe of the dumps after final grading to a maximum angle of 26° (Subsection 4.3.3.2) would be set back 90 m (295 ft) from Cabin and Howell Creeks. On occasions, where there is an agreement by MOE and MEMPR, there may be encroachment within this 90-m limit, if environmentally acceptable and required for dump stability (see Subsection 1.6.1.2).

Stability of waste dumps at the proposed mine is a concern because dump failures could have adverse effects on water quality of Cabin and Howell Creeks and the Flathead River. Dumps B, C and D appear to be most critical in this regard (Figure 3). Subsection 6.6 of this report contains historical information on waste dump stability at existing Elk River valley mines, and a discussion of dump stability at the proposed mine site.

To guard against potential entry of slide debris into Cabin and Howell Creeks, protective berms would be constructed at the toe of Waste Dump D along Howell Creek and at the toe of Waste Dump C along Cabin Creek (Stage II EA, Golder Associates 1981). Although the company has not indicated plans in the Stage II EA to construct a berm at the toe of Waste Dump B south of Cabin Creek, its consultant did recommend that measure (Golder Associates 1981). These berms would have a height of 6.5 to 10 m (21 to 33 ft) and a crest width of approximately 33 m (108 ft) and would be constructed of truck-dumped waste rock. The protective berms adjacent to the drainage courses would be constructed concurrently with development of the dumps by maintaining a distance of approximately 90 m (295 ft) ahead of the fall line (projected to the bottom of the slope) (Stage II EA). Although the common angle of repose of end-dumped waste rock is 37°, provision is made in the dump design to permit reclamation to the suggested final slope of 26° (Stage II EA). After grading to the final slopes the berms would be incorporated into the toes of the dumps. The MDC understands that the berms will generally be outside of the required 90-m (295-ft) buffer strip adjacent to Howell and Cabin Creeks.

Contaminated water ditches would intercept surface runoff from waste dumps, pits, refuse dumps, and other areas and direct it to settling ponds as shown on Figure 3. Water quality limits for total suspended solids are specified in waste management permits for discharges from settling ponds.

Primary pollutants from the pits and waste rock dumps would be total suspended solids and forms of soluble inorganic nitrogen. Suspended solids would be controlled as noted above. Soluble nitrogen levels would depend on drilling and blasting practices in the pits, which, in turn, are dependent on quantities of groundwater encountered.

Blast hole dewatering would be carried out as required. A small drill would be available to drill drain holes in the highwall to prevent groundwater buildup (Stage II EA). Where wet conditions are encountered, a slurry gel explosive may be used. Powder load calculated by Sage Creek Coal Limited is 0.71 kg/bcm (1.19 lbs/bcyd). The average consumption of explosives would be 9.5 million kg (21.9 million lbs) per year averaging 80% AN/FO, 20% slurry water/gel (described in Subsection 2.7.5). Powder factors below 0.71 kg/bcm (1.19 lbs/bcyd) could be used selectively in those areas with rock softer than the sandstones; this "softer" rock comprises approximately two-thirds of the waste rock (Stage II EA).

Prior to initiation of mine operation and before field management of soluble nitrogen from pits could be attempted, predictions of available nitrogen would be necessary. The information in the previous paragraph would be of use in such calculations. These predictions would also be based on nitrogen balances calculated at other mines and could serve to alter some mine design plans prior to construction and operation. The purposes of these measures would be to minimize nitrogen inputs to sensitive receiving streams. Further, once minimum loadings were estimated, it would be possible to identify those streams where impact could not be avoided. This aspect is examined further in Section 5 of this report.

There is no regulatory mechanism for control of surface or groundwater enriched in soluble nitrogen and entering receiving streams. Receiving water objectives are established to ensure protection of aquatic life. Monitoring of both receiving waters and surface discharges for soluble forms of nitrogen is a requirement of Waste Management permits. Historically, where various forms of nitrogen approached or exceeded objectives in the Elk Valley receiving waters, one or more of a wide variety of management practices have been implemented. These have included such things as:

- dewatering blasting area prior to blasting;
- minimizing the time between loading and blasting;
- spill control and housekeeping;
- diversion of water away from spoil;
- storage of enriched water; and
- recycling of enriched water within the operation,

on an ongoing or intermittent basis (Pommen 1983).

Creek dewatering to the pits would be managed and regulated under the Water Act through a water licence. Conditions for controlling flow losses could become part of an enforceable licence under the Water Act (verbal communication, 1985, John Dick, Manager of Mine Impact Review, MOE, Victoria). This probably would not become an issue until pit development reached the same base elevation as the surface creek flow.

4.2.7 Ponds, Ditches, and Coal Processing Plant

4.2.7.1 Major settling ponds and the tailings pond. Settling Pond 2 and associated ditches (see Figure 3) would be built during the first year of the construction period (Stage II EA). During the second year, the starter dam of Settling Pond 1 would be constructed. A portion of the containment berms around the coal refuse dump would be constructed. Presumably ditches around this dump and the coal processing plant area would also be installed. The tailings pond and possibly two associated borrow pits adjacent to Howell Creek (Klohn Leonoff 1981b), its associated ditches and reclaim water lines, and the coal processing plant with all necessary structures and buildings would be built during this initial two-year construction period.

Ultimately, four settling ponds are planned for the Sage Creek Coal Limited's proposed mine to settle suspended sediments contained in runoff from disturbed areas. These ponds would be point source discharges to the Flathead River and Cabin Creek and would also be locations where surface waters would infiltrate into the groundwater system.

Settling Pond 1 would be located on a fluvial terrace south of the plant site (Figure 3). This pond would receive disturbed area runoff from contaminated water ditches CW3 and CW4 around South Hill. Outflow from both the decant and emergency spillway structures of this pond would flow a distance of approximately 1000 m (3281 ft) south along a small natural drainage channel to the Flathead River. Settling Pond 2 would be bounded on the north by natural topography, on the west by the North Hill haul road, and by embankments on the east and south. Pond 2 would receive runoff from contaminated water ditches CW1 and CW2 located at the base of the North Hill waste dumps. Spillway and decant discharges would be to Cabin Creek.

Test pit observations indicate that the bottoms of Ponds 1 and 2 would generally have approximately 0.5 m (1.64 ft) of fine sand or silt overlying gravel. A field permeability test yielded a permeability of 7.0×10^{-1} cm/s (0.023 ft/s), typical of clean sand and gravel. This indicates that seepage from the ponds would occur so that during low flow periods the water level may remain below the decant invert. However, other factors to be considered are discussed below.

The probability of pond discharges due to pumpage of pit water into Settling Ponds 1 and 2 is difficult to assess. The field test indicates that the materials comprising the bottom of the ponds are very permeable. However, as these structures accumulate sediment from surface water inflows, the permeability will decrease. The Stage II EA estimates maximum pumpage from the South and North Hill pits at 227 and 450 L/s (3600 and 7133 gal/min) respectively. During low flow periods all or most of the flow to the ponds would be from pit pumpage. Sowers and Sowers (1970) cited a permeability range of 1×10^{-3} to 1×10^{-5} cm/s (3.3×10^{-5} to 3.3×10^{-7} ft/s) for silty-sand type soil materials. Assuming the maximum estimated pumpage from the pits, nearly all pit pumpage would be discharged from the ponds at the low end of this permeability range with estimated discharges of 0.2 and 0.4 m^3/s (7.1 and 14.2 cfs) from Ponds 1 and 2, respectively. Neither pond would discharge, given a permeability of 1×10^{-3} cm/s, (3.3×10^{-5} ft/s) and at the midpoint of this range (1×10^{-4} cm/s [3.3×10^{-6} ft/s]) only Pond 2 should discharge (at a rate of 0.2 m^3/s [7.1 cfs]).

Other variables that further complicate the pond discharge/pit water inflow issue include the uncertain quantity and timing of groundwater inflows to the pits (Subsection 4.4.1), frequency of pond cleaning, alternative methods of handling pit water (such as storage in pits), and the use of settling pond water as make-up water in the processing plant.

Settling Ponds 3 and 4 would be much smaller than Ponds 1 and 2, and would receive runoff from Waste Dump E located east of Howell Creek. Test pits were not excavated, but it is reasonable to expect that organics plus fine sand and silt overlie coarse gravel materials at these pond sites. The decant and emergency spillways of both ponds would discharge to the Flathead River. Pond 4 was originally designed to discharge to Howell Creek, but a commitment was made by Sage Creek Coal Limited to route this discharge to the Flathead River. Designs to accomplish the rerouting of this discharge have not been completed and it appears that this could result in combining these two ponds.

Rainfall intensities were estimated for 24-hour storms at various return frequencies (Stage II EA). However, data were insufficient to estimate intensities for durations less than 24 hours. To obtain estimates of these lesser events, Klohn Leonoff (1981a) applied the U.S. Soil Conservation Service Type II distribution to the 24-hour storm rainfalls estimated for the mine site. Peak runoff rates were estimated from this information and used in settling pond design.

The settling ponds are designed to settle particles with a minimum size of 0.01 mm (3.9×10^{-4} in) under ideal settling conditions by utilizing an overflow velocity less than 5×10^{-5} m/s (1.6×10^{-4} ft/s). Experience indicates that, under operating conditions, the efficiency of settling ponds designed this way may vary from the efficiency expected under ideal conditions. Operating condition efficiency would allow capture of particles with an estimated minimum size range of 0.02 to 0.05 mm (7.9×10^{-4} to 2.0×10^{-3} in).

All ponds would contain two outflow structures: the normal decant for operations up to the 50-year flood and a free crest spillway capable of discharging the peak flow from a 200-year flood. The ponds would also be designed to allow limited seepage (Klohn Leonoff 1981a). Monitoring stations would be provided at discharge points to natural watercourses. A diverging inlet section with a large diameter rip-rap bed would be used to minimize the potential for short-circuiting of the ponds. The inlet section should spread inflow, dissipate flow energy, and reduce inflow velocities. Provisions for adding flocculent would be made in the pond design.

The tailings pond would be located upstream from Settling Pond 1. The tailings pond is designed to contain tailings from 40 years of mine operation at a production rate 20% higher than the 2.2 Mt/yr planned. Flood storage is designed for the excess runoff from a wet year with a 100-year return period and a 200-year, 72-hour storm. A free crest spillway would be provided which would discharge to Settling Pond 1, should a more extreme event occur during operations.

A 200-year return period earthquake was estimated to produce ground acceleration equal to 4% of gravity. It is anticipated that materials are available on site which will be suitable for tailings pond embankment construction capable of withstanding such an earthquake. A stability analysis of the tailings pond embankment would be performed when strength parameters for construction materials are confirmed.

It is assumed in the tailings pond design that all free water (1 m [3.3 ft] depth) could be reclaimed. This would depend on the retention time required for settlement of suspended solids. This information is not available at this time but would be required for final design. Additional investigations of borrow and foundation materials are required to determine embankment stability and the depth of the seepage cutoff trench.

4.2.7.2 Uncontaminated water ditches. Permanent and temporary uncontaminated water ditches would be constructed (Stage II EA) (Figure 3). The permanent uncontaminated water ditches, which would utilize natural drainage channels to some extent, would be the ultimate upslope interceptors and conveyers of water moving toward the North and South Hill development areas.

The natural channels to be utilized are generally steeper than the excavated channels and, therefore, some rip-rap lining would be required. The ditch gradients would be limited to 0.0015 to maintain flood flow velocities of 0.9 to 1.4 m/s (2.95 to 4.6 ft/s) (Klohn Leonoff 1981a). This gradient would necessitate the use of drop structures or similar devices to convey water down some of the very steep slopes. Even so, the difficulties in meeting the design gradient might be substantial, depending on the final routing of the ditches at Stage III of the B.C. Mine Development Planning Process. Therefore, these ditches could constitute major sources of sediment.

The company has indicated that the uncontaminated water ditches would flow into the pits and into contaminated water ditches, should they overtop. Therefore, these ditches were designed for a storm of shorter recurrence interval (50-year) than contaminated water ditches and other water control structures. Freeboard of 0.3 m (1 ft) was included in the design. Ditch side slopes would be 3 horizontal:1 vertical and excavated material would be placed in a berm on the downhill side of the ditch. The ditches and berms would be revegetated following their construction.

The temporary uncontaminated water ditches would be abandoned and new ones continually rebuilt as development of North and South Hills proceeds.

The company has provided no information on the location of the temporary ditches nor on the timing of construction. The MDC has assumed that the company would prefer to avoid water in the temporary uncontaminated water ditches being intercepted by contaminated water ditches at the toes of the slopes; if so the MDC assumes that water from the temporary ditches would drain directly into Howell, Cabin, or Couldrey Creeks via discharge from temporary settling ponds. However, it is not clear from the Stage II plans that this is what would occur.

Four permanent uncontaminated water diversions at ultimate pit development would be required as shown on Figure 3. These ditches would be constructed during early stages of mining (Subsection 2.1) and, following reclamation, would remain in contour as permanent landscape features. Diversion Ditch D1 above North Hill pit and Waste Dump D would drain to Howell Creek. Ditches D2 and D3, above North Hill and South Hill pits, respectively, and their western waste dumps, would drain to Cabin Creek. Ditch D4 above South Hill pit and its southern waste dump would drain to Couldrey Creek.

Temporary settling ponds would be provided at the ends of ditches D1, D2, and D3. Their function would be to contain sediment generated in the ditches themselves due to exposure of surficial materials after construction. These ponds would be eliminated after their usefulness had terminated (Stage II EA). No design details of these ponds have been provided by the company. A temporary settling pond has not been proposed for D4, although this would likely be required by the MOE. Diversion Ditch D4 would capture uncontaminated water from a drainage area of 1.0 km^2 (0.39 mi^2) and would divert it to Couldrey Creek. This area presently drains to Cabin Creek and the Flathead River.

4.2.7.3 Contaminated water ditches. Six contaminated water drainage ditches would be required for ultimate pit development. Ditches CW1 and CW2 would carry runoff into Settling Pond 2 from the North Hill pit and dumps along Howell and Cabin Creeks, respectively. Ditches CW3 and CW4 would carry runoff to Settling Pond 1 from South Hill pit and dumps along the south side of Cabin Creek and from Waste Dump A and the coal refuse dump, respectively.

The contaminated water ditches utilize the same design criteria as the uncontaminated water ditches for sideslopes, gradient, and freeboard. Flow velocities would vary from 0.9 to 1.3 m/s (2.95 to 4.27 ft/s). These ditches are designed to handle the 200-year return storm. The design also assumes failure of the upslope uncontaminated water diversions during a storm of this frequency. Design of ditches CW1 and CW3 includes 32 L/s (500 gal/min) each to accommodate pit dewatering. Ice would be removed from contaminated and uncontaminated water ditches on an annual basis before the freshet period (Stage II EA). The MDC anticipates that ice would be removed by backhoe.

4.2.7.4 Impacts. The kinds of impacts associated with building these structures would be similar to those previously described for other construction activities. Prior to the installation of the sediment control system, the areas exposed to land clearing and disturbance from building these facilities would be vulnerable to runoff and erosion. This would only be allowed to occur during certain environmentally acceptable periods.

Once construction of settling ponds and control ditches was complete, runoff from subsequent construction and production activities would be controlled. At this point impacts from construction should be less than those predicted for the mining phase, since the disturbed area during construction would be less than at ultimate pit development.

4.2.8 Associated Activities

4.2.8.1 Logging and grubbing. It is assumed that, prior to any of the aforementioned construction activities, any merchantable timber would be removed. This might normally be considered an integral part of the land clearing and surface material disturbance of all such construction activities. However, for the actual mine areas (North and South Hills), it is assumed that complete logging of these areas would occur prior to initial pit development. Thus, North Hill would be completely logged no later than the first year of the construction phase and the South Hill would be logged prior to year 5 of the mining operation. Grubbing (land clearing) of pit areas only would occur subsequent to logging.

Historically, logging has preceded the installation of sediment control facilities on coal mining operations. Impacts associated with logging would be similar in nature to other construction-related activites.

There has been no mention in the Stage II EA regarding installation of sediment control structures prior to logging and grubbing.

4.2.8.2 Salvage of soil materials. The company has proposed that soil materials ("topsoil") be salvaged from the relatively gently sloped areas that contain fine-textured tills and colluvium, and some organic deposits (Stage II EA). Such areas would primarily include settling and tailings pond sites, road rights-of-way, the plant site, and lower waste dump slopes. Salvage operations would occur during both the construction and mining phases.

Stockpiles of salvaged soil materials have been proposed on the mine site and would be seeded to promote stability. The stockpiles would also be located to provide sediment containment by the drainage control facilities. Stockpile locations have not been shown on any maps submitted as part of the Stage II plan (see Subsection 4.3.3.3 for a discussion of the proposed use of salvaged soil materials in reclamation.)

4.2.8.3 Flathead Road relocation. The existing Flathead Road from the crossing at Howell Creek south toward the International Boundary would require relocation because of the encroachment of the coal refuse dump, tailings pond, and a contaminated water ditch on the existing road. The route would be moved east toward the Flathead River as shown on Figure 3. However, no details of this relocation have been provided. Impacts during construction would be similar to those for the main haul road discussed earlier. Impacts during operation would be expected to be similar to those of the existing road.

4.3 RECLAMATION PHASE

4.3.1 Introduction

A mining company is required under the Mines Act to obtain a reclamation permit prior to production. The permit is issued by the Minister of Energy, Mines and Petroleum Resources (EMPR) based upon recommendations of the interministry Reclamation Advisory Committee which is composed of employees of the Ministries of EMPR, Environment, Forests, Agriculture, and Lands, Parks, and Housing. This committee is chaired by the Chief Inspector of Mines. Mine reclamation is administered by the Inspection and Engineering Branch of the Mineral Resources Division, EMPR.

Bonding is required for the issuance of a reclamation permit and, by statute, is a maximum of $2500 per hectare of disturbed land. The bond is normally returned three to five years after the mine is closed down and the land has been reclaimed to the satisfaction of the Minister of EMPR. If there is a condition which may affect water quality or quantity or other aspects of the site, bonding can be retained indefinitely, or until the problem is resolved.

A mining company is required to submit an annual reclamation report. Should the mining plan be altered substantially, a report describing the changes is required to amend the permit, and is subject to the Mine Development Review Process.

4.3.2 Reclamation Experience

Reclamation practices, research, and results are well documented at the operating mines in the Elk Valley area of British Columbia. The following has been demonstrated.

- Species of plants used in revegetation (mostly agronomics) and their relation to elevation, slope, aspect, and rooting materials are established for the area.
- Glacial till will support the vegetation.
- On reclaimed areas to date, normal growth medium has been the waste rock material where the carboniferous shales and mudstones break down to a fine granular material. With the use of annual applications of fertilizer for one to three years, a sustained vegetative growth can be established. Winter and summer wildlife habitat has been established on reclaimed areas at several of the operating mines with a high degree of success.
- Some topsoil has been salvaged from valley bottom areas, but has yet to be used on reclaimed areas.
- Agronomic plant species are used for reclamation in most cases. Research work on native species is in progress.
- Conifers and native shrubs have been planted in considerable numbers at one of the existing Elk River valley operations. Substantial success has been attained, but damage caused by elk browsing has also been experienced.

4.3.3 Mine Site Reclamation

A summary of the proposed reclamation for the Sage Creek Coal Limited mine is as follows (from B.C. Research and Norecol 1982).

4.3.3.1 Post-construction. Construction areas which have been disturbed would be seeded immediately following completion of construction. Agronomic species of grasses and legumes would be used for road embankments, drainage ditches, pond embankments, the plant area, and soil storage areas.

4.3.3.2 Mining phase. Reclamation on some waste dumps would commence before mining is completed. Prior to reclamation the dump slopes would be at the angle of repose (37°) and in lifts of 30 m (100 ft) in vertical elevation. These would be resloped to 26°. The benches and resloped areas would then be seeded.

The North Hill pit area has few faults and thus the footwall would be relatively smooth with a dip of about 30° to the east. The South Hill pit area has more faulting and mining around these faults would produce some major benches in the footwall. The highwall in the pits would be at an overall angle of 45° and would be benched according to the approved mining plans. All benches would be revegetated.

4.3.3.3 Post-mining. Drainage systems would be restored according to a detailed reclamation plan which would be prepared at Stage III. Ditches would remain in contour as permanent landscape features, and would not be disrupted during this period except for redirecting flows away from the settling ponds to natural drainage channels. Economics of the Sage Creek Coal Limited project dictate leaving the North and South Hill pits open. The pits would be expected to contain water. Hydrological and environmental studies, and engineering design, would be required in the planning of these future lakes.

With the completion of mining, all roads except the main haul road would be reclaimed. All road surfaces would be ripped. A surface dressing of topsoil would be applied, if necessary, to establish vegetation. Bridges and culverts which could become plugged would be removed. All facilities, buildings, and structures would be removed on the completion of mining. The plant site area would be ripped and a layer of topsoil would be spread on the surface. Revegetation efforts would be employed to encourage the development of meadow lands similar to those which presently exist in the pond and plant site areas.

All disturbances of the mine are proposed to be revegetated except the inundated areas of the pits and the footwall and highwall areas of the pits where only benches would be revegetated to some extent.

Two phases of revegetation have been proposed by the company: an initial effort using agronomic species to establish a rapid stabilizing cover, followed about five years later with planting of native species in areas where they have not already invaded (Stage II EA). Final plant community types are proposed to include spruce/alpine fir and Douglas fir/larch forests, dry to wet grasslands, and riparian shrubland. The company is proposing to develop different types by varying replaced topsoil thickness in relationship to slope and aspect.

The majority of reclaimed landscape units are proposed to be resurfaced with topsoil. Exceptions include the pits, ponds, and drainage ditches. The tailings pond may require a "thin layer of topsoil" (Stage II EA) to lower high surface temperatures which may occur due to the black coaly sediments in the pond. However, at an existing mine in the Elk Valley an agronomic species (Rye grass) was seeded and has been growing for two years on a tailings pond using irrigation.

4.3.3.4 Land use. Ultimate land use would be wildlife habitat, forestry, and recreation.

4.3.3.5 Potential impact. The water-related parameters of concern during the reclamation phase would be expected to be similar to those identified during the mining phase (Subsections 4.2 and 4.4).

4.4 POSSIBLE ENVIRONMENTAL IMPACTS ON GROUNDWATER

There are a large number of variables which should be considered in assessing the potential hydrogeological impact at the proposed coal mine. Some of the variables could play a significant causal role in local and downstream water quality impacts, whereas others would likely play a minor and perhaps insignificant role in influencing the downstream environment.

Groundwater contaminated from leaching of mining-related materials may have direct, short-residence-time flow paths (e.g., travel from settling pond recharge to discharge in Howell or Cabin Creeks). Conversely, they may have much longer, slower flow paths (e.g., from dumps, through the Fernie Formation, through the Kishenehn Formation, and through the alluvial fill to Cabin or Howell Creeks). Impacts from the direct paths may be detected within a few days to a few weeks. Loading estimates in Section 5 of this report are based on assumed short-residence-time flow paths for groundwater, which results in the highest loading rates.

The deeper circulation paths may take tens of years before contaminants are discharged to the creeks. Consequently, the concentration of contaminant loading via groundwater to the receiving waters would be reduced, but contaminant release would continue for many years after mining is completed.

Downstream impact would also be variable because of local contaminants affecting groundwaters on-site. For example, groundwater impacts would be significantly different in the vicinities of the explosives plant, maintenance yards, tailings pond, and sewage effluent discharge facilities. Groundwater flow rates and attenuation of subsurface contaminants would vary with site location, host rock, contaminant source, and downstream discharge.

The following groundwater impacts are expected from the Sage Creek Coal Limited development.

4.4.1 Groundwater Flow System

Undisturbed water-table surfaces of shallow aquifers tend to mimic the topographic expressions of the land surface. Consequently, in homogeneous media where hydraulic properties are equal in all directions (isotropy), groundwater flow is approximately perpendicular (normal) to the surface topography and in a downhill direction. This is an idealized case, approached only in well sorted dune sands.

In more complex geological settings, such as at the proposed mine site, the geologic materials that compose the aquifers show distinct differences in their ability to conduct water in directions parallel and normal to the bedding of the geologic unit. Commonly, the hydraulic conductivity (permeability) is 5 to 10 times greater parallel to the bedding of the geologic unit than perpendicular to it. The ability of a geologic unit to transmit water in different directions parallel to bedding may vary considerably because of variations in lateral hydraulic conductivity (anisotropy). Figure 7 schematically depicts the flow directions for groundwater that would be expected to exist in a relatively homogeneous aquifer system in a topographic setting similar to that at the proposed mine site. This diagram incorporates the assumption that there is a flux of groundwater flow to both deeper aquifers and surface waters.

With the existing weak data base it is not possible to quantify how much groundwater flows into Howell Creek, Cabin Creek, the Flathead River, or subsurface aquifers underlying the Flathead Valley floor. This first approximation of the flow system assumes relative homogeneity; perched groundwater on top of the coal beds reported in the Elk River valley is not shown in Figure 7. Preliminary hydrogeological evaluations that have been carried out at the proposed mine site indicate a complex hydrogeological setting (Dames and Moore 1976; Pacific Hydrology Consultants 1982). Therefore, groundwater flow paths at the proposed mine site are expected to be far more complex than flows indicated in Figure 7 because of known heterogeneity and anisotropy.

Alterations to the groundwater flow regime would be expected shortly after commencement of the construction phase. Thus, a gradual increase of precipitation recharge to the underlying aquifers would occur (Subsection 5.1.1), causing increased hydraulic gradients between recharge and discharge areas. Figure 8 schematically depicts this condition. The frequency of the flowlines represents the volume of flow, hence the greater frequency of flowlines below the disturbed area. Note that during the construction phase the quantity of discharge shown in this figure increases to both the tributary creek and the main river.

Recharge to groundwater at these locations is expected to decrease with time as sediment fines would tend to settle into the interstices and locally lower the vertical hydraulic conductivities. As mine development phases into operation, additional modifications are expected to alter existing groundwater flow systems. In order to briefly depict the changes in the groundwater flow systems, Figure 9 schematically relates flow changes to the various mining stages. The locations where gains and losses to the groundwater upwellings may be expected within the stream channels are shown in Figures 10 and 11, respectively. These locations are approximate. During the mining phase the affected areas would increase to the maximum depicted size and then decrease towards those existing during premining conditions. These figures provide a preliminary overview for further discussions on the changes to the groundwater flow systems caused by the mining operation. However, the lack of sound site-specific hydrogeologic data for the mine site

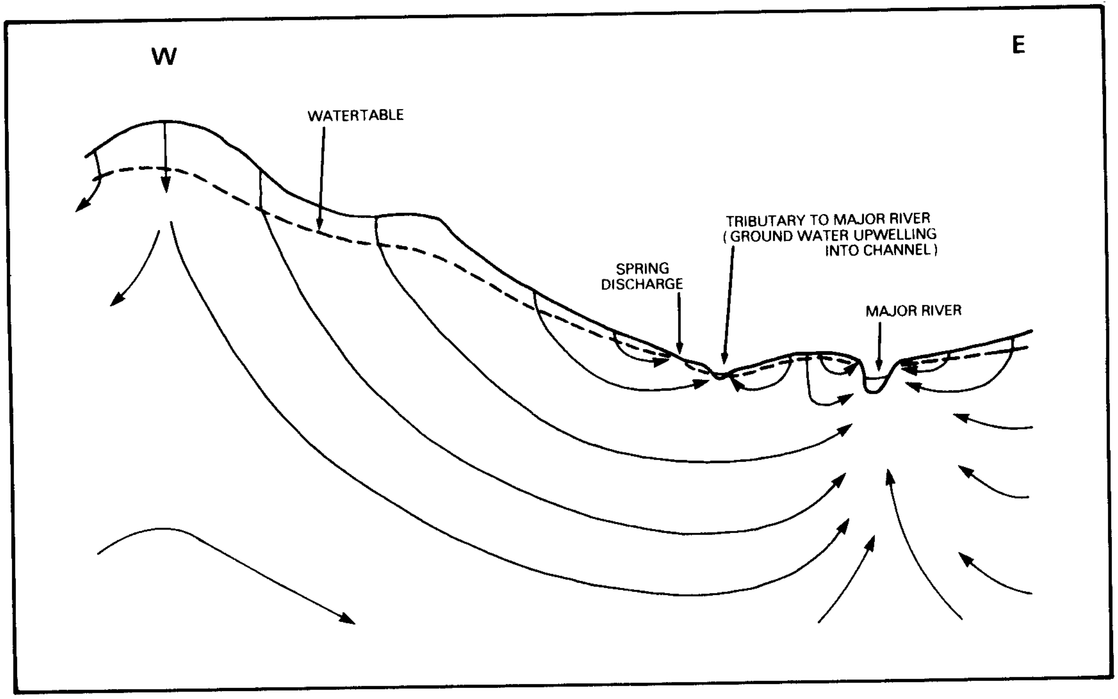

Figure 7. Hypothetical cross-section for a relatively homogeneous groundwater flow system in an <u>undisturbed</u> setting similar to the proposed mine site.

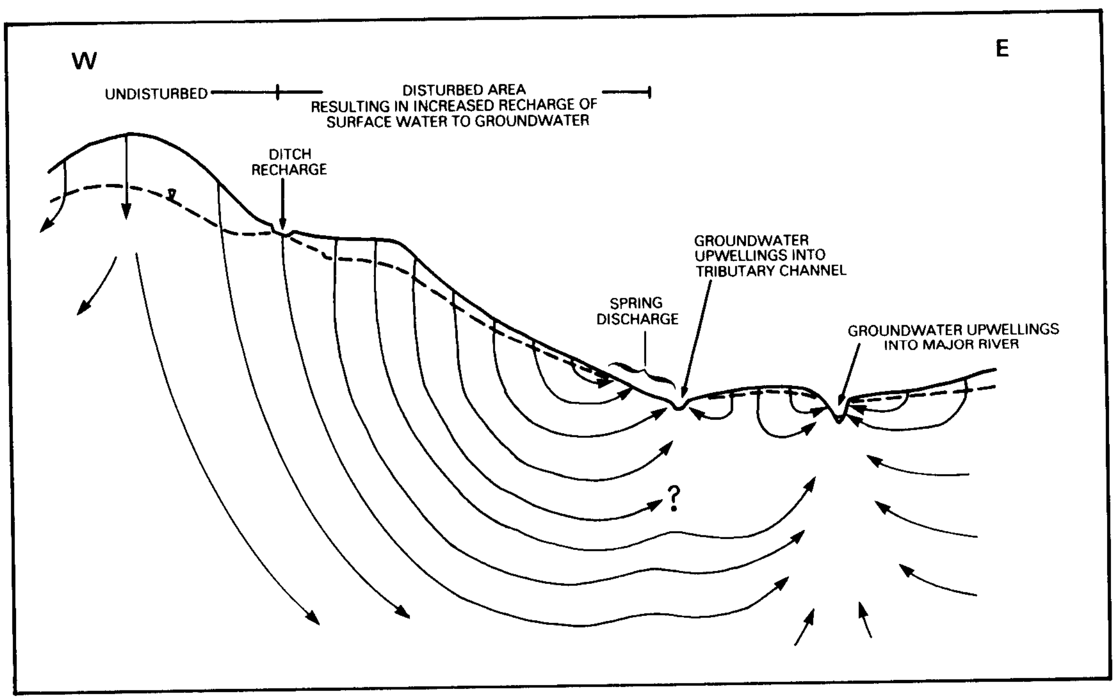

Figure 8. Hypothetical cross-section for a relatively homogeneous groundwater flow system in a <u>disturbed</u> setting similar to the proposed mine site.

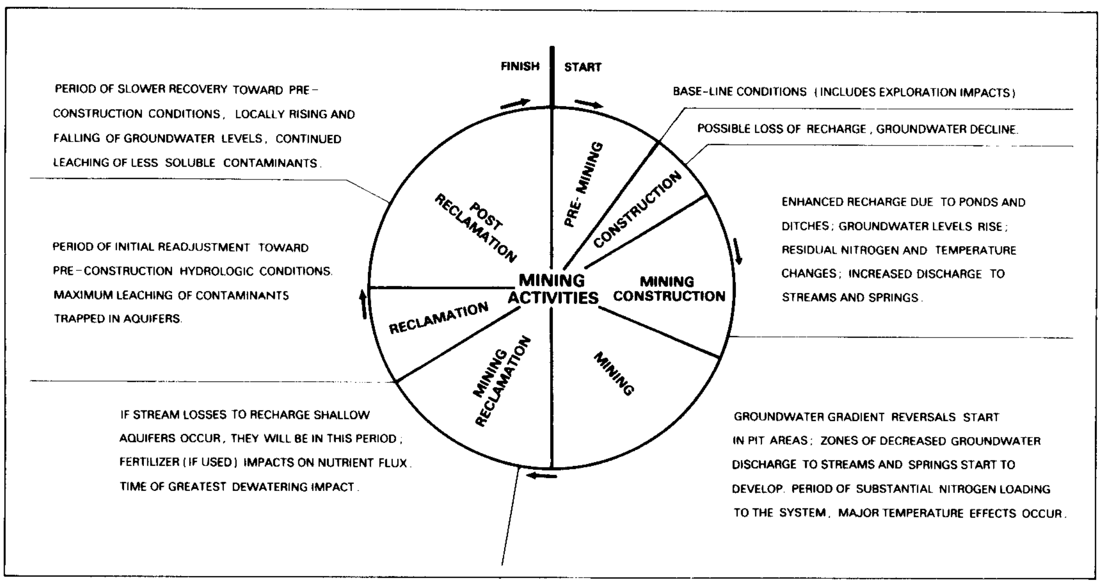

Figure 9. Hydrogeologic effects of mine site activities.

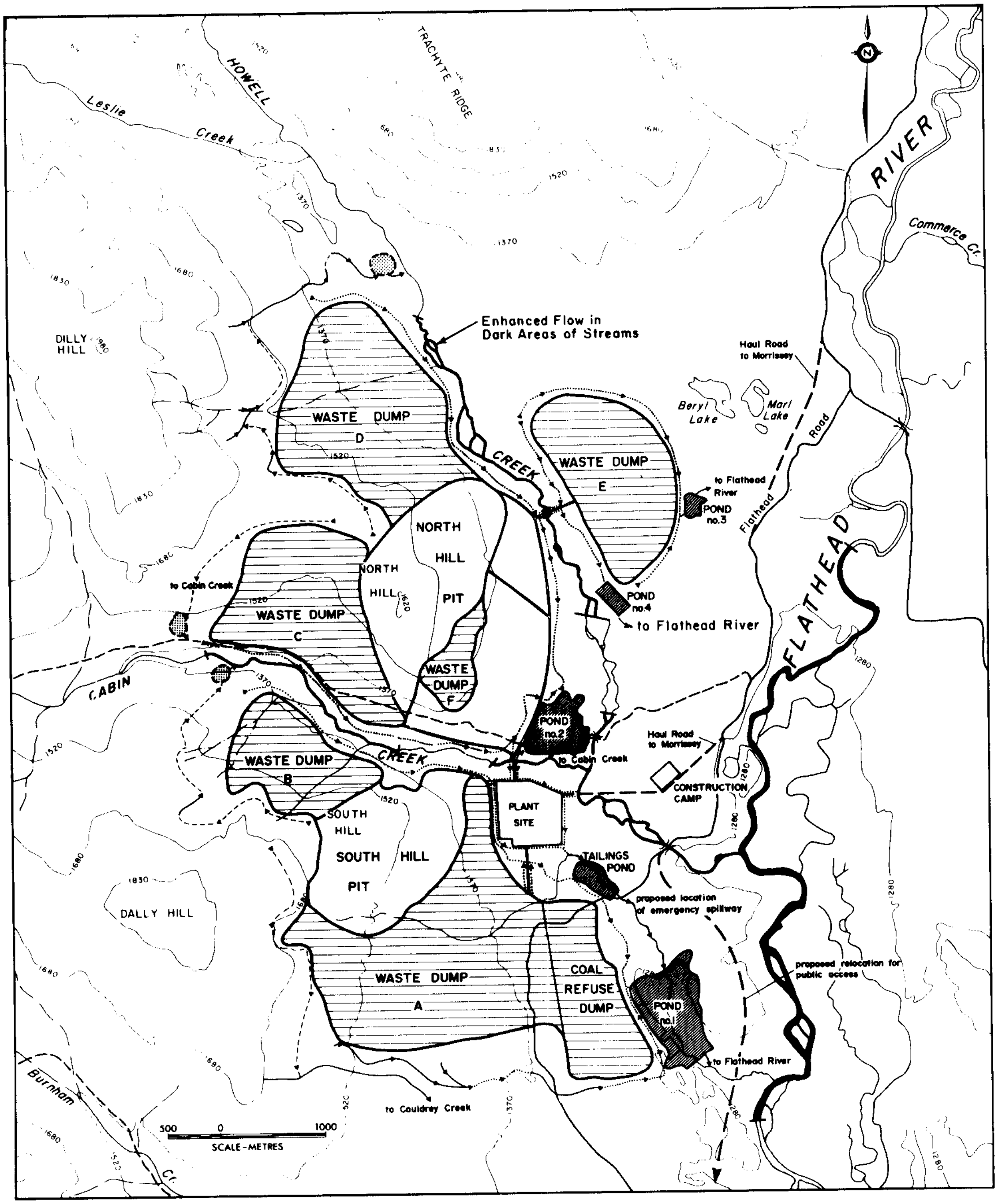

Figure 10. Stream reaches expected to receive increased groundwater discharge (dark areas) after waste dumps and ponds become operational.

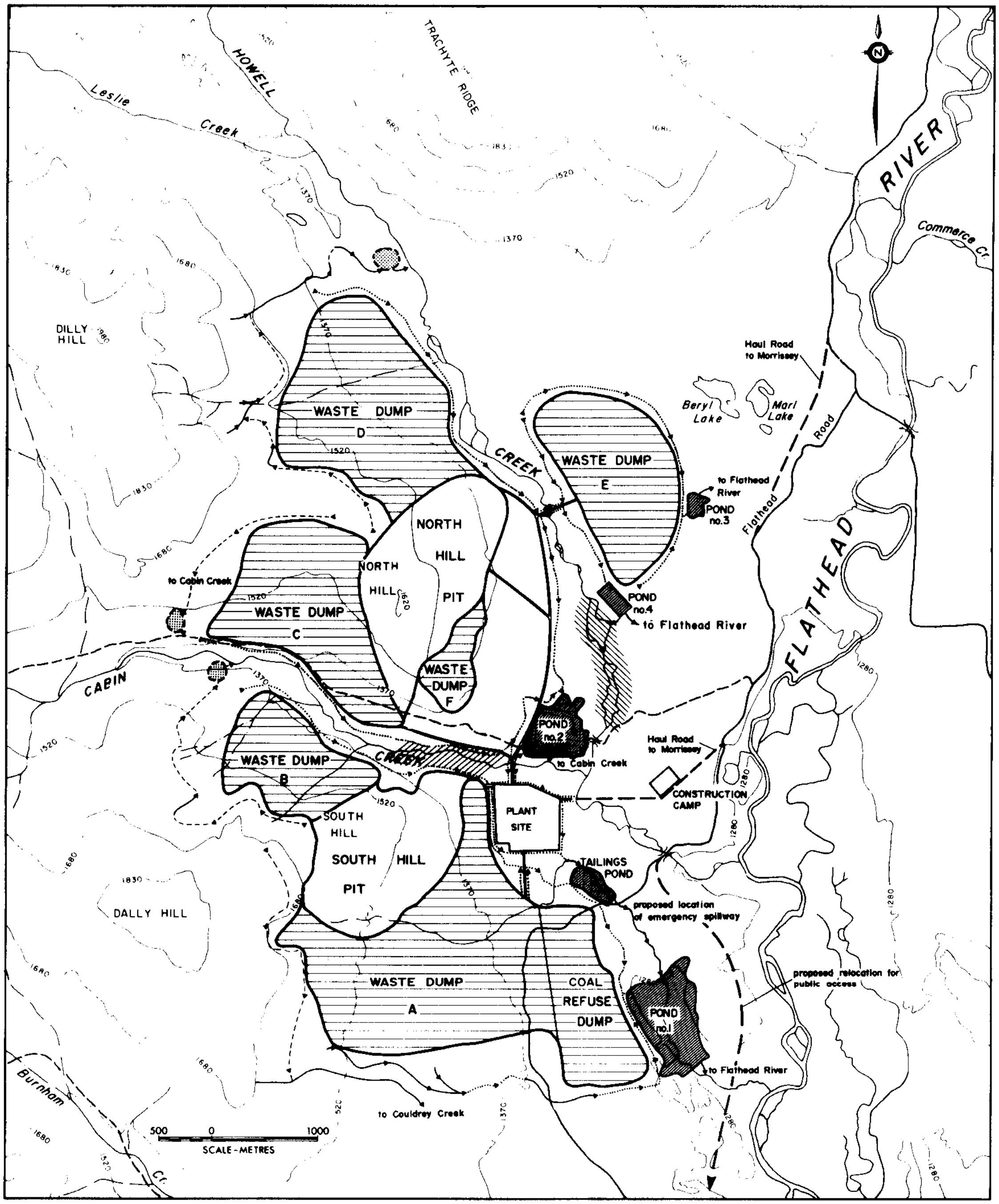

Figure 11. Stream reaches which may lose surface flow to groundwater (diagonally hatched areas) after pits extend below creek level.

precludes providing more than a conceptual analysis of groundwater impacts. A rigorous hydrogeologic characterization of the mine site is necessary before the magnitude of the groundwater impacts can be quantified.

In general, groundwater flow modifications would initially include local increased flow when ponds and waste dumps become operational (Figure 10). This increased flow could have potentially adverse effects relating to nitrite and ammonia concentrations, and temperature of receiving waters (See Section 5).

Later, reduced flow of groundwater upwellings into the creeks, decreased flow at local spring discharges, and reduced recharge to deeper-seated aquifers would likely occur. This would be caused by lowering the hydraulic heads due to block dewatering prior to explosives use, pit dewatering, surface water diversions, and other factors. After pit floors drop below creek levels, groundwater flow reversals could occur. It is anticipated that one or both creeks might become influent, causing loss of surface waters to groundwater (Figure 11). Much of this water would later return to the Flathead River system via pit dewatering and rerouting of the water to the settling ponds or tailings pond. However, during the later phases of mining when local groundwater gradients would be expected to be at a minimum, it is anticipated that the minimum impact would be a reduction in flow at groundwater upwellings in Howell Creek immediately east of the North Hill pit.

During the reclamation phase hydraulic gradients would gradually rise, or attempt to rise, towards their former levels. Groundwater flow velocities would gradually increase towards historical flow rates. It is anticipated that surface water recharge to groundwater would remain greater than preconstruction recharge because of reduced vegetative cover, ditch water infiltration, pond leakage, high recharge into the waste dumps, increased bedrock fracture permeability due to previous explosives use, and other factors.

4.4.2. Groundwater Chemistry

Mining activities speed up natural weathering processes and frequently introduce contaminants into local groundwaters. Groundwater contamination occurs from a number of premining, mining, and postmining activities and conditions. These are generally site-specific and controlled by the physical environment, operational activities, mine management, and minesite development.

Groundwater contamination resulting from coal mining activities is known to occur. These problems appear to consist mainly of elevated concentrations of nitrate, nitrite, and ammonia (Figure 10 shows stream reaches that would be affected).

Groundwater chemistry should not be significantly affected as a result of construction phase activities. Anticipated changes during this phase include slightly increased concentrations from sewage effluent facilities, and infiltrations of waste from the maintenance yard and other facilities. This would likely result in increased concentrations of phosphorus, nitrogen, chloride, hydrocarbons (fuel and oil), and, to a lesser extent, other constituents. Once these compounds infiltrate into the groundwaters they would move in the direction of groundwater flow and migrate within the groundwater flow system at variable rates. Factors and processes which control the migration of solutes in the aquifer systems include aquifer characteristics, aquifer boundaries, types of wastes, advection, dispersion, and geochemical and biochemical reactions. Contaminant movement in groundwater would be slower than groundwater movement for most dissolved constituents as a result of one or more of these controlling processes.

Dissolved constituents would increase as site development progresses into the mining phase because of physical disturbances in the groundwater recharge areas and because of the use of chemicals on site (see Appendix 4). With the development and expansion of the proposed mine site, groundwater contamination would be expected to increase throughout the mining phase. This would be due to increased leaching of contaminants from waste dumps, continued explosives use at lower elevations under "wetter" conditions, explosives spillage, and from other contaminant sources listed earlier. Surface water contamination caused by contaminated groundwater discharge would likely continue to increase following the mining phase and into the reclamation phase. The time lag would depend on the subsurface behaviour of each chemical species, distance from discharge areas, and local hydrogeological settings.

4.4.3 Groundwater Temperature

Groundwater temperatures are generally dependent upon aquifer depth and surface water-groundwater interflow. Groundwaters maintain relatively stable seasonal temperatures which commonly vary less than 2 to 3°C (3 to 5°F). Surface water temperatures in southwestern British Columbia frequently range between 0 and 17°C (32 and 63°F). As groundwaters discharge into surface waters they cause a moderating effect which warms the surface waters in the winter and cools them in the summer. Minor temperature changes in the groundwater thermal regime would be expected during the construction phase and larger impacts will occur as the mining phase progresses.

Significant temperature changes could occur to surface waters during the mining operation. The Pacific Hydrology Consultants (1982) report indicates that groundwater dewatering would be required during the middle and latter stages of mining activities. This would particularly apply during the period when the mine pits extend below the valley floor. The resulting impact would depend largely upon how the water from dewatering wells and the pits is handled. This matter was not adequately addressed in the Stage II report. Surface water temperature measurements differ above and below an existing coal mine in the Elk River valley. Specific causes of the fluctuations are not certain, but it is believed that warm surface water or groundwater discharges originate from solar heated settling ponds and tailings ponds.

Surface water and groundwater temperature alterations during the reclamation phase would likely be less than during the mining phase because of termination of site dewatering. The effect that solar heating of water-filled pits would have on groundwater temperature and the subsequent effect of that on stream temperatures is discussed in Subsection 5.2.3.

5. PARAMETERS, CONCENTRATIONS, LOADINGS, AND FLUXES

In this section effects of the proposed mine on surface and groundwater are quantified, where values can be reasonably estimated. Two operational cases, adverse and optimal, are presented to show the range of potential impacts. The adverse operational case involves allowance for variances due to problems with environmental control structures and the effects of human error and chemical losses (see Section 6 for qualitative evaluation of extreme or unusual events). This is based upon information from mines currently operating in the Elk River valley. The optimal operational case is predicated upon the assumption that British Columbia regulations are adhered to, and that state-of-the-art waste water management programs and facilities would be employed by Sage Creek Coal Limited. Both of these operational cases require "best professional judgement" in the interpretation of available data.

Not all mine generated solids and fluids pass through controlled discharge points. Consequently, the "additive" approach of estimating overall mine contributions (summation of individual contributions from the point of discharge outfalls) does not yield a total as great as the "holistic" approach. The latter method accounts for all loading increases caused by the mining operation (mass of constituent below the mine site minus the mass of constituent above the mine site). This approach includes areal contributions (uncontrolled sources) such as dustfall that are not accounted for by the additive approach and thus provides a more realistic assessment of mining impacts.

To implement the holistic method, one uses the difference in constituent concentrations of interest, and the difference in receiving water discharge above and below the mining operation to calculate the mass fluxes from the operation.

The holistic approach was applied using data from an existing coal mine on the Fording River. This mine constituted the best available analogue to the proposed Sage Creek Coal Limited operation because it contains open pit development below the elevation of the Fording River and is located in similar geologic materials. Also, the relative locations of the mine facilities and tailings pond are similar to those proposed by Sage Creek Coal Limited. However, the existing mine is relatively old and was not originally designed to meet current environmental standards. Data from this mine, and from other Elk River valley mines when Fording River data were unavailable, were used as inputs for the adverse operational case.

Based upon the available data, the MDC recognizes that there are potential environmental concerns which should be addressed in Stage III regarding nitrogen, phosphorus, total suspended solids, receiving water temperatures, and containment and recovery of accidental chemical losses. The possibility also exists that there may be impacts from constituents for which the MDC lacked data.

5.1 METHODOLOGY

In order to calculate the mass loading factors for the proposed mine, various assumptions were made with respect to hydrology and geochemistry and are discussed below. Estimates which are not accompanied by references were based upon professional judgements.

5.1.1 Hydrologic Assumptions

5.1.1.1 Precipitation. The average annual precipitation for Elko, Beaver Mines, and Fernie is 767 mm (30.2 in) (Stage II EA). Forty-eight months of precipitation data are available for a station at the top of Dally Hill, above the proposed South Hill pit and waste dump area. The total precipitation for that site is 70% of the precipitation at Fernie, B.C., for the same period of record. Using 0.7 as a correction factor to Fernie's mean annual precipitation of 1082 mm (42.6 in) (Stage II EA, p. 3-11) yields a calculated mean annual precipitation of 757.4 mm (29.8 in). To facilitate calculations, 762 mm (30 in) was assumed as the annual precipitation at the mine site.

The Mine Development Committee recognizes that this quantity of precipitation at the mine site is considerably less than the average for the Cabin or Howell Creeks drainages. The mine site is at nearly the lowest point in these basins and the orographic effect upon precipitation is quite pronounced in this area. Thus, while the projected runoff from the mine site is less than the average for these drainage basins, it is a valid estimate for the mine site area. This is further supported by the fact that the assumed precipitation is greater than the 10-year average of data collected at Butts, B.C., in the Flathead River valley, near Howell Creek, and is also greater than the average of data from Polebridge, Montana for a 42-year period of record (see Subsection 3.4).

The assumed partitioning of precipitation into runoff, groundwater recharge, and evapotranspiration is summarized in Table 3 for various periods of the operation.

Table 3. Assumed partitioning of precipitation.

Stages of Mining	Runoff	Groundwater Recharge	Evapotranspiration
Baseline	50%	10%	40%
Mining	60%	30%	10%
Reclamation	50%	20%	30%

5.1.1.2 Groundwater recharge. Under natural conditions an estimate of 10% for recharge to aquifers was assumed. Mining practices include ground disturbance, creation of permeable zones by end-dumping, and contouring dump lifts during the operation to drain water away from the edges to prevent erosion. Consequently, a recharge factor of 30% of annual precipitation has been assumed for the construction and mining phases, and a factor of 20% was assumed for recharge during the reclamation stage.

5.1.1.3 Runoff. Under natural conditions an estimate of 50% of precipitation was assumed. During the construction and mining phases, a runoff factor of 60% was assumed. The reclamation stage factor assumed was 50% of the annual precipitation.

5.1.1.4 Evapotranspiration. The baseline estimate assumed was 40%. This would be greatly reduced by the operational impacts. For the period following the initial disturbance, a factor of 10% was estimated; it was also assumed that upon reclamation this factor would increase to 30%.

5.1.1.5 Groundwater flow limitations. The limiting factor would be the hydraulic conductivity of the least permeable unit or zone in the flow path. A secondary limit would be imposed by the amount of head differential (hydraulic gradient) that can be established.

5.1.2 Geochemical Assumptions

5.1.2.1 Reaction rates. Because blasting, handling, and dumping of overburden cause rock breakage, new surfaces are created which accelerate the chemical weathering of the waste materials. Both runoff and groundwater leaving the waste dumps would have higher concentrations of suspended and dissolved constituents than would surface and groundwater in the natural environment.

5.1.2.2 Nutrient consumption. It is expected that reductions in nutrient levels (particularly orthophosphate) would occur in surface waters during the annual period of algal and microbial growth through direct assimilation, and also due to adsorption on sediments. It is beyond MDC terms of reference to estimate these temporary reductions.

5.1.3 Example Calculations

5.1.3.1 Runoff. Using 762 mm (30 in) as an annual average precipitation, runoff during the period encompassing post-logging to re-establishment of vegetation after reclamation should average 457 mm (18 in) per unit area of disturbed ground. The natural timing for peak runoff should be close to that measured for the Flathead River at the International Boundary. Data provided by the U.S. Geological Survey (USGS) for a 29-year period indicate that: average peak flow occurred on May 28th; lowest peak flow occurred on May 15th; and highest peak flow occurred on June 9th. This information provides a range of dates and values which vary with maximum winter snowpack and regional weather conditions.

Roughly 50% of the runoff will occur in May and June (B.C. Research and Norecol 1982, p. 3-25). In this two-month period mine site runoff would vary from 5.13 x 10^5 m^3 (416 acre-ft) when only the North Hill's north dump is considered (roughly year 4 of the mining plan) to 2.35 x 10^6 m^3 (1905 acre-ft) at the end of the mining proposed in the Stage II EA. Pond 2 would be expected to receive 8.88 x 10^5 m^3 (720 acre-ft) during this main runoff (freshet) period once the north and west dumps are installed.

5.1.3.2 Groundwater discharge. During and following the life of the mine, several different groundwater scenarios are likely to occur. Factors which were only generally considered in these scenarios because of the paucity of data include:

- pre-mining groundwater flow directions, discharge locations, quantities, temperatures, and chemistry;
- groundwater quantities draining into the mine pits and from dewatering shot holes (these pits function as large wells);
- induced recharge on dumps, flow directions, discharge areas, temperature, and chemistry;
- leakage from settling and tailings ponds and sewage lagoons; and
- thicknesses and hydrologic characteristics of the rocks and sediments affected by the mining activities.

Land disturbance normally increases runoff and sediment yield. Impacts on groundwater flow and discharge are less predictable because of the large number of unknown controlling variables referred to in Subsection 4.4.1. Mining methods used in the Elk River valley emphasize runoff control and diversion to settling ponds. Some settling ponds function primarily as sediment traps and act as point sources for artificial recharge to shallow, surficial or alluvial aquifers. These ponds are commonly designed to allow leakage, and accumulated sediment is routinely removed to maintain pond volume and infiltration capacity.

The proposed settling ponds and tailings pond for the Sage Creek Coal Limited's mine would be situated upon highly transmissive fluvial deposits (based upon transferring locations of these structures onto the NTS 82 G/2 Terrain Map of Surficial Geology [B.C. Ministry of Environment 1977]). The MDC expects that these ponds would leak and discharge to the shallowest aquifer.

For the purpose of calculating most loadings, waters lost to the shallow aquifer systems can be considered as surface water, except for suspended solids and effects on dissolved oxygen (DO), groundwater temperature, iron, and manganese. The groundwater temperature variation would increase due to pond inputs, while DO should decrease. Iron and manganese are expected to rise relative to surface water concentrations.

Gross calculations and estimates of impact can be phased relative to the contribution from each successive waste dump as it comes on line. The Stage II EA indicates that Dumps A, B, C, D, E, and F (Figure 3) would have surface areas of 4.59, 1.04, 1.93, 2.47, 1.58 and 0.34 km^2 (1135, 252, 477, 611, 391, and 84 acres), respectively. Groundwater recharge to these dumps was estimated to be 228.6 mm (9 in) of water per year. The recharge would be expected to be roughly three times that occurring in the undisturbed state (Table 3). Average annual groundwater discharges from the dumps, once equilibria were established, are calculated to be 1.05×10^6, 2.33×10^5, 4.41×10^5, 5.65×10^5, 3.61×10^5, and 7.77×10^4 m^3 (851, 189, 358, 458, 289, and 63 acre-ft) from Waste Dumps A, B, C, D, E, and F, respectively.

Highly transmissive unconfined aquifers in fairly steep terrain show considerable variation in discharge to creeks during the year. This is due to the range of seasonal head difference developed (controlled by the thickness and hydraulic conductivity of the least permeable unit in the flow path) and bank storage. With essentially no data to work with, a factor of five was used as an initial estimate of variability based on professional judgement. Thus, for example, at a small discharge location (seepage or spring) the measured discharge would be expected to vary from 4 to 19 L/min (1 to 5 gal/min) during the year. Peak groundwater discharge should occur shortly after the peak runoff and then decline until late March or early April of the following year.

Groundwater flow from the dumps would be approximately perpendicular to the contours of the prepared, pre-dumping land surface.

The average annual flow, once equilibrium was established, would be 0.0866 m^3/s (3.06 cfs) for the combined five dumps. This would constitute a three-fold increase over the pre-mining groundwater discharge of 0.0288 m^3/s (1.02 cfs). As the mean annual discharge would be roughly 1.8 times the minimum discharge for the postulated range of discharge values, maximum and minimum groundwater discharges from the dumps were estimated under operational conditions as follows:

Dump	Maximum (m^3/s)	Minimum (m^3/s)
A	0.092	0.0185
B	0.021	0.0041
C	0.039	0.0078
D	0.050	0.0099
E	0.032	0.0064
F	0.007	0.0014

5.1.4 Summary of Water Fluxes

The assumptions in Subsection 5.1.1 apportion the annual precipitation among runoff, groundwater recharge, and evapotranspiration (ET). At maximum development, increased discharge from the disturbed portions of the mine site would occur: runoff would be expected to increase by 20%; and groundwater recharge and discharge would be expected to increase three-fold. These increases would result from reduced ET losses.

In calculating the impact upon the overall water budget, it has been assumed that use of only the total dump area would account for the maximum increase of water discharge at any point during the life of the mine. This is because some dump areas would be in initial reclamation stages before others were fully developed. In the first half of pit development groundwater would be depleted, but this should be roughly compensated for by enhanced surface and groundwater discharge for the total dump area. This, plus the extreme reduction in the ET assumed in Table 3 (from 40% to 10% of annual precipitation), permits the calculation of increased discharge using the areas of the dumps alone.

To facilitate comparisons, Table 4 displays the calculated water fluxes including the "unimpacted" areas in the baseline, mining, and reclamation stages (initial hydrologic assumptions retained). While the mining phase analysis did not involve separating out the pits, the reclamation phase analysis did involve addressing the pits separately. It was necessary to make relatively crude estimates apportioning precipitation for these pits. However, the key point is that runoff is reduced to pre-mining levels once vegetation is established, but increased quantities of groundwater recharge (and eventual discharge to Cabin and Howell Creeks and the Flathead River) are maintained. In the following discussion, runoff and groundwater recharge are assumed to be equal to surface water discharge and groundwater discharge, respectively.

It was estimated that the pre-mining runoff from the 11.95 km^2 dump area would be 50% of the annual precipitation. Thus, the baseline value was calculated as (11.95 x 10^6 m^2 x 0.762 m [precip/yr] x 0.5) = 4.55 x 10^6 m^3/yr (3689 acre-ft/yr), for a year with average precipitation. The baseline groundwater recharge for this area may be calculated as (11.95 x 10^6 m^2 x 0.762 m [precip/yr] x 0.1) = 9.11 x 10^5 m^3/yr (739 acre-ft/yr), also for an average year. Using the assumptions in Table 3, similar calculations for maximum flows were: surface runoff = 5.46 x 10^6 m^3/yr (4426 acre-ft/yr); and groundwater recharge = 2.73 x 10^6 m^3/yr (2213 acre-ft/yr). Thus, at maximum impact the calculated increase in runoff, and thus surface water discharge, would be 0.91 x 10^6 m^3/yr (738 acre-ft/yr) while the calculated increase in groundwater recharge, and thus discharge, would be 1.82 x 10^6 m^3/yr (1475 acre-ft/yr). These values are for years with average precipitation. Hence, the estimated maximum increase in combined surface and groundwater discharge from the mine site would be 2.73 x 10^6 m^3/yr (2213 acre-ft/yr) for a year with average precipitation.

When the annual precipitation is different from the average value the surface and groundwater contributions to discharge will change somewhat. The following estimates will give an approximation for the disturbed area during mining to correct for dry or wet years.

1. In dry years: (1) maintain the 76.2 mm (3 in) ET loss (9.11 x 10^5 m^3/yr [739 acre-ft/yr]); (2) 75% of the decreased precipitation will result in reduced surface water

Table 4. Summary of calculated water fluxes assuming precipitation is 762 mm per year.

Mining Stage	Condition (area)	Runoff/Surface Water Discharge $10^6 m^3/a$ (%)	Groundwater Recharge/Discharge $10^6 m^3/a$ (%)	Evapotranspiration $10^6 m^3/a$ (%)
1. Premining	"Unimpacted" (20.7 km^2)	7.89 (50%)	1.58 (10%)	6.31 (40%)
	Totals	7.89	1.58	6.31
2. Mining	Impacted (11.95 km^2)	5.46 (60%)	2.73 (30%)	0.91 (10%)
	"Unimpacted" (8.75 km^2)	3.33 (50%)	0.67 (10%)	2.67 (40%)
	Totals	8.79	3.40	3.58
3. Reclamation	Impacted (11.95 km^2)	4.55 (50%)	1.82 (20%)	2.73 (30%)
	Pits (3.61 km^2)	0 (0%)	1.65 (60%)	1.10 (40%)
	"Unimpacted" (5.14 km^2)	1.96 (50%)	0.39 (10%)	1.57 (40%)
	Totals	6.51	3.86	5.40

discharge; and (3) 25% of the decreased precipitation will result in reduced groundwater recharge and later reduced groundwater discharge.

2. In wet years: (1) partition 10% of the total precipitation for ET losses; (2) 75% of the remaining surplus precipitation should be attributed to surface water; and (3) 25% of the remaining surplus (after step 1) is expected to appear as increased groundwater recharge and eventual discharge.

These procedural estimates are incorporated into Table 5 which summarizes runoff, groundwater recharge/discharge and ET during the mining operation as a function of a wide range of precipitation.

5.1.5 Maximum Parameter Concentrations

In keeping with the optimal and adverse operating condition definitions, Tables 6 and 7 were prepared to represent the highest average daily concentrations of constituents (except total suspended solids [TSS]) that might be expected, in receiving and effluent waters respectively, in any given year with average precipitation. (see Subsection 5.4 for discussion of TSS). Effluent water is any liquid discharge leaving the mining operation as opposed to receiving waters which are any bodies of surface water into which a discharge may flow.

The tables summarize the results of more detailed discussions presented in the following subsections. The discussions include calculations of annual loadings (where applicable) and timing of releases. Dilution would be less, and therefore concentrations of constituents would be higher, for the combined Cabin Creek and Howell Creek drainages than for the Flathead River above Couldrey Creek. Consequently, the receiving water aspects presented in Table 6 are for Howell Creek at the edge of the mining property. This location is comparable to NAQUADAT Station No. 00BC08NP0008 at the current Flathead road bridge across Howell Creek about 750 m (2460 ft) above the confluence with the Flathead River (Sheehan et al. 1985). The sole exception to this condition is for TSS concentrations which apply in either Cabin or Howell Creeks immediately above their confluence.

Table 5. Calculated distribution of varying amounts of precipitation.

Precipitation in mm ($10^6 m^3$ for 11.95 km^2)	Runoff/Surface Water Discharge $10^6 m^3/yr$	Groundwater Recharge/Discharge $10^6 m^3/yr$	Evapotranspiration $10^6 m^3/yr$
400 (4.78)	2.22	1.65	0.91
500 (5.98)	3.12	1.95	0.91
600 (7.17)	4.01	2.25	0.91
700 (8.37)	4.91	2.55	0.91
762 (9.11)	5.46	2.73	0.91
800 (9.56)	5.77	2.83	0.96
900 (10.76)	6.58	3.10	1.08
1000 (11.95)	7.38	3.37	1.20
1100 (13.15)	8.19	3.64	1.31
1200 (14.34)	9.00	3.91	1.43

Table 6. Estimated receiving water concentrations at the proposed Sage Creek Coal Limited mine site.

Receiving Water Parameters	Optimal Operating Condition (Lower Maximum Concentration)	Adverse Operating Condition (Upper Maximum Concentration)	Objective or Regulatory Limit or Range
Particulate P	0.050 mg/L increase	0.150 mg/L increase	--
Soluble Reactive P	0.002 mg/L increase	0.004 mg/L increase	No increase[a]
Nitrate (as N)	<5 mg/L	<10 mg/L	10 mg/L[a]
Nitrite (as N)	0.01 mg/L	0.02 mg/L	0.060 mg/L[a,b]
Ammonia + Ammonium (as N)	0.05 mg/L	0.15 mg/L	0.838 mg/L[a,c]
Temperature Change	-1 to +1°C	-2° to +3°C	±1°C [d]
pH	7.3 ≤ pH ≤ 8.4	7.3 ≤ pH ≤ 8.7	no change[d]
TSS	≤ 10 mg/L increase	43 mg/L increase	10 mg/L increase or increase of 10% of background if background > 100 mg/L[a]
Dissolved Oxygen	≥ 90% of natural	≥ 80% of natural	≥ 90% of natural[d]
Alkalinity	15 mg/L increase	25 mg/L increase	≥ 20% of natural[d]
Chloride	≤ 1.5 mg/L	≤ 3 mg/L	≤ 25 mg/L[d]
Barium (dissolved)	--	--	1.0 mg/L[a]

a Condition of Stage II approval-in-principle

b 0.02 mg/L for prolonged periods

c Assumes NH_3 = 3.58% of (NH_3^0 + NH_4^+) for conditions of T = 10°C and pH = 8.3
NH_3^0 (un-ionized ammonia) limits: 30 µg/L at any time
7 µg/L for prolonged periods (10 days or more)

d B.C. MOE, Pollution Control Board (1979)

Table 7. Estimated effluent water concentrations emanating from the proposed Sage Creek Coal Limited mine site.

Effluent Water Parameters	Optimal Operating Condition (Lower Maximum Concentration)	Adverse Operating Condition (Upper Maximum Concentration)	Objective or Regulatory Limit or Range
Al (dissolved)	<0.10 mg/L	<0.10 mg/L	0.5-1.0 mg/L[a]
As (dissolved)	<0.010 mg/L	<0.03 mg/L	0.1-1.0 mg/L[a]
Ba (dissolved)	<0.200 mg/L	<0.30 mg/L	--
Cd (dissolved)	<0.005 mg/L	<0.010 mg/L	0.01-0.1 mg/L[a]
Co (dissolved)	<0.010 mg/L	<0.020 mg/L	0.5-1.0 mg/L[a]
Cr (dissolved)	<0.030 mg/L	<0.050 mg/L	0.05-0.3 mg/L[a]
Cu (dissolved)	<0.020 mg/L	<0.020 mg/L	0.05-0.3 mg/L[a]
Hg (total)	<0.0001 mg/L	<0.0001 mg/L	nil-0.005 mg/L[a]
Mo (dissolved)	<0.015 mg/L	<0.020 mg/L	0.5-5.0 mg/L[a]
Ni (dissolved)	<0.015 mg/L	<0.030 mg/L	0.2-1.0 mg/L[a]
Pb (dissolved)	<0.025 mg/L	<0.050 mg/L	0.05-0.2 mg/L[a]
Se (dissolved)	<0.010 mg/L	<0.015 mg/L	0.05-0.5 mg/L[a]
Zn (dissolved)	<0.040 mg/L	<0.050 mg/L	0.2-1.0 mg/L[a]
TDS	<700 mg/L	<1000 mg/L	2500-5000 mg/L[a]
TSS	---	---	25-75 mg/L[a]
pH	$<7.3 \leq pH \leq 8.6$	$<7.3 \leq pH \leq 9.0$	6.5 to 8.5-10.[a]

[a] B.C. MOE, Pollution Control Board (1979)

5.2 PARAMETERS REGULATED BY RECEIVING WATER CHARACTERISTICS

While the concentration of Total Suspended Solids (TSS) is also regulated under requirements for receiving water, it has been evaluated separately here in Subsection 5.4.

5.2.1 Phosphorus

5.2.1.1 Introduction. The Provincial objectives for receiving stream water quality relevant to the proposed Sage Creek Coal Limited mine state that there shall be no increase in phosphorus except that related to increased sediment (Subsection 1.5.1.3). This exception is interpreted as sediment-bound or particulate phosphorus which equals total phosphorus minus dissolved phosphorus. The objective can only be approached if a high priority is given to, and extreme care is taken with, the planning for and installation of sewage treatment facilities.

Ministry of Environment Waste Management data may be interpreted to suggest that the major contributing sources of soluble reactive phosphorus (orthophosphate) are human population centers, not the mining activities themselves. Thus the sewage treatment facilities for both the construction camp(s) and the plant become critical in attaining the objective.

A recent report on phosphorus from operating surface coal mines (Norecol 1985) lists several potential sources of both dissolved and total phosphorus, in addition to sewage, for release to the aquatic environment. These include disturbed ground and soil stockpiles that are unvegetated, fresh waste rock, areas of active fertilized reclamation, haul roads, plant sites, groundwater, and ditch discharges.

5.2.1.2 Particulate phosphorus. The major sources of concentrated particulate phosphorus are from strata which underlie the coal beds proposed for mining. Christie and Kenny (1980), in summarizing the results of Kenny's research on phosphate-bearing strata in southeastern British Columbia, state that, stratigraphically, the highest horizon of possible economic interest for phosphate (P_7 zone) is in the Rock Creek member of the Fernie Formation. At Crowsnest this zone is 45 to 75 m (145 to 245 ft) above the base of the Fernie Formation (Telfer 1933).

The optimal operational case is based upon the assumption that the company would minimize particulate phosphorus contribution to streamload by integrating construction and mining plans with the bedrock geology, and developing plans to minimize disturbance of phosphorus-rich units beneath the coal-bearing horizons.

These units include:

1. the lower Fernie Formation (Jurassic age);
2. the Llama, Whistler, and Vega members of the Sulphur Mountain Formation (Triassic age);
3. the Ranger Canyon, Ross Creek, and Johnston Canyon Formations (Permian age); and
4. the basal Exshaw Formation (uppermost Devonian to lower Mississippian age).

Particulate phosphorus is present in the waste rock between the mineable coal seams. Gibson (1985) describes the Mist Mountain member (which contains the coal seams) and comments on the presence of phosphate nodules and phosphatic cement, particularly in chert-rich siltstones.

Very limited phosphorus data available from the existing mine on the Fording River have been used as a guide for impact assessment. Monitoring data from the Elk River valley on Bodie, Michel, Erickson, Harmer, and Six Mile Creeks, which include both receiving and discharge waters, have a combined average total phosphorus value of 0.065 mg/L. Maximum recorded concentrations range from a low of 0.031 mg/L on Erickson Creek to a high of 7.5 mg/L on Bodie Creek, which is permitted as an effluent discharge system. Peak values noted in the Elk River valley run 6 to 10 times greater than average values, and normally occur during peak discharge periods for the respective water courses.

Baseline data for Howell Creek, just below the proposed mine site, were obtained from the Kootenay Air and Water Quality Study, Phase II Report (B.C. Ministry of Environment 1978, p. 277). Total phosphorus (which includes both particulate and dissolved species) averaged 0.021 mg/L in 13 samples with values ranging from 0.009 to 0.062 mg/L. Data in Table 10 of Appendix 3.3.3-1 of the Stage II EA were derived from samples at approximately the same site. In this case total phosphorus values averaged 0.062 mg/L and ranged from less than 0.002 mg/L to 0.218 mg/L (nine samples). The four B.C. Research samples collected for Sage Creek Coal Limited on May 9 and 24, June 6, and July 21, 1978 yielded total phosphorus concentrations of 0.050, 0.218, 0.198, and 0.062 mg/L respectively. Together they produced an average value of 0.132 mg/L. In addition, baseline samples collected at the Cabin Creek cableway during the 1986 freshet yielded total phosphorus values of up to 0.40 mg/L (1986 unpublished data, R. Noble, Montana Bureau of Mines and Geology, Butte, Montana).

The disparity among these data sets and the high but uncertain background levels necessitated that the MDC list mining impacts as increases above the background levels for phosphorus in Table 6. The increases listed are based upon unpublished 1985 Environmental Protection Service (EPS) data (1985, K. Ferguson, Environmental Protection Service, Environment Canada, Vancouver, B.C., personal communication) for the five Elk River valley creeks discussed two paragraphs earlier and for Line Creek, which is also in the Elk River valley. These data constitute a reasonable estimate of the maximum impact.

Without mean annual TSS concentrations, which the MDC is not satisfied can be calculated within acceptable error levels (see Subsection 5.4 of this report), it is difficult to establish an annual loading calculation for particulate phosphorus. However, to provide other committees with a reasonable estimate the following procedure was used.

1. Total mine site area is 8.69% of the drainage area. It was assumed that, because of enhanced runoff, this constitutes 9.00% of Howell and Cabin Creeks' drainages.
2. Average particulate P concentration, as an increase, was estimated at 0.0065 mg/L for the receiving water below the operating mine on the Fording River. This value was calculated as follows. Using the Kootenay Air and Water Quality Study, Phase II data (B.C. Ministry of Environment 1978, Table 11) mean particulate phosphorus concentration above the mining area was subtracted from the mean concentration near the downstream margin of the mining area (sites 0200110 and 0200201, respectively). The resulting value (0.013 mg/L) was then divided by two to roughly

account for differences between the operating and proposed mines in terms of the proportion of the drainage basins that would have disturbed runoff characteristics. Assuming the mine effluent constitutes 9% of the surface flow of Howell Creek below the confluence with Cabin Creek (Subsection 5.1.5), the effluent concentration was calculated by dividing the average concentration increase by the proportion of drainage area disturbed by mining (0.0065/0.09 = 0.072 mg/L).

3. Total mine site surface water release was estimated at 60% of precipitation on dump areas and at 50% of precipitation on non-dump areas. At maximum development this would amount to 8.79 x 10^6 m^3/yr (7126 acre-ft/yr) when precipitation is 762 mm/yr (30 in/yr).
4. Annual particulate phosphorus from the mine was then calculated as (0.072 mg/L) x (8.79 x 10^6 m^3) x (10^3 L/m^3) = 6.33 x 10^8 mg = 633 kg (1396 lbs) when annual precipitation = 762 mm. This value is thought to be an upper limit during normal years.

The greatest uncertainty in the calculations above is related to the average increase in particulate phosphorus in the receiving water.

An alternate approach which can be used is to assume that a 25 mg/L effluent standard (Table 7) for TSS (which is more stringent than the 10 mg/L increase for receiving waters) would constitute the average sediment contribution from controlled discharges and that only controlled discharges would constitute the increase above background contributions. This is a rather optimistic appraisal, but it helps to put lower limits on the proposed mine's particulate phosphorus impact. Using the calculated mean annual surface runoff of 5.46 x 10^6 m^3 (4426 acre-ft), an average TSS concentration of 25 mg/L, and a phosphorus content of sediment of 0.128 weight percent (calculated from the Phase II data [B.C. Ministry of Environment 1978]) the annual particulate phosphorus loading was calculated to be 175 kg (386 lbs).

One limitation of these calculations is that the assumed P content of 0.128 weight percent was based upon a collection procedure that may not be truly representative. This procedure, using pickle jars partly buried in the streambed, probably underestimates the P content because a disproportionately small amount of the clay-sized particles is trapped. Phosphorus adsorbed on clays is believed to be a significant factor in the particulate phosphorus flux.

The particulate phosphorus loadings presented above represent the upper and lower limits which the MDC believes are applicable. A value more than twice as large as the 633 kg (1396 lbs) upper value could have been calculated using the data published by Nordin (1982, Table 2). The MDC believes that Nordin's data collection strategy was oriented toward peak values, but, more importantly, that such a calculation would grossly overestimate the particulate phosphorus contribution for a new mine being developed under the current regulatory conditions. The average annual loadings would probably range from 250 to 500 kg (551 to 1103 lbs) for the proposed Sage Creek Coal Limited mine. Approximately 80% of the particulate phosphorus load would be released during the freshet in May and June. These numbers represent the best professional judgement of the MDC.

5.2.1.3 Soluble reactive phosphorus (orthophosphate). The background data base for soluble reactive phosphorus (SRP) is less reliable than that for particulate phosphorus. For instance, the USGS, which is a source for these data, has asked that its data set not be used because the accuracy of the data is questionable. None of the samples is believed to have been analyzed within 24 hours of collection. Delay between collection and analysis results in reduced SRP values. However, these are the only data available.

The data on Table 10 of Appendix 3.3.3-1 of the Stage II EA indicate a range of from <0.002 to 0.012 mg/L. The SRP concentrations from Elk River valley mining areas range from below the detectable level (Line Creek), upward. Most of these Elk River valley mines have more mining-disturbed ground per unit area of drainage basin than the proposed Sage Creek Coal Limited mine. The average SRP content from the EPS data set, discounting Bodie Creek which is permitted as an effluent system, is 0.005 mg/L. Consequently, the estimated increases for optimal and adverse conditions in Table 6 are 0.002 and 0.004 mg/L, respectively. These numbers may slightly understate the peak values; however, the SRP concentration does not fluctuate nearly as greatly as that of particulate phosphorus.

In calculating annual loadings for SRP, both groundwater and surface water discharges were considered. For the total mine area, the surface water discharge was previously calculated to be 8.79 x 10^6 m^3/yr (7126 acre-ft/yr). Assuming 30% recharge to groundwater for the dump area and 10% for the remaining mine area, a groundwater discharge estimate of 3.40 x 10^6 m^3/yr (2756 acre-ft/yr) was calculated (Table 4). The combined surface and groundwater discharge would then be 1.22 x 10^7 m^3/yr (9889 acre-ft/yr). If the average receiving water increase was assumed to be 0.002 mg/L, calculations similar to those provided for particulate phosphorus would result in an annual loading quantity of 271 kg (598 lbs) SRP.

A crude cross-check on this number can be made using annual per capita SRP production of 2.2 kg (4.85 lbs) (1986, B. Kangasniemi, B.C. Ministry of Environment, Victoria, B.C., personal communication) and the proposed work force (500 people). Multiplication of these factors yields 1100 kg/yr (2426 lbs/yr) for human waste and laundry. Workers are estimated to spend roughly 40% of their waking time on-site, but it was assumed that laundry would be done off the mine site. Thus, if one-fourth of the "people waste" was released on site, this would amount to 275 kg/yr (606 lbs/yr). Additional contributions from disturbed ground, waste rock, fertilizers, eroded soil, and other sources (Norecol 1985) could be reasonably expected to add an additional 150 kg/yr (331 lbs/yr). Hence, the loading estimate, 271 kg/yr (598 lbs/yr), does allow for limited sorption (roughly 50 to 60%) of sewage phosphate after discharge to the ground; this does not seem unreasonable considering that sands and gravels are believed to underlie the proposed septic discharge field at a shallow depth.

The figures do not include the SRP loading during the construction phase. It is unclear in the Stage II report what the nature of the sewage treatment facilities would be at this stage. The initial ground disturbance should enhance release of "soil solution" phosphorus, which is orthophosphate or SRP, present at levels of 0.1 to 1.0 mg/L (Norecol 1985, p. 2-3). It is not clear whether slash from logging would be burned; slash burning is believed to be a significant source of phosphorus release (Norecol 1985). Because the operational plans for the proposed mine are quite vague, it was not considered feasible to calculate loadings for this phase of the operation.

5.2.1.4 Discussion. One factor normally involved in real systems, algal P uptake, has not been quantified. As an example, data from an existing Elk River valley mine (McDonald 1984) show the Erickson Creek settling pond water to have contained 0.029 mg/L SRP on 1985 June 15, whereas the 16 available samples collected at the mouth of Erickson Creek in 1985 ranged from 0.002 to 0.008 mg/L. The extent to which this difference was due to dilution, biological consumption, or adsorption by sediments is not known, but it does provide an estimate of the extent of the temporary attenuation that may be caused by the combination of dilution, sorption, and biological consumption in the creeks draining the mine area. Because SRP concentration does not fluctuate greatly, seasonal loadings would be roughly proportional to receiving water flows; exceptions to this would occur in cases similar to nitrogen (Subsection 5.2.2.1 below) shortly before freshet, when flows are very low and concentrations build up because there is less dilution.

5.2.2 Inorganic Nitrogen Species

5.2.2.1 Introduction. Data available to the MDC indicate that the overwhelming source of nitrogen would be the explosive materials used in mining (Nagpal 1982). Nitrate (NO_3^-), nitrite (NO_2^-), un-ionized ammonia (NH_3) and ammonium (NH_4^+) have been detected in groundwater at many mines.

The reduced forms may continue to exist when contaminated groundwater moves toward receiving streams, but usually are fairly rapidly oxidized in the well-oxygenated creeks and rivers in the mine site areas. The oxidation of nitrogen species is more rapid under warmer conditions; hence the winter and spring periods are the worst for the continued presence of nitrite and ammonia/ammonium species, particularly when stream areas are covered by ice.

The peak nitrogen concentrations in surface waters appear to occur during winter low flow in both mining-impacted and unimpacted streams. Maximum values of nitrate in impacted surface waters may exceed 10 mg/L (as N) in the Elk River valley (Fording Coal Limited 1985); however, dilution or biological attenuation normally reduces the concentration in these impacted tributaries by the time the water reaches the tributary mouth. Pumping of pit water directly to the receiving streams can significantly increase loadings to those streams. On the other hand, environmentally conscientious blasting and water management programs can significantly reduce such loadings.

5.2.2.2 Nitrate as N. Most impact assessments have concentrated upon nitrate because this is the predominant form of nitrogen. The generally accepted practice for assessing nitrogen released due to the use of explosives was presented by Pommen (1983). The powder factor suggested for the Sage Creek Coal Limited operation is 0.71 kg/bcm (1.19 lbs/bcyd), and the projected average annual consumption is 9.5×10^6 kg (2.1×10^7 lbs) (Stage II EA). Explosives used would be ammonium nitrate mixed with fuel oil (AN/FO), which should average 33% nitrogen by weight (Pommen 1983, p.3), and slurry water gels with an approximate nitrogen content of 25 weight percent (Pommen 1983, and 1986, Larry Pommen, B.C. Ministry of Environment, Victoria, B.C., personal communication).

The groundwater study submitted by Sage Creek Coal Limited as a Stage II support document (Pacific Hydrology Consultants Ltd. 1982) points out that substantial dewatering problems would probably be encountered (Section 4). Consequently, the ratio of AN/FO to slurry may initially be 80% to 20% as indicated in the Stage II text, but may become 20% to 80% once the pits progress well below the pre-mining groundwater levels. This high slurry use would not seem unreasonable based upon data from Fording Coal Limited, in the years 1978, 1979, and 1980. During those years, most of the mining was from pits with extreme dewatering problems; consequently the slurry usage was 99.9, 96.4, and 96.7% of the total explosives used.

Nitrogen losses from AN/FO and slurry have been estimated at 1 and 6%, respectively (Pommen 1983, p. 72). If slurry use reached 80%, the calculated annual nitrogen loss would be

$$= [(0.8) \times (9.5 \times 10^6 \text{ kg}) \times (0.25) \times (0.06)] + [(0.02) \times (9.5 \times 10^6 \text{ kg}) \times (0.33) \times (0.01)]$$

$$= 114{,}000 + 6270 = 120{,}270 \text{ kg } (2.65 \times 10^5 \text{ lbs}),$$

or approximately 120 t/yr. This agrees reasonably well with a worst case scenario annual loading value of 160 t calculated by Pommen (see Appendix 6). Pommen also calculated receiving water impacts for summer and winter low flows of 5.1 and 8.5 mg/L of nitrogen, assuming an average daily release of 440 kg (970 lbs) of nitrogen. The occurrence of dissolved nitrogen peaks (in terms of concentration) at the end of base flow or the beginning of freshet, before the runoff is substantially increased, should be offset by the water management plan diversion of Dump E and South Hill runoff to the Flathead River. Hence, there is good agreement between Pommen's impact estimates and the values in Table 6.

The calculation of total nitrogen loadings was included in this section of the report because more than 95% of the nitrogen leaves the mining property as nitrate. As nitrate is not expected to exceed the B.C. receiving water objective in Cabin or Howell Creeks or in the Flathead River, no further discussion is presented.

5.2.2.3 Nitrite as N. The maximum nitrite concentrations were estimated using Fording River data provided by MOE (letter dated February, 1986, M.M. Strosher, B.C. Ministry of Environment, Waste Management Branch, Cranbrook, B.C. to N. Harrington, Montana Department of State Lands, Helena, Montana). The peak value reported from within a coal mining property was 0.059 mg/L (as N) in January of 1985. Below an operating coal mine, levels as high as 0.11 mg/L (as N) were reported in the same data set. The high nitrite values may be overstated. Pommen (1983) presents data (Table 34, p.144) which show that company results are fairly consistently low in un-ionized ammonia plus ammonium and high in nitrite; that report implies that the cause is a sample preservation problem.

As the receiving water data in Table 6 are to represent the maximum concentration expected at a point below the mining property (or its discharge point, if on the Flathead River), it is assumed that mixing would have occurred. Hence, the impact would be greater on Howell Creek at the station below the confluence with Cabin Creek than on the Flathead River.

5.2.2.4 Total Ammonia (NH_3^o + NH_4^+) as N. As mentioned above, un-ionized ammonia plus ammonium (NH_3^o + NH_4^+) data collected by the mining company on the Fording River may understate actual values. The data provided by the Ministry of Environment (MOE) (letter dated February, 1986 from M.M. Strosher, B.C. Ministry of Environment, Waste Management Branch, Cranbrook, B.C. to N. Harrington, Montana Department of State Lands, Helena, Montana) show peak concentrations of 0.22 and 0.24 mg/L as N in the Fording River within the mine boundary during January and May of 1985.

Oxidation in surface waters, which is temperature dependent as well as dependent upon the supply of oxygen, will quite rapidly reduce total ammonia concentrations to acceptable levels during the summer and fall. However, the ammonia content of discharging groundwater that comes from the pits and waste dumps may cause problems in mine site receiving streams. Company data for a surface water sample collected in the vicinity of the Erickson Creek settling pond show total ammonia concentrations of 0.015 mg/L in the surface water and 0.207 mg/L in the groundwater seeping from a coal refuse dump. Groundwater from an observation well below mining activities along the Fording River contained 0.218 mg/L total ammonia. The highest total ammonia concentration reported in Bodie Creek, a permitted discharge site, was 6.3 mg/L. These concentrations indicate that excessive total ammonia concentrations may exist locally during the mining and initial reclamation stages. Limited reaches of the receiving streams may be affected, particularly in areas where groundwater upwellings occur.

Table 8 is included to help the reader evaluate the significance of un-ionized ammonia. The 0.24 mg/L total ammonia concentration cited above was collected on 1985 May 6 when the pH was 8.10 and the water temperature was 5°C (40°F). The table shows that for these conditions the un-ionized ammonia content should be 1.54% of the total value; this amounts to 0.0037 mg/L or only one-half of the Sage

Table 8. Percentage of un-ionized ammonia in aqueous ammonia solutions at different pH and temperatures.

Temp	pH								
(C)	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
0	.00827	.0261	.0826	.261	.820	2.55	7.64	20.7	45.3
1	.00899	.0284	.0898	.284	.891	2.77	8.25	22.1	47.3
2	.00977	.0309	.0977	.308	.968	3.00	8.90	23.6	49.4
3	.0106	.0336	.106	.335	1.05	3.25	9.60	25.1	51.5
4	.0115	.0364	.115	.363	1.14	3.52	10.3	26.7	53.5
5	.0125	.0395	.125	.394	1.23	3.80	11.1	28.3	55.6
6	.0136	.0429	.135	.427	1.34	4.11	11.9	30.0	57.6
7	.0147	.0464	.147	.462	1.45	4.44	12.8	31.7	59.5
8	.0159	.0503	.159	.501	1.57	4.79	13.7	33.5	61.4
9	.0172	.0544	.172	.542	1.69	5.16	14.7	35.3	63.3
10	.0186	.0589	.186	.586	1.83	5.56	15.7	37.1	65.1
11	.0201	.0637	.201	.633	1.97	5.99	16.8	38.9	66.8
12	.0218	.0688	.217	.684	2.13	6.44	17.9	40.8	68.5
13	.0235	.0743	.235	.738	2.30	6.92	19.0	42.6	70.2
14	.0254	.0802	.253	.796	2.48	7.43	20.2	44.5	71.7
15	.0274	.0865	.273	.859	2.67	7.97	21.5	46.4	73.3
16	.0295	.0933	.294	.925	2.87	8.54	22.8	48.3	74.7
17	.0318	.101	.317	.996	3.08	9.14	24.1	50.2	76.1
18	.0343	.108	.342	1.07	3.31	9.78	25.5	52.0	77.4
19	.0369	.117	.368	1.15	3.56	10.5	27.0	53.9	78.7
20	.0397	.125	.396	1.24	3.82	11.2	28.4	55.7	79.9
21	.0427	.135	.425	1.33	4.10	11.9	29.9	57.5	81.0
22	.0459	.145	.457	1.43	4.39	12.7	31.5	59.2	82.1
23	.0493	.156	.491	1.54	4.70	13.5	33.0	60.9	83.2
24	.0530	.167	.527	1.65	5.03	14.4	34.6	62.6	84.1
25	.0569	.180	.566	1.77	5.38	15.3	36.3	64.3	85.1
26	.0610	.193	.607	1.89	5.75	16.2	37.9	65.9	85.9
27	.0654	.207	.651	2.03	6.15	17.2	39.6	67.4	86.8
28	.0701	.221	.697	2.17	6.56	18.2	41.2	68.9	87.5
29	.0752	.237	.747	2.32	7.00	19.2	42.9	70.4	88.3
30	.0805	.254	.799	2.48	7.46	20.3	44.6	71.8	89.0

(From Emerson et al. 1975)

Creek Coal Limited Stage II required limit for prolonged exposure (Table 6).

5.2.2.5 Dissolved nitrogen gas (N_2). This parameter has not been quantified. However, the manager of the U.S. Federal fish hatchery near Ennis, Montana recently provided the information that modest N_2 supersaturation prevented spawning of trout and sculpins (1986 September 10, Wesley Orr, U.S. Fish and Wildlife Service, Ennis, Montana, personal communication). The springs which provide the fish hatchery water supply issue from a carbonate bedrock unit. The chemical composition of this water is similar to that currently documented for the alluvial aquifer at the proposed mine site (Appendix 5). However, the total dissolved solids content of the fish hatchery water is closer to that predicted for mine-impacted groundwater. Consequently, it is believed that annual increases of up to 120 t/yr of nitrogen as N, caused by explosives loss to surface water and groundwater (see Subsection 5.2.2.2), could result in N_2 supersaturation within groundwaters discharging to Howell and Cabin Creeks.

5.2.3 Temperature

The impact of the proposed mining operation on surface water temperatures should be a mixture of surface water and groundwater effects. The surface water effects would result from ditching and ponding, plus solar and climatic factors. To achieve sediment control, waters would be impounded to permit suspended solids to settle out. These ponds would normally be constructed in cleared areas and solar heating might become a significant factor in the summer months, raising stream temperatures at the time they receive mine site discharges (surface water plus groundwater); temperature differentials would be substantial relative to the flow and temperature of the receiving streams.

Very limited MOE data for the Fording River show temperature increases of over 5°C (9°F) in the mine area during late summer suggesting that surface water solar heating may cause temperature increases at any mine site.

Conversely, groundwater contributions to streams tend to moderate the range of stream temperature fluctuations, because even shallow groundwaters vary less in temperature range than do surface waters. In the vicinity of the proposed mine site it is estimated that the shallow groundwater temperatures average 5 to 6°C (40 to 43°F) with an annual fluctuation of 2°C (3.6°F) above and below the average. Where these waters discharge as springs within the streambed, the springs provide a stabilizing control on stream temperature. Alteration of the groundwater flow system may:

1. increase discharge to surface waters;
2. reduce discharges to surface waters; or
3. cause a loss of surface water to groundwater recharge,

in addition to changing the natural range of temperature variation. During the life of the mine, it is possible that each impact could occur sequentially (see Subsection 4.4.1).

During the construction period and the first few years of mining, increased groundwater recharge due to loss of vegetative cover, ground disturbance, and especially leakage from ditches and ponds is expected to occur. High permeability zones in the end-dumped waste would result in increased groundwater flow velocities and possibly greater fluctuation in discharging groundwater temperatures. When more permeable zones are not created, the increased recharge would require that steeper groundwater gradients develop to permit the larger volumes of water to flow through the same cross-sectional area; this would result in increased flow velocities and permit greater climatic influence upon groundwater temperatures.

If fracture permeability in the "host rock" is adequate, then, as the pit becomes deeper, a cone of depression caused by pit dewatering might expand and drain much of the groundwater recharge back into the pit, causing reduced groundwater discharge to streams. This would reduce baseflow in late summer and cause some increase in stream temperature. After the pits are developed below the levels of Cabin and Howell Creeks, it is possible that the groundwater gradient could actually be reversed and the streams would lose surface water to the pits, in addition to loss of groundwater contributions through the affected reach. This would provide additional groundwater recharge to the pits (Subsection 4.4.1).

The above reversal is unlikely if Tertiary-aged sediments, which overlie the coal and underlie Howell and Cabin Creeks east of the pits, are laterally extensive and relatively impermeable. However, the areal distribution and the hydrologic characteristics of the Tertiary-aged rocks in the vicinity of the proposed mine site are essentially unknown, and the loss of surface water could occur along with its associated impact upon streamflow and temperature.

A small amount of data from the Fording River show surface water temperature increases of up to 8°C (14°F) within the mine impact zone and temperature decreases below this zone. The impact zone has no vegetative buffer strips along the water courses. Defensible calculations could not be made from these data. The -2 to +3°C (-4 to +6°F) impact listed for the adverse case in Table 6 is simply professional judgement based upon impacted area percentages and expanded slightly to account for peak impacts which probably were not measured due to the monthly data collection schedule on the Fording River.

5.2.4 pH

Data for the hydrogen ion activity ($-\log_{10}[H^+]$) or pH show a fairly wide range, clustering near 8.0 for background waters. Values are slightly higher in waters below coal mine impact areas. For instance, data from the Fording River for August 6, 1985 show a pH value of 8.3 above the operating mine, a value of 8.5 within the mine and a value of 8.6 below the mine. This is an extreme instance from the limited data available; normally the shift is 0.1 to 0.2 units toward more basic (alkaline) water.

5.2.5 Dissolved Oxygen

As long as mine discharges are approximately 10% of total flow of receiving streams, and receiving waters are near oxygen saturation above the mine site, DO levels should not decline below 85% of saturation. The only case where major DO level reductions might occur in mine-vicinity creeks would be caused by the release of large volumes of effluent with excessive oxygen demand during low-flow and high temperature conditions. There are no reliable DO data available from the operating mines to test this projection.

5.3 PARAMETERS REGULATED BY EFFLUENT WATER CHARACTERISTICS

The concentration of Total Suspended Solids (TSS) is also regulated under requirements for effluent water. However, it has been evaluated separately in Section 5.4.

5.3.1 Data Problem

There are very few good effluent surface or groundwater sample sets from the Elk River valley mines for the parameters which follow. Considerable emphasis had to be placed upon samples that lacked some constituents and also had very high detection limits.

The major data base was provided by the Waste Management Branch (memo dated 1985 August 28, M.M. Strosher, B.C. Ministry of Environment, Waste Management Branch, Cranbrook, B.C.). Additional data from leaching and soil paste extraction from coal refuse can be found in Appendix 2. The MOE data are from an operating mine's program for internal environmental management.

5.3.2 Individual Constituent Discussions

Table 7 values and the rationale for them are presented below. Some entries are very brief while others are fairly extensive. In all cases the relevant data available to the committee are presented to the reader as follows.

5.3.2.1 Aluminum (dissolved) <0.10 mg/L.

- Erickson Creek Settling Pond - Total Al <0.15 mg/L.
- Erickson Creek Well @ Pond - Total Al = 0.11 mg/L.
- Soil Paste - Dissolved Al <0.03 mg/L.
- Distilled Water Leach - Dissolved Al = 0.147 mg/L.

These values can be explained as follows.

1. Aluminum solubility is very pH dependent; as the expected pH range would be 7.3 to 8.6 the distilled water leach (pH = 6.4) overstates aluminum solubility.
2. Sediment in the Erickson Creek well sample probably constitutes a significant portion of the total aluminum as the pH was 7.7 for that sample.

3. Up to 15 weight percent aluminum may be added to AN/FO to increase its explosive strength (Pommen 1983, p. 3).
4. Consequently, the <0.10 mg/L value is thought to be reasonable for the slightly alkaline effluent waters from a coal mine.

5.3.2.2 Arsenic (dissolved) <0.03 mg/L.

- The USGS reports 0.0009 mg/L dissolved and 0.012 mg/L total for the Flathead River at the International Boundary.
- All other data are less than 0.005 or 0.03 mg/L.

5.3.2.3 Barium (dissolved) <0.3 mg/L.

- Based upon the data available to the MDC, it appears that the majority (60%) of the barium transported in the streams is dissolved. The source of this barium is not known but could come in part from the weathering of calcic plagioclase and partly from the weathering of minerals within undetected epithermal mineralization in the drainage basin. Another potential source is past and present use of barite drilling muds in exploratory wells drilled in the Flathead River valley. The highest concentrations occur during low flow. The increased dissolved sulfate, which is characteristic of mine-impacted waters in the Elk River valley, would be expected to help prevent increases in dissolved barium concentration above the recommended limits. This might reduce the concentration of barium in surface and groundwaters.
- Erickson Creek data indicate 0.183 mg/L for groundwater and 0.075 mg/L for surface water. These values are totals.
- No other barium values have been included in effluent data sets, but effluent sulfate values range from a low of 8.7 mg/L in groundwater below the refuse dump to 370 mg/L in Erickson Creek Settling Pond water. Estimated sulfate in the effluent of the proposed Sage Creek Coal Limited operation is 100 to 250 mg/L which should preclude much

dissolved barium in the effluent due to the relative insolubility of barium sulfate (barite).

5.3.2.4 Cadmium (dissolved) <0.01 mg/L.

- Background roughly 0.001 mg/L dissolved, 0.0076 mg/L total (USGS data).
- Mine site total values <0.025 mg/L (operating mine data).
- Probable values 0.005 mg/L (dissolved), and 0.015 to 0.020 mg/L (total).

5.3.2.5 Chromium (dissolved) <0.05 mg/L.

- Background values <0.005 mg/L (Fording), 0.0086 and 0.033 mg/L (Flathead, USGS for total and dissolved).
- Totals are 0.033 mg/L (refuse groundwater) and <0.03 mg/L from Erickson Creek data.
- Chromium is often used in polymerizing the explosive slurries (Pommen 1983, p.37).

5.3.2.6 Cobalt (dissolved) <0.02 mg/L.

- Erickson Creek samples show <0.02 mg/L (total).
- Flathead samples (USGS data) give 0.031 mg/L total and about 0.001 mg/L dissolved.

5.3.2.7 Copper (dissolved) <0.02 mg/L.

- Background averages 0.0109 mg/L (total) and 0.0012 mg/L (dissolved) for Flathead (USGS data).
- Erickson Creek total copper data show <0.015 mg/L; groundwater below the refuse dump had total copper of 0.022 mg/L.
- The coal-refuse, soil paste extract had dissolved copper of 0.03 mg/L; this should be the worst case condition and will be diluted before leaving mine site.

5.3.2.8 Lead (dissolved) <0.050 mg/L.

- Background values from the Flathead River are 0.072 mg/L total, and 0.0047 and <0.0012 mg/L dissolved at two different sampling sites.

- Operating mine samples show <0.08 mg/L from Erickson Creek and 0.014 mg/L in groundwater below a coal refuse dump.
- Lead was not run by atomic absorption on leach and soil paste samples, nor was the value reported with inductively coupled argon plasma data. It is therefore presumed to have been below the plasma detection limit. Lead should co-precipitate with iron hydroxides at alkaline pH values.

5.3.2.9 Mercury (total) <0.0001 mg/L.

- Only USGS data show detection of mercury at or above 0.0001 mg/L and these data are not considered reliable.

5.3.2.10 Molybdenum (dissolved) <0.02 mg/L.

- The Erickson Creek total molybdenum samples were <0.04 mg/L.
- The coal-refuse, soil paste dissolved value was 0.02 mg/L.

5.3.2.11 Nickel (dissolved) <0.03 mg/L.

- Background values for the Flathead River at the border were 0.0031 mg/L for total and 0.0028 mg/L for dissolved nickel (USGS).
- Erickson Creek total nickel values are 0.027 and 0.028 mg/L.
- The coal-refuse, soil paste extract yielded a value of 0.01 mg/L for dissolved nickel.
- An upper value of 0.03 mg/L seems reasonable for this, if the background total/dissolved ratio holds for impacted areas.

5.3.2.12 Selenium (dissolved) <0.015 mg/L.

- Only background data are available. Crossplots of arsenic (As) versus selenium (Se) using these data give a weight ratio of As/Se of 2. That is the basis for calculating this value from the projected effluent As content.

5.3.2.13 Zinc (dissolved) <0.05 mg/L.

- Background Flathead averages are 0.027 (total) and 0.011 (dissolved) mg/L.
- Erickson Creek (total) values of <0.015 (groundwater) and 0.016 (surface water) mg/L.
- Coal-refuse, soil paste extract = 0.035 mg/L, dissolved.
- Zinc is probably the most common contaminant in water samples. It is also commonly the first metal to appear as a real contaminant from mechanical equipment (zinc and molybdenum are used as lubricants in many greases). Therefore, the maximum value (0.05 mg/L) for total effluent discharge has been increased slightly compared with other metals.

5.3.2.14 Total dissolved solids <1000 mg/L, average value 400 to 700 mg/L.

- Background values are about 135 mg/L.
- Erickson Creek surface water = 1150 mg/L (1 sample), groundwater = 745 mg/L (average of 3 values).
- Refuse soil paste was about 1200 mg/L; this is a worst case sample as it is the initial pore volume of leachate.

5.3.2.15 pH <9.0.

- The more basic range is increased by extrapolation of receiving water impacts. There are very few data to support an effluent value.

5.4 TOTAL SUSPENDED SOLIDS (TSS)

5.4.1 Adverse Operational Case

Projected impacts of TSS from the Sage Creek Coal Limited mine were based on four years of operational data from an existing mine on the Fording River in the Elk River basin. To quantify the comparison, basic assumptions had to be made and similarities in contaminated and receiving water drainage basins had to be identified.

Table 9 compares drainage areas of both the contaminated areas and entire receiving stream watersheds. It is evident that the Fording River drainage area above the existing mine is roughly equivalent to that of Howell Creek or Cabin Creek, and the Flathead River drainage area is an order of magnitude greater in size. The unit discharges (Table 10) are similar during peak and low-flow periods which occur in May/June and January/February, respectively.

Other assumptions which characterize the extent of the operational impact are as follows.

1. Existing data include contributions from fugitive dust which had accumulated through the winter in the snow pack.
2. Existing data include contributions from adjacent roads and bridges.
3. Existing data include construction activity as well as normal mining activity, but limited reclamation activity.
4. Existing data include impacts of some logging activity.

Table 11 shows the frequency of occurrences exceeding 10 mg/L total suspended solids concentration over background levels in the receiving water (this is the receiving water objective that Sage Creek Coal Limited would be required to meet). Table 11 data are based upon weekly grab samples collected during a four-month period around freshet, and monthly grab samples during the remainder of the year. This yields a total of approximately 25 samples per year. Of the 100 samples taken in the 4 years from 1981 to 1984, Table 11 shows 16 occurrences exceeding the 10 mg/L TSS concentration above background levels.

Flow data shown in this table should be used for relative flow comparisons only. Loading calculations from these flows and concentrations would not be representative of any time scale loading estimate for the proposed mine site. These samples are instantaneous measurements, and therefore cannot be used to calculate loadings. The Waste Management Branch MOE has requested that these samples be collected at the time of day believed to represent the peak diurnal discharge to evaluate whether the mine is meeting regulatory criteria.

If the frequency and magnitude in Table 11 are averaged and if these averages are assumed to apply directly to the proposed mine, 4 occurrences per year, each of 3 days duration, and with peak daily

Table 9. Comparison of drainage basins for Sage Creek Coal Limited and an existing operating mine in the Elk River basin and their receiving streams.[a,b]

	Drainage Area (km^2)
Fording River Station below Clode Cr. (08NK021)	104
Kilmarnock Cr. near mouth (08NK029)	43[c]
Flathead River at Flathead (08NP001)	1110
Howell Creek above Cabin Creek (08NP003)	145
Cabin Creek near mouth (08NP004)	93.2
Contaminated Drainage Sage Creek Coal Limited (includes clean water diversion drainage areas)	20.7
Contaminated Drainage from a mine on the Fording River (includes clean water diversion drainage areas)	27[d]

a Klohn Leonoff (1981a).
b Inland Waters Directorate (1983).
c This drainage has been partially impacted by a mine in the past four years and is considered in Table 11 results.
d Approximate.

Table 10. Unit discharges for selected streams, in $m^3/s/km^2$.

Month	Fording River (08NK021) 1971 to 1982 (b)	Howell Creek (08NP003) 1977 to 1982 (a)(b)	Flathead River (08NP001) 1929 to 1980 (a)(b)
January	.002	.004	.004
February	.002	.004	.004
March	.002	.004	.005
April	.010	.017	.022
May	.059	.072	.091
June	.078	.063	.080
July	.029	.027	.025
August	.015	.013	.010
September	.009	.009	.007
October	.006	.006	.009
November	.004	.005	.008
December	.003	.005	.007

[a] Klohn Leonoff (1981a)
[b] Inland Waters Directorate (1983)

Table 11. Total suspended solids concentrations greater than 10 mg/L increase above background, upstream and downstream of an operating coal mine (Fording River 1981 to 1984).[a]

Date	Flow[b] Station (08NK021) (m^3/s)	Upstream Station (mg/L)	Downstream Station (mg/L)
81.04.15	0.28	4	25
81.04.22	1.4	1	12
81.05.19	4.93	2	76
81.05.26	21.8	19	201
81.06.02	9.12	2	19
82.04.27	1.28	5	84
82.05.11	7.16	1	12
82.05.19	6.47	2	15
82.05.25	9.92	6	79
82.06.01	4.78	1	67
82.06.15	10.9	2	21
82.08.10	0.85	1	27
83.04.19	0.64	2	29
83.05.24	7.02	2	15
84.04.17	2.55	6	51
84.05.15	2.89	1	13
Average	--	3.6	46.6

[a] Fording Coal Limited (1985, 1984, 1983, 1982).
[b] Inland Waters Directorate (1983).

increases of 43 mg/L above background might be expected to occur in either Cabin or Howell Creeks (Table 12).

Table 12. Summary of adverse operational case impacts of total suspended solids on adjacent receiving streams on an annual basis.

Occurrences per Year	Time of Year	Peak Daily Duration of Occurrence[a] (days)	Location of Increase above Background (mg/L)	Impact and Probability (%)
4	April/May/June	3	43	Cabin (80) or Howell (20)
0.25	July to October	3	43	Cabin (80) or Howell (20)

[a] Occurrences are possible during flows below peak mean annual flow (MAF) (see Table 13).

This average of TSS concentrations from the comparison mine is believed to adequately represent the adverse operational case for TSS at the Sage Creek Coal Limited mine site for the following reasons.

1. The proportion of receiving water drainage that would be contaminated is 9% for the proposed mine and 18% for the comparison mine (Table 9).
2. The conceptual design of Sage Creek Coal Limited's mine allows for construction of interceptor collection ditches parallel to the receiving streams. The comparison mine does not have this feature. This factor would tend to reduce the area source contribution of TSS at the Sage Creek Coal Limited site, and thus reduce the expected loading to and concentration in the receiving stream.
3. Three of the four settling ponds at the proposed mine would discharge to the Flathead River; this would constitute roughly two-thirds of the contaminated surface water discharge.
4. Data from the comparison mine include measurement of the

effects of scouring after a river relocation (81.05.26 from Table 11) (McDonald 1982). No river relocations are planned at the Sage Creek Coal Limited site. It would be erroneous, therefore, to apply this as a peak value to Howell or Cabin Creeks, although it was used in the average in Table 11.

Each factor mentioned above would tend to result in the overstatement of the impact of the proposed mine on Howell and Cabin Creeks if individual readings or peaks from the comparison mine data (Table 11) were used. In addition, the MDC believes that, because of these factors, the estimated receiving water concentrations of TSS resulting from the proposed mine sufficiently overstate the mine impacts to account for any shortcomings resulting from the use of weekly grab samples during freshet rather than daily depth-integrated cross-sectional samples.

Therefore, the MDC decided that an average of TSS values (Table 11) from the comparison mine would best represent the adverse case for the Sage Creek Coal Limited site. The four occurrences (Table 12) would all be predicted to occur during freshet (April, May, June). Based on this data set, it is also expected that a heavy rainfall event capable of producing a secondary flow peak similar to the mean annual flow (MAF) peak could occur later in the summer. One additional occurrence every 4 years with an increase above background of 43 mg/L occurring between July and October would seem reasonable to account for such an event based on rainfall intensity in this area of the Flathead (Klohn Leonoff 1981a).

Using 43 mg/L TSS on either Cabin or Howell Creeks (Table 12) yields adverse case estimates of 20 mg/L and 4 mg/L increases above background on Howell Creek below Cabin Creek and the Flathead River downstream of Howell Creek, respectively. These concentrations are based on the dilution capabilities of the receiving streams at these points. Except for the adverse events identified, TSS increases due to the mine for the remainder of the year should not exceed 10 mg/L above background and would frequently be much lower than 10 mg/L above background in any reach of Cabin or Howell Creeks and the Flathead River. Impacts from Settling Ponds 3 and 4 which discharge to the Flathead River above Howell Creek would not be detectable, considering the relative flows from these ponds compared to that of the Flathead River (Table 13).

Table 13. Flood flow estimates for discharge and receiving waters.

Measurement Point	Low Flow (m^3/s)	Q_1[a] (m^3/s)	Q_{10}[a] (m^3/s)	Q_{50}[a] (m^3/s)	Drainage Area[d] (km^2)
Sedimentation Ponds:					
1. Sediment Pond - to Flathead	no significant surface discharge flow	1.7	3.1	4.7	9.7
2. Sediment Pond - to Cabin Creek	"	1.7	3.1	4.7	9.6
3. Sediment Pond - to Flathead	"	0.1	0.3	0.5	0.7
4. Sediment Pond - to Flathead	"	0.1	0.3	0.5	0.7
Diversion Ditches:					
D_1 - to Howell Creek	no significant surface discharge flow	0.4	0.9	1.4	2.3
D_2 - to Cabin Creek	"	0.3	0.6	1.0	1.5
D_3 - to Cabin Creek	"	0.4	0.7	1.2	1.9
D_4 - to Couldrey Creek	"	0.2	0.4	0.7	1.0
Receiving Water Stations:					
Howell Cr. Stn. 08NP003	0.5[c]	21	34	47	145
Cabin Cr. Stn. 08NP004	0.4[c]	14	23	32	93.2
Flathead R. Stn. 08NP001	5.0[c]	137	309[b]	387[b]	1110

[a] Hydrocan Engineering Continental Ltd. (1983).

$Q_1 = 0.22\ A^{0.92}$
$Q_{10} = 0.41\ A^{0.89}$
$Q_{50} = 0.68\ A^{0.85}$

where A = drainage area in (km^2)
Q = maximum annual mean daily discharge for the return period specified in m^3/s

The flood estimates given above consider a combined rainfall/snowmelt occurring during freshet - usually in May or June. The reference document uses a regional flood frequency analysis with a regression method. The frequency curves are fitted using a three-parameter, log-normal distribution.

[b] Based on actual data points fitted using three-parameter, log-normal distribution, not the averaged power equation derived from it as is used above.

[c] Low flow estimates for receiving streams based on an average monthly for the period of record (Inland Waters Directorate 1983).

[d] Klohn Leonoff (1981a).

The adverse operational scenario in Table 12 would apply to the construction phase and mining phase periods, but not to the reclamation phase (see assumption 3 above in this subsection). Regarding the impacts during the reclamation phase, there are virtually no available data from the Elk River valley. This is due to the very limited occurrence to date of this phase of coal mining operations.

Nevertheless, it would be expected that the adverse operational case for the reclamation phase would show reduced impacts compared to those for the mining phase (i.e., TSS concentrations would decrease over time compared to the mining phase). This judgement is based upon the assumptions that: disturbing activity at the end of mine life would be eliminated; disturbed lands would be partially reclaimed; and continual maintenance of control facilities would be required until water quality objectives could be consistently met without them as a result of acceptable reclamation practice.

5.4.2 Optimal Operational Case

For the optimal operational case it is expected that the receiving water impacts for TSS would be less than or equal to a 10 mg/L increase above background. Based on improved sediment control practices in the Elk River valley, it is expected that the proposed Sage Creek Coal Limited operation would exhibit a reduction in both the concentration and number of cases where TSS exceeds the receiving water objective of a 10 mg/L increase above background (Table 11). Assuming the proposed mine would be developed using these improved sediment control practices, it is logical to assume that the 10 mg/L receiving water objective would not be exceeded. This concentration limit would apply to either Cabin or Howell Creeks immediately above their confluence.

For calculation purposes it was assumed that approximately 70% of the TSS contributions to receiving waters (Cabin and Howell Creeks) would come from controlled point source discharges (settling ponds) and 30% would come from uncontrolled sources. This allocation was used only to assess relative contributions to total concentration in order to evaluate the likelihood of reaching a 10 mg/L increase in TSS above background concentrations. Estimated discharges from controlled sources are shown in Table 13.

The ratios of the maximum mean annual 24-hour flow for the receiving stream to the maximum mean annual 24-hour flow for controlled discharges (Table 13) were used to evaluate the likelihood of TSS concentration increasing to 10 mg/L above background. It is concluded that the 10 mg/L objective could be reached on Cabin Creek. In contrast, however, since the only direct discharge to Howell Creek above the confluence with Cabin Creek is uncontaminated water Diversion Ditch D1, effluent TSS concentrations 9 times greater than those for Cabin Creek would be required to attain a 10 mg/L increase in Howell Creek. Since there is a low probability of this occurring, any increase above background in Howell Creek would likely be negligible. In summary, during freshet TSS concentrations should not exceed 10 mg/L above background in Cabin Creek. TSS concentrations at other times of the year on Cabin Creek as well as TSS concentrations in Howell Creek at all times of the year should frequently be much lower than 10 mg/L above background for the optimal case.

Below the confluence of Howell and Cabin Creeks the TSS increase above background would be expected to be less than 5 mg/L. Dilution is so great for controlled sources discharging to the Flathead River that any increase above background TSS concentrations in the Flathead River would be negligible. These contributions of TSS to receiving waters would be greatest during the freshet when approximately 50% of runoff occurs. Additional contributions may occur during the fall in response to storm runoff.

Uncontrolled sources of TSS such as dustfall, dust particles contributed from snow melt and precipitation runoff, and runoff from a disturbed area which was not routed through a control structure, are assumed by the MDC to be included in any of the above TSS estimates. These sources of sediment are included in the 30% allocation of TSS concentrations attributed to uncontrolled sources (see above).

Increases in TSS for the optimal operational case are expected to be greatest for the mining phase. Facilities for surface water control should be among the first to be constructed and therefore disturbance would be minimal over a short duration prior to completion of the control structures. For the reclamation phase, TSS contributions would be likely to decrease slowly from the concentrations estimated here. Control structures would be maintained until runoff into the ponds meets the objectives. It is expected that after this time TSS contribution would continue to decrease as reclamation matures. Therefore, no other estimates of TSS were made for the construction and reclamation phases of the operation.

5.4.3 Particle Size

Under operating conditions, experience indicates that the efficiency of settling ponds may vary from that under ideal conditions. Under such conditions, settling ponds may capture particles of a minimum size in the estimated range of 0.02 to 0.05 mm (7.9×10^{-4} to 2.0×10^{-3} in). Therefore, the particle size of the majority of the suspended solids contained in the settling pond effluent should be less than .01 to .05 mm (4.0×10^{-4} to 2.0×10^{-3} in) during normal decant operations.

Site-specific particle size information is not available for the Sage Creek Coal Limited mine site. The limited information available does not include grain size distribution for particles less than 0.1 mm (4.0×10^{-3} in). Grain size distributions of grab samples from creek beds leading from coal mining operations (Klohn Leonoff 1981a) may be the best source of information for uncontrolled sources. Grain size distribution data from settling pond effluent are not available and would likely be very site-specific. The use of flocculents when necessary would also increase the average particle size present in settling pond effluent. Accurate predictions of particle size of suspended solids in effluent cannot be made at this time due to uncertainties relating to final pond design, influent particle size, and potential use of flocculents.

5.5 WATER QUALITY ASPECTS NOT COVERED ABOVE

5.5.1 Additional Parameters

Average adverse case effluent concentrations for these parameters are roughly estimated to be: sodium, <25 mg/L; potassium, <10 mg/L; calcium, <100 mg/L; magnesium, <60 mg/L; alkalinity,

<350 mg/L as calcium carbonate; hardness, <480 mg/L as calcium carbonate; and chloride, <25 mg/L. The effluent waters from the mine site would likely be similar to the Flathead groundwater samples (Appendix 5) with the concentration of most constituents roughly doubled. Alkalinity would not normally double due to the more than two-fold increase in chloride, nitrate, and sulfate concentrations.

5.5.2 Polyaromatic Hydrocarbons

The members of the MDC were unable to locate any data relating to polyaromatic hydrocarbons. However, the available data concerning total organic carbon (TOC) are discussed below.

5.5.3 Total Organic Carbon

- Background data (36 samples at the International Boundary) give an average value of 3.9 mg/L and a maximum value of 11 mg/L.
- The only Erickson Creek (in the Elk River valley) surface water value is 19 mg/L.
- A few analyses of total organic carbon (TOC) and dissolved organic carbon (DOC) are available. Surface water discharges from the Eagle Settling Pond effluent to the Fording River in June, July, and August of 1975 contained 17, 10, and 3 mg/L TOC. Content of TOC is often a function of well construction, development history, and pumping stress at the time of sampling and should not be used for groundwater loadings. Dissolved organic carbon in three groundwater samples below the Erickson Creek dam ranged from 2.5 to 3.0 mg/L.
- A reasonable estimate of average receiving water concentration is considered to be 10 to 15 mg/L during May and June. For the period July through April, an average value of 8 to 10 mg/L appears reasonable, although it could be considerably lower. A maximum value during an "event" should probably not exceed 50 mg/L.

6. NON-QUANTIFIABLE ASPECTS

6.1 EXTREME OR UNUSUAL EVENT

A quantitative assessment of the impacts resulting from an extreme event has not been attempted.

6.1.1 Earthquakes

An assessment of the earthquake potential for the mine site area was made in the Stage II Assessment and Tailings Pond Design Report (Klohn Leonoff 1981b). The 200-year return seismic event was estimated to be 4% of gravity. Analysis of Montana seismicity data presented by Qamar and Stickeny (1983) supports this estimate. Ponds, buildings, ditches, and other structures should be stable during such an event. Therefore, significant increases in effluent concentrations of contaminants are not expected to occur as a result of such seismic events.

6.1.2 Floods

For surface water runoff, the extreme event assumed for this discussion would be a 50-year return flood flow. A flood flow of this magnitude could decrease retention times in sedimentation ponds or cause short circuiting of control structures. Debris could limit peak flows from discharge structures, or could cause a breach of a diversion ditch. Nevertheless, all settling ponds would contain two outflow structures: the normal decant to handle flows up to the 50-year flood, and a free crest spillway capable of passing the peak flow from a 200-year flood. Therefore, direct impacts to control structures from a 50-year flood would not be expected to be severe.

Such an event could increase TSS contributions to the receiving waters, but other parameters would likely not be increased significantly due to dilution associated with the increased runoff.

The probability of a given return period flood or greater event occurring within a specific time period (mine project life) can be estimated using the formula $p = 1 - (1-1/T)^n$, where T is the return period of the event, and n is the period of observation or project life (Barfield et al. 1981). Using this equation, the probabilities of flood flow events occurring which equal or exceed various return frequencies during 25-year and 35-year periods were estimated. Active project life of 25 years was estimated by summing the pre-mining construction period (2 years), the mine phase (21 years), and an assumed (but as yet unspecified by the company) period of 2 years after mining to complete reclamation activity. The 35-year period was derived by summing the active project life and an additional 10 years into reclamation. The results are presented in Table 14.

Table 14. Probability of occurrence of floods equal to or greater than floods of given magnitudes during indicated periods.

	Probability of Occurrence Time Span	
Flood Frequency	25 years	35 years
50-year	40%	51%
100-year	22%	30%
200-year	12%	16%
500-year	5%	7%

These estimates indicate that there is a 40% probability of occurrence for a flood flow that would equal or exceed the capacity of the normal pond decant design (50-year), resulting in flow from the emergency spillway during the active project life (25 years). The probability of a flood flow equalling or exceeding the design capacity of the emergency spillway is 12% during the active project life. These probabilities increase as shown in Table 14 when the project life is increased to 35 years.

These probabilities are based on average return frequencies of flood events and can be used to evaluate the confidence of the design of a structure. These probabilities should not be interpreted as absolute certainties. For example, a 50-year flood occurs an average of once every 50 years. However, in a specific 50-year time period a 50-year or greater flood could occur more than once or not occur at all. The average frequency of occurrence over an extended time period, however, would be 50 years and probabilities were estimated using this average.

6.1.3 Accidents

Contributions of various contaminants to receiving water could occur from accidents, such as chemical spills. Such events have been accounted for to some extent, in making quantitative estimates in Section 5. Subsections 2.7.4, 2.7.5, 2.7.6 and 4.4.2 deal with chemical use and potential spillage.

6.2 DUSTFALL

It may be helpful to note some general considerations with respect to fugitive dust and dustfall. Fugitive dust generation is caused by two basic physical phenomena:

1. pulverization and abrasion of surface materials by application of mechanical force through implements (wheels, blades, etc.); and
2. entrainment of dust particles by the action of turbulent air currents, such as wind erosion of exposed surface by wind speeds over 19 km/h (12 mi/h) (U.S. Environmental Protection Agency 1983).

The particle size of the material being handled or disturbed greatly influences the amount of fugitive dust generated. Fine-grained or silty material will become airborne much more easily than coarser material. Further, it is generally the heavier or coarser material which quickly settles out as dustfall quite near the source.

Wind speed and direction also significantly influence both the amount of fugitive dust generated and the extent of area impacted.

Surface moisture is another important consideration with respect to dust control. The source of such moisture may be natural precipitation or purposeful application by the operator.

Generation of dust at the Sage Creek Coal Limited mine site would occur during the construction and mining phases. During the mining phase, the major sources of particulate emissions would be: the general mining activities (overburden and coal removal and mine haul roads), the thermal coal dryer, the haul road to Morrissey, and wind erosion of disturbed areas and coal stockpiles. These are all fugitive dust sources with the exception of the coal dryer.

Concern for dust generation as it relates to water quality is associated with direct fallout of dust particles on Cabin and Howell Creeks, the Flathead River, and other tributaries along the haul road. It is also related to fallout on the adjacent terrain outside of sediment control structures; such dust then has the potential to wash into adjacent streams during snowmelt and precipitation events.

The Pollution Control Objectives for the Mining, Smelting, and Related Industries of British Columbia (B.C. Ministry of Environment, Pollution Control Board 1979) include objectives for dustfall (1.7 to 2.9 $mg/dm^2/d$) (14.6 to 24.8 $tons/mi^2/mo$). The company estimated dustfall from the mine operation and haul road to Morrissey to be 1.0 and 2.2 $mg/dm^2/d$ (8.56 and 18.8 $tons/mi^2/mo$), respectively (B.C. Research and Norecol 1982).

Using these estimates, objectives for dustfall, and actual dustfall data from operations in the Elk River valley and Montana, the MDC attempted to estimate quantities of sediment from uncontrolled dustfall entering receiving streams. However, the calculations required values for certain variables such as the surface area of the receiving streams over a given length of stream for a given discharge rate, and the sediment delivery efficiency of terrain adjacent to receiving waters. Also required were various assumptions regarding the radius from the source over which the fallout rate would remain constant. Since such variables or assumptions could not be quantified with any degree of certainty, a separate quantitative estimate of sediment loading of receiving waters from uncontrolled dustfall is not presented.

Alternatively, the MDC feels that a more realistic approach regarding the contribution of dustfall to TSS is to be found in the estimates of TSS impacts presented in Subsection 5.4. These estimates provide an integrated examination of the sediment from both controlled and uncontrolled sources which would include dustfall. Thus, while the numbers do not permit a sorting out of contributions from various sources, they inherently include dustfall for both the optimal and adverse operational cases.

6.3 STREAM GEOMORPHOLOGY

The highest potential for direct effects on stream geomorphology would occur at locations of channel or floodplain encroachment. Such locations would include bridge crossings of Cabin and Howell Creeks at the mine site, and culvert and bridge installation sites along the transmission line and Morrissey haul roads. The eastern approach to the Howell Creek bridge accessing Waste Dump E would include a culvert in a backwater channel of Howell Creek. In addition, several other features of the mine encroach on the Howell Creek floodplain. These include the southern end of Waste Dump E, Pond 4, the southeastern corner of Pond 2, and some of the contaminated water ditches on each side of Howell Creek near the proposed bridge to Waste Dump E (Appendix 3.3.2-2, B.C. Research and Norecol 1982).

Finally, Howell Creek bank stability measures have been proposed above and below the upper Howell Creek bridge to prevent the creek from either migrating into or encroaching on these mine facilities (see Subsection 4.2.5). This reach of Howell Creek is braided and there is evidence for major historical channel shifting (Appendix 3.3.2-2, B.C. Research and Norecol 1982). Thus, encroachment into or changes in the floodplain, banks, or active channel could potentially cause changes in channel pattern, stream flows, channel gradient, and erosion and/or sedimentation in the stream. The deflection or "narrowing" effect of the proposed facilities and bank stabilization measures could potentially alter erosion/deposition patterns and cause a shift in pools and riffles. Further, the adjacent ditches, ponds, and waste dump could become direct sources of contamination if stream encroachment occurred during flood flows.

Quantification of such possible effects was not deemed feasible due to the complexity of the situation and the range of variables involved. Noteworthy is the fact that a 1 km (0.6 mi) reach of the Fording River, which is adjacent to the existing mine selected for TSS comparison purposes, was permanently relocated in 1977. It is not known whether, or to what extent, any effects of this relocation are reflected by the Fording River TSS data presented in Table 11, with the exception of one value in 1981 (see discussion in Subsection 5.4.1).

6.4 ADDITIONAL CONSTRUCTION PHASE CONSIDERATIONS

6.4.1 Morrissey Haul Road and the Transmission Line

Quantification of impacts during construction of these facilities would be exceedingly unreliable using a direct approach to disturbance. This is due to the myriad of site variables and design factors for which little information is available.

There are various locations along the transmission line and haul road where the impacts could be greater than the overall average. These include stream crossings and other locations where these facilities and associated disturbances, such as borrow pits, are in close proximity to the streams during construction. The seasonal timing of disturbance and construction activity and the degree of streambed disturbance would be especially critical for all of these sites.

During operation of the haul road, the potential for sedimentation to streams would be expected to decline compared to the construction phase under the following assumed conditions: the haul road would be paved (see Subsection 4.2.4); disturbed slopes and ditches would be successfully revegetated and stabilized; drainage from the road would be properly managed; and minimal spillage or loss of coal from the trucks would ensue during transit because the haul trucks would be covered (Stage II EA). If any of these conditions are not met, the potential for sedimentation would be greater than it otherwise would be during operation of the haul road.

6.4.2 Mine Site

It is assumed that all sediment control facilities proposed for the mine site during construction would be installed prior to most other disturbance (except for logging which is discussed in 4.2.8.1 and 6.5). Nevertheless, some disturbance such as access road building, bridge construction, and land clearing for the ditches and ponds themselves would occur without having facilities for sediment control. The sequencing and timing of such activities, therefore, becomes critical regarding the potential for episodes of serious sedimentation. This may be especially true for those facilities that would be in close proximity to Cabin Creek or Howell Creek.

6.5 LOGGING

The relationship between forests and water is very complex depending on the type of forest, precipitation, geology, topography, and soils. Forests intercept precipitation and evaporate some back into the air; they consume large amounts of water, and with root systems stabilize soil and promote infiltration. Duff and humus on the forest floor dissipate the rainfall, minimizing overland flow and reducing erosion. The shading effect retards snowmelt and reduces flood peaks.

Forest removal directly affects the hydrological cycle, creating the potential for a variety of impacts as follows (Toews and Brownlee 1981, pp. 47 to 49):

- increased peak flows cause abnormal bedload movements, shifting and displacing stream gravels used by spawning fish;
- debris can create physical obstructions and cause scouring of stream beds;
- increased flow, coupled with land disturbance during construction and mining, results in increased erosion and suspended sediment and nutrient loading to streams;
- physical damage to the streams can be caused by logging and road building equipment; and
- removal of riparian vegetation can result in excessive water temperatures from reduced shading as well as reduced biological substrate.

A variety of studies have been done which have documented these effects, but little quantitative information exists (Toews and Brownlee 1981, p. 48). However, it is known that much can be done in the way of forestry management practices to avoid or reduce these impacts.

Some studies on the effects of logging have been done near the Sage Creek Coal Limited project area. Smith et al. (1985) did a short-term study of the Akamina-Kishinena watershed. In this case no logging-induced water quality deterioration was apparent from the limited data collected. It was concluded that proper management practices during logging were probably responsible, but that the literature indicates a several-year lag phase between logging and some of the impacts. This study would not have been long enough to identify such impacts.

Schultz (1984) conducted an eight-year study of logged and unlogged drainage basins in the Stillwater and Swan River State Forests, located in the southern portion of the U.S. Flathead Basin. He found that the water quality was acceptable for fisheries in terms of total suspended solids except during flood stage. Logging in the upper portions of the Stillwater watershed did not directly affect nutrient concentrations in a downstream lake. The direct impacts attributable to logging could not be ascertained by the MDC using Schultz's (1984) conclusions because of the different geologic characteristics of the drainage basins, the lack of detailed information on the logging activities, and the pre-logging hydrologic characteristics of the drainages.

Additional effort was made by the MDC to find watershed research in the literature that could be used to quantitatively estimate nutrient and sediment effects of logging at the proposed mine site. The MDC felt that any such research should include a study area that is similar to that of the proposed mine site area in terms of vegetation type and density, as well as geology, soils, land forms, climate, and hydrology. In addition, such a study should be characterized by water quality sampling at least on a weekly or bi-weekly basis and streamflow measurements at least on a bi-weekly or monthly basis. During the freshet period, daily sampling and analysis of water quantity/quality should have been done. The area studied must have had such samples taken both before and after logging for a reasonable length of time, such as a year before and after. Finally, the logging practices, which can be quite variable (and therefore have variable effects from one site to another), should be similar to those to be employed at the proposed mine site, but at least must have been documented.

It was not possible to find a study of this nature in the literature. Thus the following two logging scenarios are discussed, but in a general, qualitative sense.

In the optimal operational case it is assumed that ideal logging practices would not be employed in that the area would have to be clear-cut rather than selectively logged. However, the MDC has also assumed that stream buffer strips would be left, there would be avoidance of machines working in streams, and proper road building practices would be employed. The stream buffer strips would include the 90-m (295-ft) buffer strip requirement placed upon Sage Creek Coal Limited (Section 1.6.1.2). Further, some mine diversion and containment ditches and corresponding ponds for the North and South Hill areas would be constructed prior to logging to divert and treat sediment-laden runoff. Such practices would be expected to significantly reduce adverse impacts.

The adverse operational scenario would be essentially the same as above, except that the diversion ditches and settling ponds would be constructed after logging and during the remaining construction period. The result of this would probably be a substantially increased potential for suspended sediment and nutrient loading to the streams in the period of time between logging and construction of the water and sediment control system.

6.6 STABILITY OF CERTAIN MINE SITE FEATURES

6.6.1 Historical Stability of Mine Waste Dumps, Tailings Ponds and Settling Ponds in the Elk Valley

As indicated in Subsection 1.5, since 1970 substantial improvements have been made at these mines in all aspects of open-pit coal mining. However, stability of waste dumps, settling ponds, and tailings ponds are a concern and with this in mind a summary of the Elk Valley mines is as follows.

- The mines in this area (see Subsection 1.5 for location) are generally at the top of a mountain or at high elevation which necessitates the initial end-dumping of waste material on the upper portions of steep slopes, creating dump slope lengths in excess of 400 m (1312 ft). Coarse rock falls to the bottom of the dump and allows the drainage necessary at the base. In the initial phase of its formation the dump has a stability safety factor of 1.1 or greater if the ground slope is flat and the base material contains appreciable amounts of water. The safety factor is defined as the force resisting movement divided by the force required for movement. As the mining proceeds to lower elevations, wrap-around dumps are established. As the wrap-around dumps proceed downward, the factor of safety increases. This also allows final resloping to 26 to 28° for reclamation, as described in Subsection 6.6.2 below.

- Proper water control impoundments are normally required downstream prior to commencement of any dumping. Ditches and ponds are required for all dumps according to site-specific needs. Settling ponds are located so that dump failures would not affect them.
- Prior to 1975, there was little engineering and waste dump management in the Elk Valley area. In the past ten years there have been substantial improvements in waste dump management. All dumps are monitored both for safety of workers and machines and to control failures.

There have been a number of major dump failures in the coal mines of the Elk Valley area. Some of these failures occurred prior to 1977 and little or no information concerning them is available. Nine major dump failures were considered to have the potential for environmental impact or to affect safety of workers and property. These are described below.

Two failures occurred on one dump 400 m (1312 ft) in height, causing a material movement of 500,000 to 600,000 bcm (6.54×10^5 to 7.85×10^5 bcyd). These were both type 3 failures (dump-face failure due to rapid loss of support at toe [see Subsection 6.6.2]). In these cases, the mud and fines flowed out from the toe of the dump to distances of 515 m and 550 m (1690 and 1804 ft), respectively. Their cause was considered to be dumping on a base with a slope of 31°, and overloading the dump crest.

There were three waste dump failures in the early 1970's at one mining operation that involved movement of 1,000,000 bcm (1.3×10^6 bcyd) of material over distances of up to 600 m (1969 ft) from the toe. The heights of the dumps were over 500 m (1640 ft). The waste material from these failures flowed into a valley which was planned eventually to be the site of a valley fill (valley to be filled with waste rock). Two settling ponds had been built, one at each end of the valley, and these controlled sedimentation resulting from the failures. A combination of causes of failure was described by the company, including overloading the crest of the dump and a partial base failure.

Another type 3 failure occurred at a mining operation which involved a dump 280 m (919 ft) in height. Material from this dump flowed into an area which was planned as the site of a valley fill. The failure involved about 300,000 bcm (3.95×10^5 bcyd) of material which ran onto the other side of a narrow valley and resulted in a mud flow 400 m (1312 ft) down the valley. Sedimentation there is controlled by a rock drain and settling ponds.

Type 4 failures (massive downslope movement due to sliding on the bases [see Subsection 6.6.2]) occurred at two mining operations. One failure involved 150,000 bcm (1.98×10^5 bcyd) of material with a runout of 200 m (656 ft). The dump was constructed on soft saturated soil that should have been excavated prior to dumping. The other failure involved about 200,000 bcm (1.32×10^5 bcyd) of waste with a runout of 200 m (656 ft). Material had been dumped on old coal waste material which lay over saturated soil. The majority of the mud flow was diverted down a drainage channel and some of the coarser material approached the edge of the stream. Sedimentation to the nearby stream was visually observed to be minimal and lasted less than 24 hours. No samples were taken for TSS analysis.

Another minor dump failure in terms of volume of material occurred where a mud flow consisting of a combination of water and fine material flowed down an existing creek. The volume of material had built up gradually and suddenly was released, flowing down to the Elk River with some material going into the river. Sedimentation was observed to last less than 24 hours but no water samples were collected.

Dump failure has been a continuing problem but is now controlled by berms. In addition, adjacent settling ponds function as primary settling structures with subsequent drainage of effluent to major settling ponds at a lower elevation.

There have been no failures of tailings ponds to date at any mines in the Elk Valley.

There has been only one case (involving two ponds) of settling pond failure in the Elk Valley; this occurred in May of 1986. A report on the 1986 failures and their implications for the proposed Sage Creek Coal Limited project is given in Appendix 7.

6.6.2 Waste Dump Stability at the Proposed Sage Creek Coal Limited Project

The waste dumps at the proposed operation would be developed by end-dumping. They would be developed outwards in a series of level benches generally 30 to 35 m (100 to 115 ft) apart in elevation. Due to steep topography in some areas, the maximum single lift elevation difference from crest to toe would be approximately 120 m (400 ft). End-dumping in this manner would result in significant size segregation of material from the crest to the toe of the dump. Large diameter material would accumulate at the bottom of the dump lift while the finer materials would remain near the crest. This size segregation would promote drainage of water through the base of the dump. This would prevent the buildup of high pore water pressure within the dump and therefore would enhance stability of the dumps.

Waste dumps constructed in this manner are subject to four types of failure (Golder Associates 1981). These are discussed below.

Type 1: Sliver failure near the dump crest.

Type 2: Slumping of the dump face due to yielding at the toe.

Type 3: Failure on the dump face as a result of a rapid loss of support at the toe.

Type 4: Massive downslope movement as a result of sliding on the base.

Type 1 and, less commonly, Type 2 failures can occur irrespective of the slope of the foundation on which the dump is constructed. Type 3 and 4 failures are governed by both the slope of the foundation area of the dump and the shear strength of surficial materials below the dump.

A Type 1 (sliver) failure occurs as a result of oversteepening of the dump face near the crest. The presence of fine materials near the crest contributes added cohesion which allows the face below the crest to stand at an angle greater than the angle of repose. As the size of this area increases, the weight of the materials overcomes the shear resistance and failure occurs. The material moves down the face of the slope and comes to rest near the toe of the dump. This type of failure is not likely to pose a threat to water quality as the materials are distributed along the face and at the toe of the dump; this assumes that the rate of dumping is controlled and the slope is not too steep. Therefore, materials from this type of failure would not be expected to reach the creeks at the proposed Sage Creek Coal Limited mine site.

A Type 2 failure results from yielding of soft soil foundation materials near the toe of the dump. These weak foundation materials yield to stresses from the dump, resulting in displacement of the soft soil, yielding of the dump toe, and subsequent slumpage of the dump face. Displaced materials remain near the toe of the dump and, as such, this type of failure does not pose much of a threat to water quality. This type of failure is shown in Figure 12.

A Type 3 failure occurs when a steeply sloping foundation is combined with surficial foundation materials with a shear strength less than that of the waste rock. A failure occurs near the toe of the dump (mass 1, Figure 13). This failure results in a rapid reduction of lateral support of the dump material above (mass 2, Figure 13). This latter material then fails, accelerates, and attains a high velocity. Materials from this type of failure can travel suprisingly long distances from the toe of the dump and could pose a threat to water quality at the proposed mine site.

The vertical angle from the horizontal surface of the dump at the crest to the farthest point of travel of waste materials is known as the Fahrboschung. Empirical data for the Fahrboschung are shown in Figure 14. The minimum Fahrboschung from the empirical data is 11°. Given this minimum angle and the topography of the proposed mine's waste dump areas, if any slides of this type occur, they could travel a few thousand metres from the dump crest (see Figure 14).

A Type 4 failure is an en masse failure. This type of failure occurs as a result of sliding on the base of the dump when the weight of the dump overcomes the frictional resistance to sliding. This type of

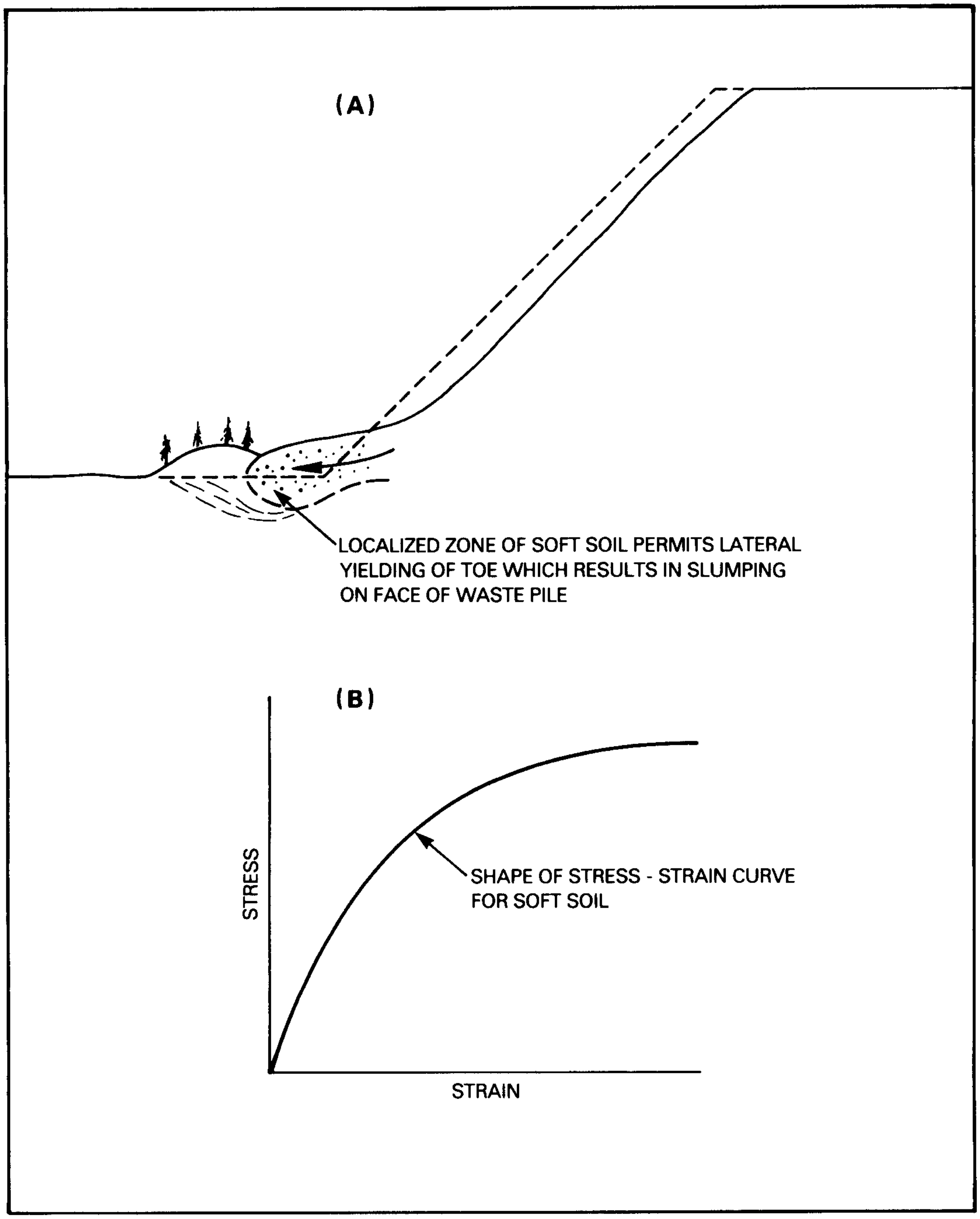

Figure 12. Type 2 failure - slumping on face due to lateral yielding at the toe.

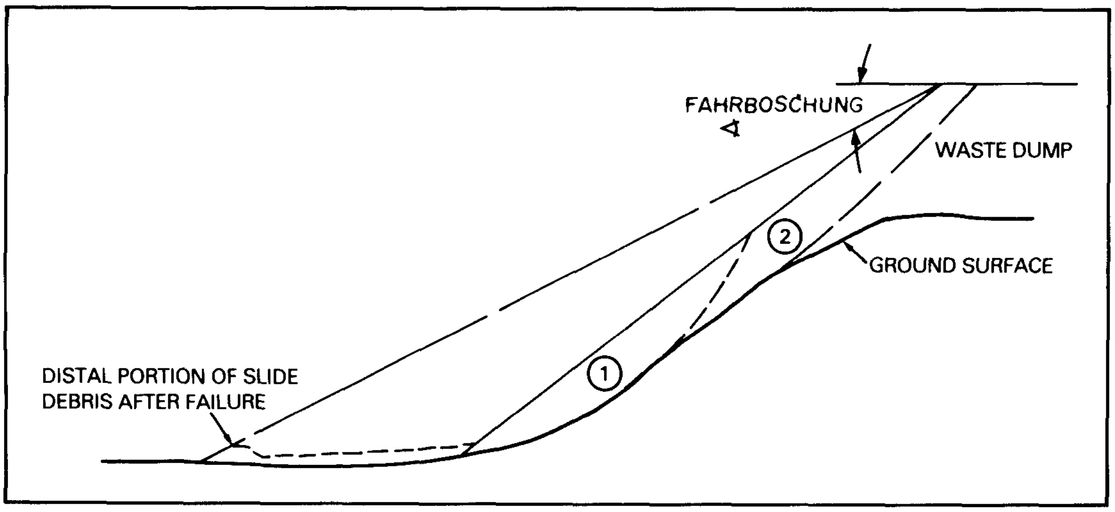

Figure 13. Type 3 failure.

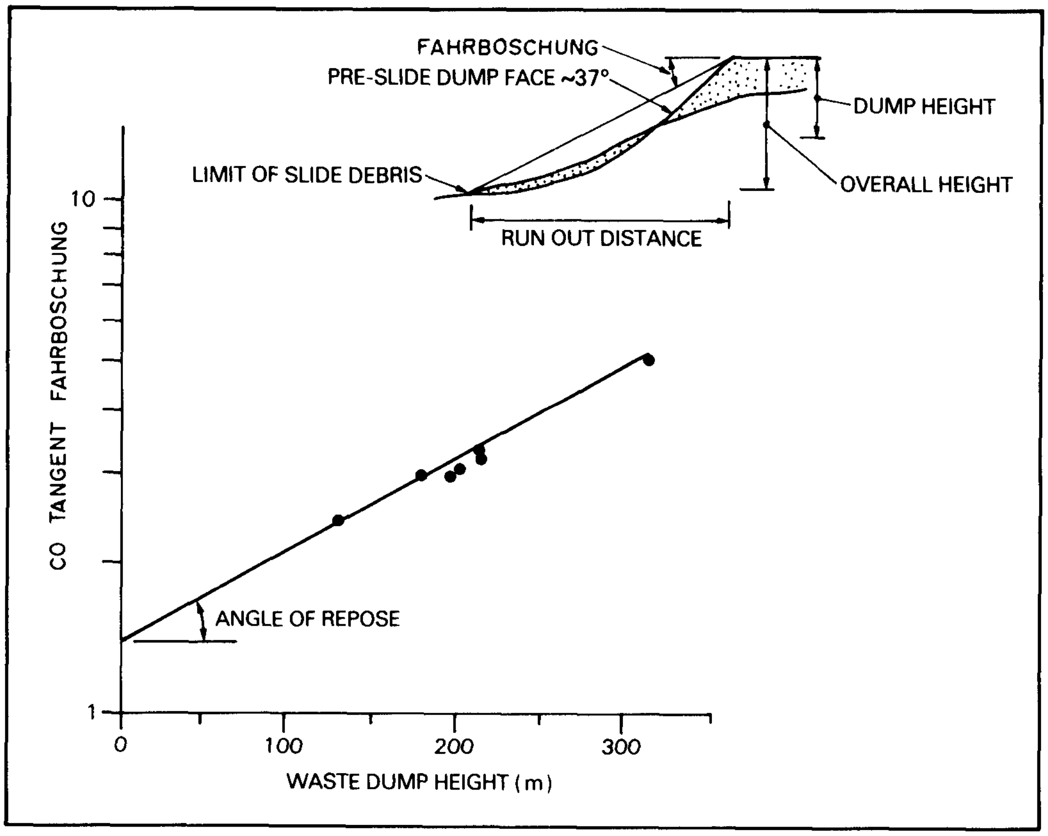

Figure 14. Type 3 failure illustrating Fahrboschung.

failure is the most severe. Golder Associates (1981) conducted stability analyses of the proposed mine's waste dumps for en masse failures. Results of these analyses are summarized below.

Location of a waste dump also determines its potential for impacting water quality. Proposed waste dump locations, cross-section locations for stability analysis, test pit locations, and relationship to other facilities at the proposed mine are shown on Figure 15. Dumps D and E would be adjacent to Howell Creek. Relatively long lengths of Dumps B and C, as well as a small portion of Dump A, would be adjacent to Cabin Creek. Waste Dump F would be a small dump between the creeks but located several hundred metres from them.

Waste Dump D would be located with over 1 km (3300 ft) of its length adjacent to Howell Creek. The dump would consist of 8 benches at 30 to 35 m (100 to 115 ft) elevation intervals. The dump would be constructed in two stages. The maximum elevation difference of the entire dump would be 290 m (951 ft). Slopes of the foundation would vary from nearly flat to 30° in the upper reaches. Bedrock would make up the foundation materials for the upper reaches of the dump, while glacial till would be the foundation material for the lower reaches. The bedrock materials are covered with a thin layer of colluvium. Stability analyses associated with dump development are shown in Figure 16. The minimum factor of safety is 1.4. This dump would be considered stable with respect to mass movement.

Waste Dump E would be located adjacent to the east side of Howell Creek. The dump would be on nearly flat flood plain gravels. These gravels would be considered a competent foundation. The dump would be developed in two stages, reaching a maximum elevation difference of 68 m (223 ft). This dump was considered inherently stable (Golder Associates 1981) with respect to mass movement, and therefore, stability analyses were not conducted. The extreme southeast corner of the waste dump would be located within the 200-year flood level. This corner of the dump is proposed to be rip-rapped with coarse sandstone for erosion protection.

Waste Dump C would be developed in three stages and would be adjacent to Cabin Creek. The first stage would be a bench with a crest elevation of 1640 m (5381 ft) and a toe elevation of 1540 m (5052 ft).

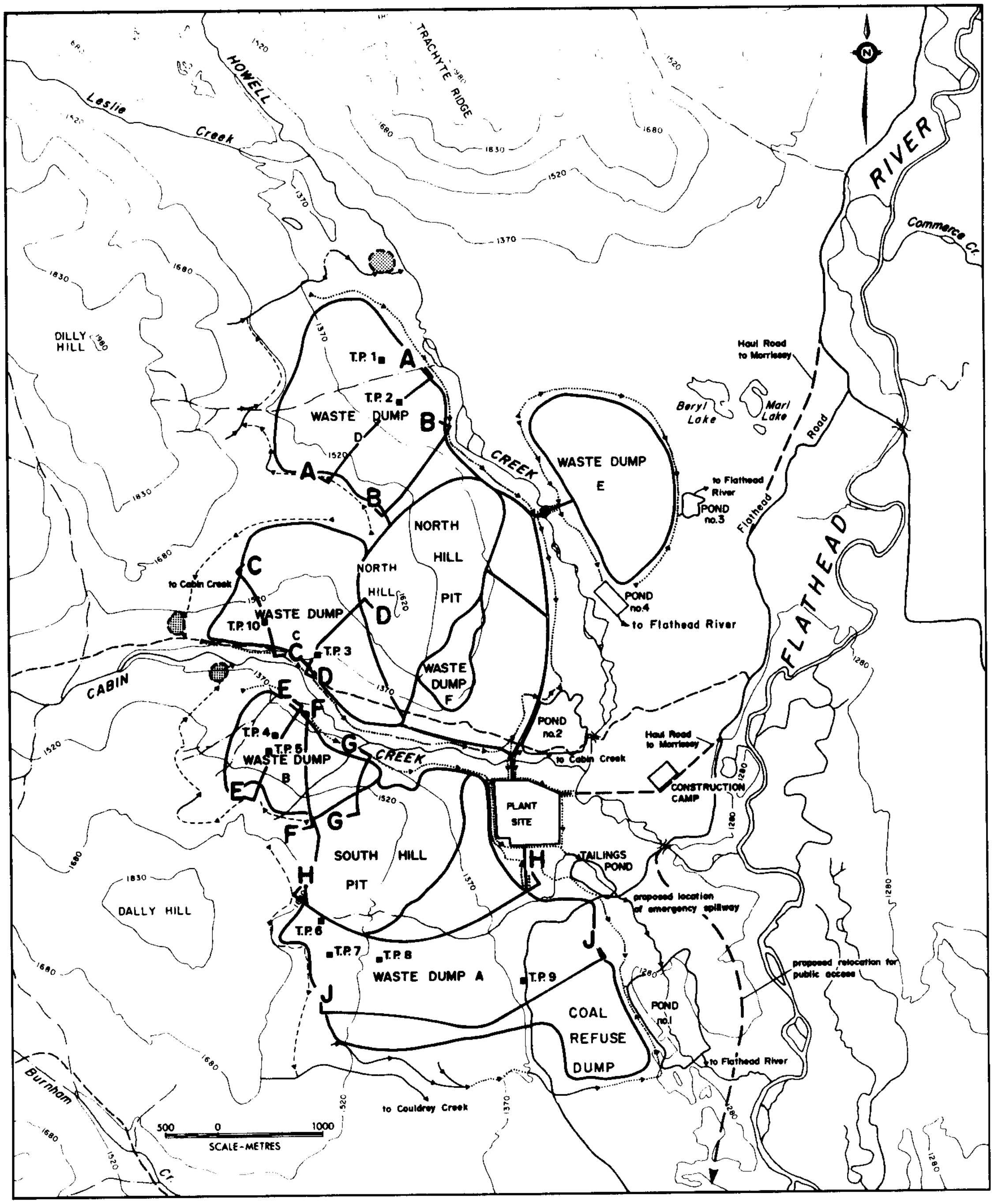

Figure 15. Site plan showing waste dump cross-sections (e.g., G⊔G) and test pit locations (e.g., T.P. 7).

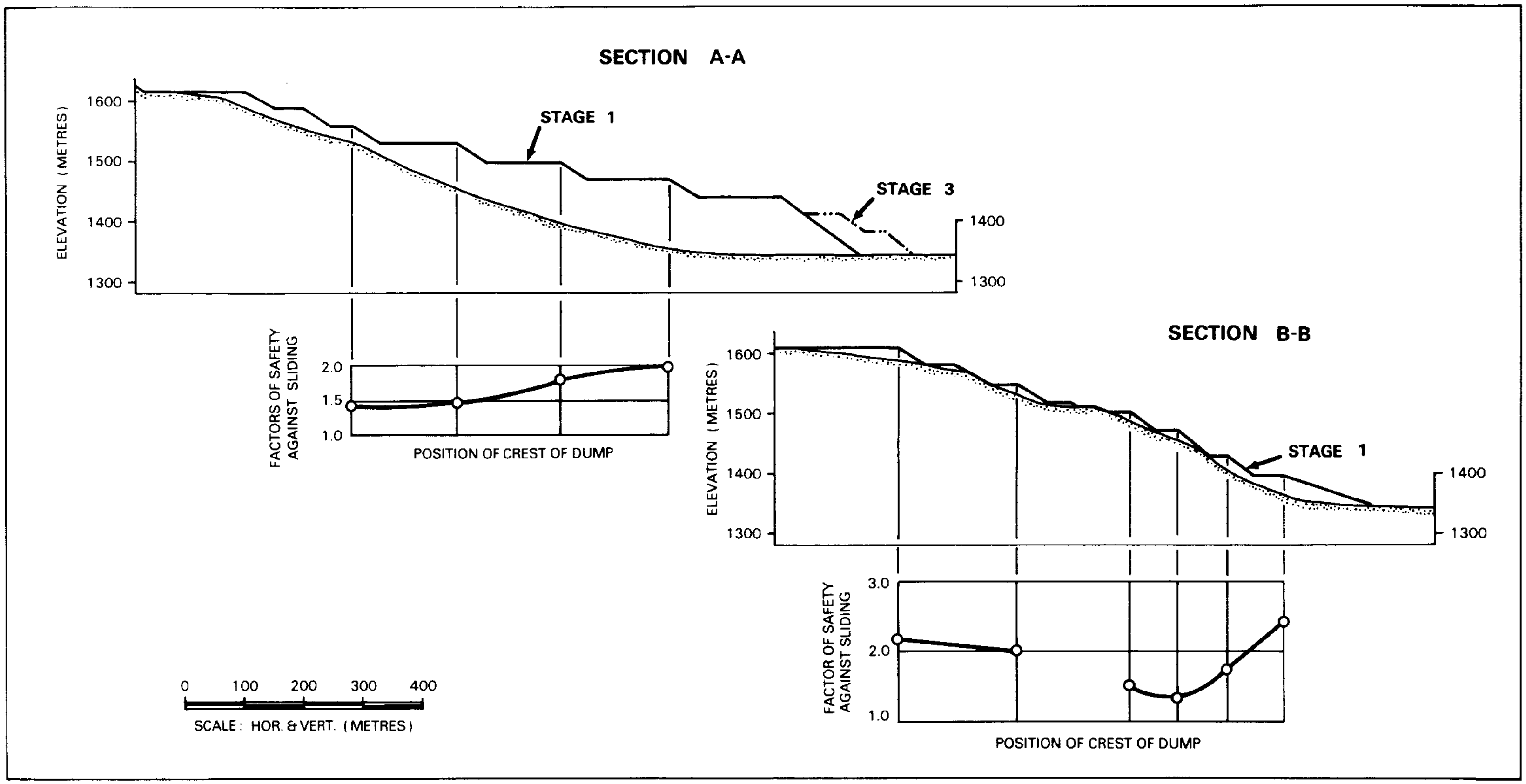

Figure 16. Cross-section profile of North Hill Waste Dump D (see Figure 15). Stage refers to the stage of the mine plan for the North Hill (see Subsection 2.1). (From Golder Associates 1981.)

The second stage would consist of 2 additional benches at elevations of 1600 and 1560 m (5248 and 5117 ft). Seven benches at approximately 30 m (100 ft) elevation intervals from 1540 m to 1356 m (5052 to 4449 ft) would be developed during the third stage. The total elevation difference between the top and bottom of Dump C would be approximately 305 m (1000 ft). The slope of the foundation would vary between 15° and 34°.

The upper area foundation of Dump C materials would be bedrock with thin colluvium. The lower dump area foundation would be bedrock masked with hard glacial till materials. The dip of the bedrock would not adversely affect stability. Cross-joints dip at 65° to 80° subparallel to the slope. Stability analysis results are shown on Figure 17. The minimum factor of safety calculated was 1.2, with stability increasing with progressively lower benches. Golder Associates (1981) considered this dump safe with respect to base sliding.

Waste Dump B would also be adjacent to Cabin Creek. The dump would be developed in two stages. Stage 1 would be characterized by development of 6 benches from elevations of 1585 to 1430 m (5200 to 4692 ft). Stage 2 would consist of development of a single bench at an elevation of 1417 m (4649 ft). The upper foundation of the proposed dump would be bedrock and colluvium. Foundation materials from the mid- to lower- levels of the dump would consist of glacial till. A spring was found near test pit 5 (Figure 15) and organic soils were associated with the spring. Bedrock dips to the east with strike perpendicular to the slope. Joint patterns were noted on aerial photographs. The stability analyses are shown on Figure 18. The minimum factor of safety calculated was 1.3. This was considered adequate with respect to mass failure (Golder Associates 1981).

Type 2 failures in Waste Dump B would be likely to occur in the area of the spring and organic soils. To preclude this type of failure, Golder Associates (1981) recommended removal of the organic soils prior to dumping in this area. The coarse material at the base of the dump should prevent the buildup of high pore water pressures.

In the southeast portion of Dump B located in the vicinity of GG in Figure 15, the bedrock sandstone forms slopes as steep as 39°. If Waste Dump B was advanced into this area prior to construction of lower

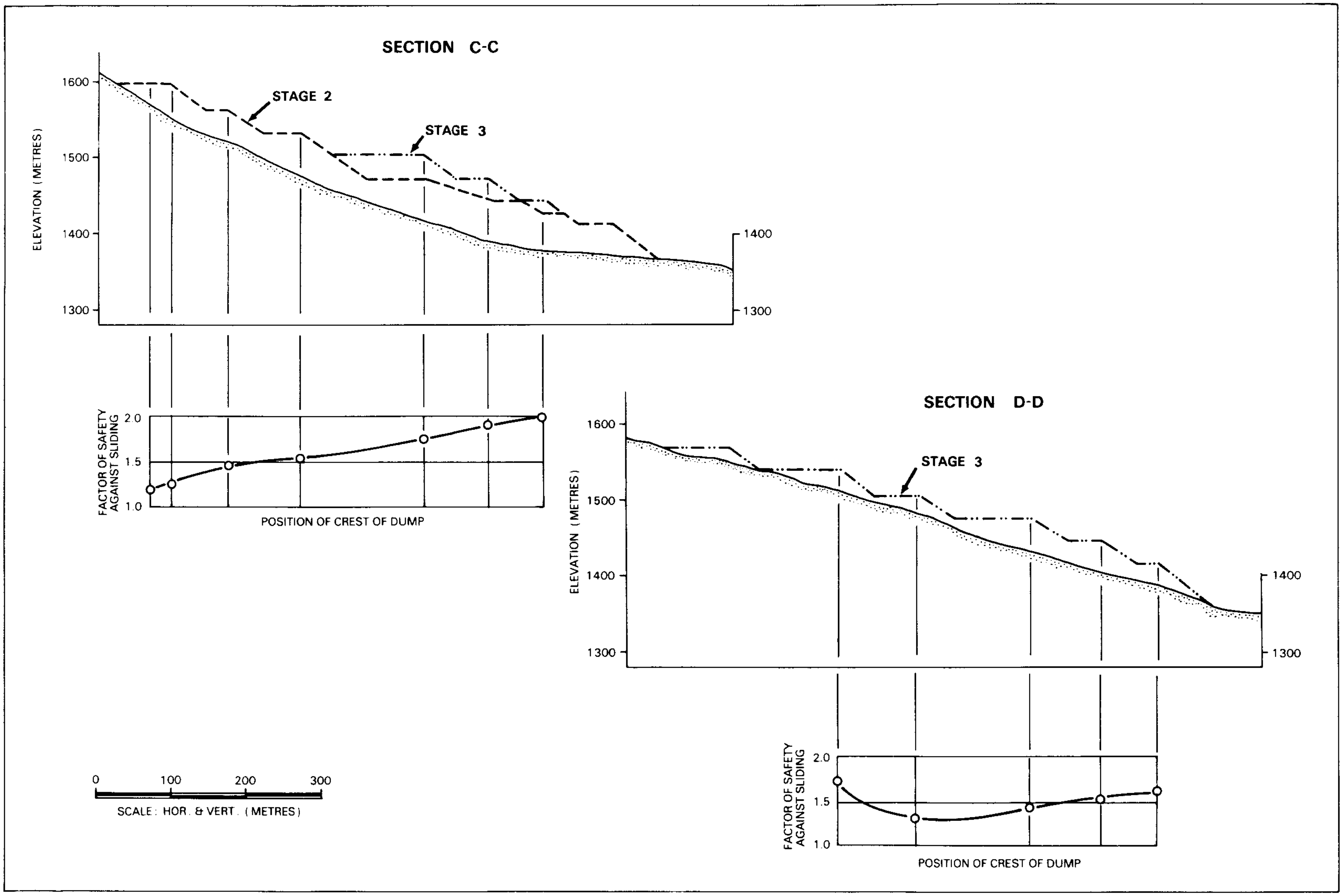

Figure 17. Cross-section profile of North Hill Waste Dump C (see Figure 15). Stage refers to stage of the mine plan for the North Hill (see Subsection 2.1). (From Golder Associates 1981.)

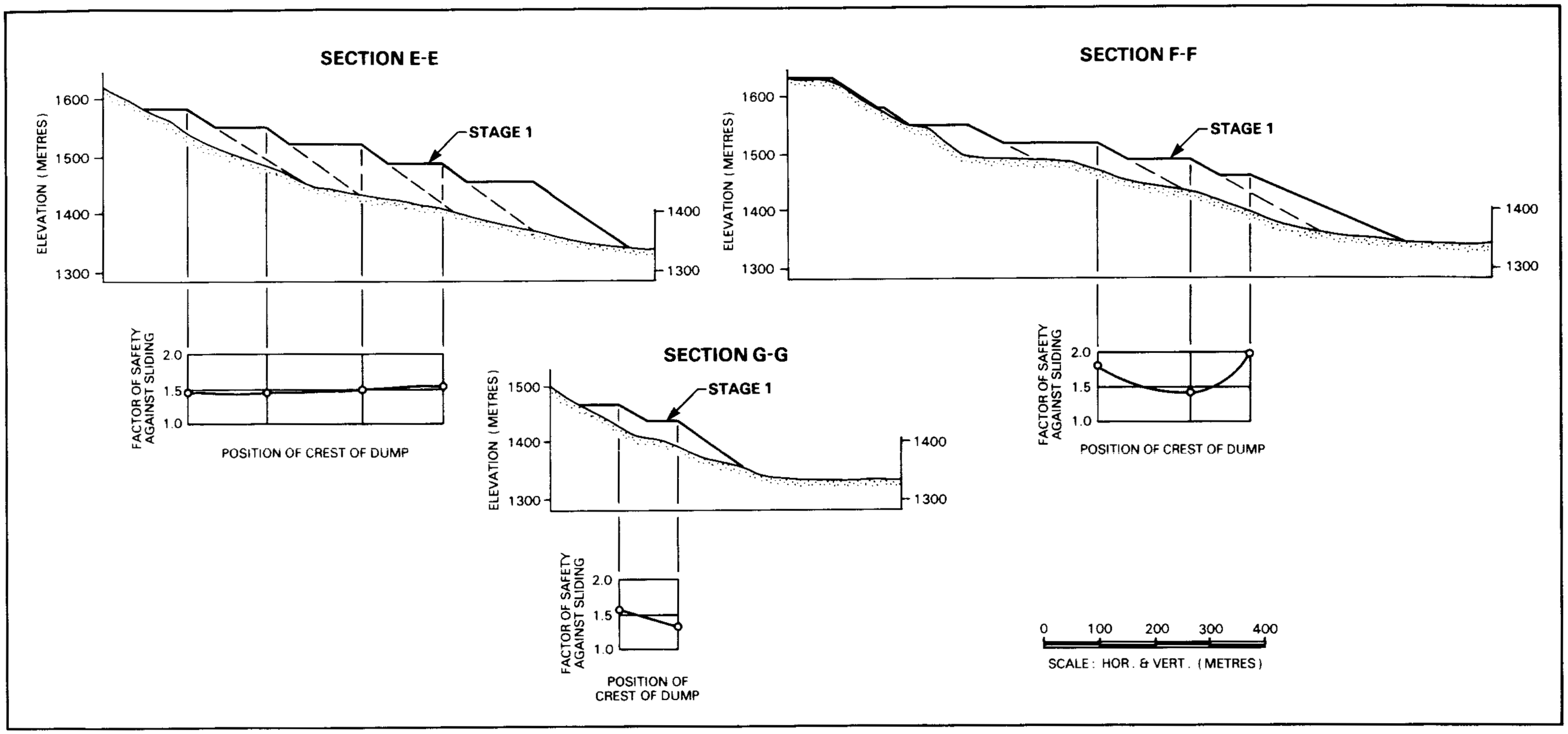

Figure 18. Cross-section profile of South Hill Waste Dump B (see Figure 15). Stage refers to stage of the mine plan for the South Hill (see Subsection 2.1). (From Golder Associates 1981.)

levels an occasional Type 3 failure might occur. If the lower benches were developed first this would decrease the probability of a Type 3 slide. The shear strength of the sandstone foundation material would likely be strong enough to make a Type 3 slide a remote possibility. Based upon the Fahrboschung empirical data, an angle of 22° was estimated. Using this angle, a slide of this type could reach the ultimate limit of the dump. If a Type 3 slide did occur, the impact to Cabin Creek could be significantly reduced by constructing and maintaining a berm at the toe of Dump B as proposed by Golder Associates (1981). Although a berm was not proposed around Dump B in the Stage II EA, the MDC assumes that to meet consistent environmental controls, a berm would be constructed here similar to what has been proposed for Dump C on the opposite side of Cabin Creek from Dump B.

The area in the vicinity of line FF on Figure 15 has been discussed as a possible old slide in materials of the Fernie Group. No drilling has been done to investigate this. The straight reach of Cabin Creek above the proposed bridge appears to be coincident with a fault. Golder Associates (1981) believed that any past mass movement of rocks would have affected or obliterated the surface effects of this fault. It is apparent that movement has not occurred, because Cabin Creek flows along the toe of the steep slope on the south side of the valley. From reviewing this information and aerial photographs of the area Golder Associates (1981) concluded that this area was not an old slide.

A minor portion of Waste Dump A would be located adjacent to Cabin Creek and additional portions within 186 to 372 m (610 to 1220 ft) of Howell Creek below the confluence with Cabin Creek. Stage 1 development of this dump would consist of 11 benches with elevations of 1645 to 1341 m (5397 to 4400 ft) and a 12th bench at an elevation of 1326 m (4350 ft). The second stage would raise this bench to 1341 m (4400 ft) in elevation (Figure 19). The slope of most of the dump area would be less than 14°, but a small area in the upper reaches of the dump would contain slopes up to 28°. Foundation materials are glacial till and clay. The glacial till is thought to be thin because the surface effects of bedrock structure can be seen in the till. A fault system with a northwest-southeast orientation exists in this area. Stability

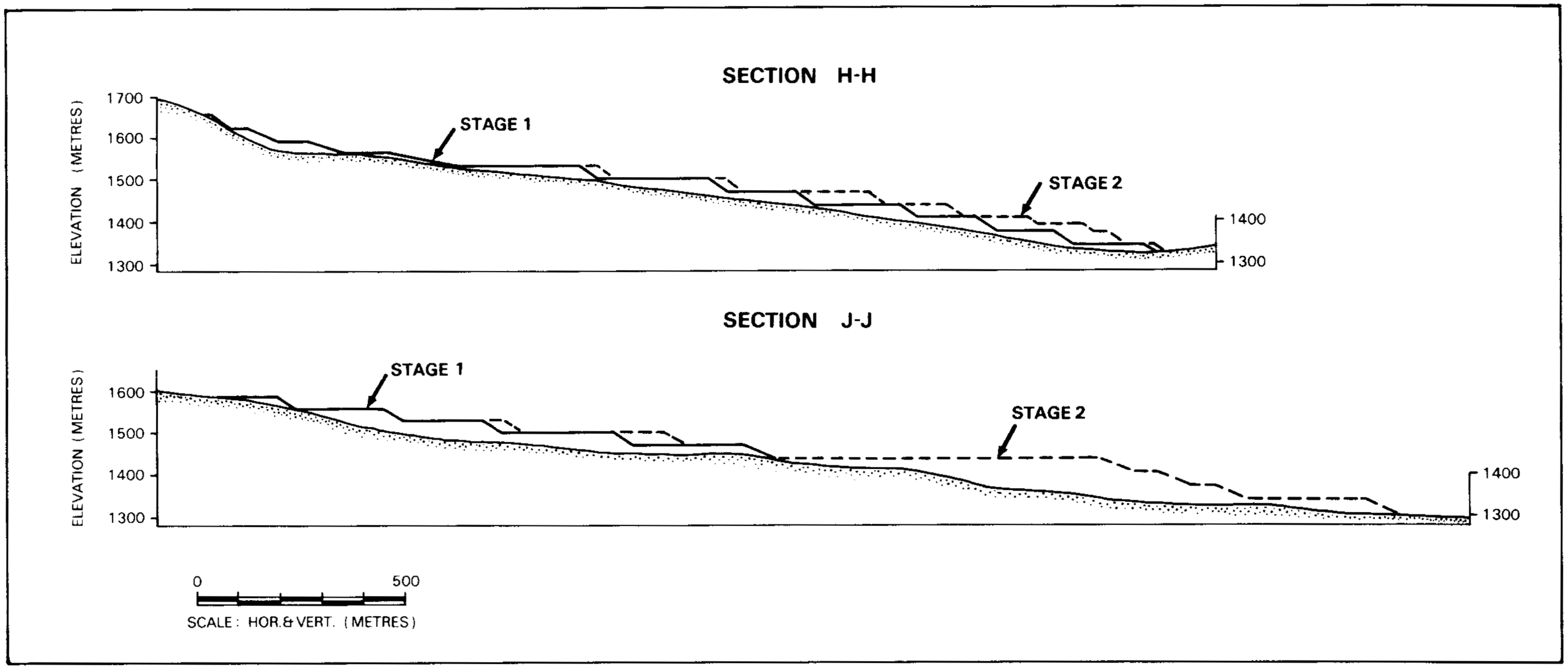

Figure 19. Cross-section profile of South Hill Waste Dump A (see Figure 15). Stage refers to stage of mine plan for South Hill (see Subsection 2.1). (From Golder Associates 1981.)

analyses were not run due to the flat slopes on which the dump is placed. This dump would be expected to be very stable (Golder Associates 1981).

In the toe area of Dump A, minor local depressions appear to be associated with a fault. These depressions are characterised by poorly drained organic soil. As the dump advances onto these areas, Type 2 failures would be expected to occur. The company has proposed to remove these soils for reclamation purposes where possible (Stage II EA p.4-43); this would improve dump stability. However, it is not clear where the organic deposits are located. Also, a number of mine site structures are proposed which lie below portions of Dump A (Figure 15). These include the refuse dump and a berm around the base, the processing plant near the northeast corner of Dump A, and the tailings pond just east of Dump A. The first two of these may be barriers to material movement, and therefore may prevent water quality impacts. However, it is not clear whether the tailings pond would be a means of minimizing or contributing to water quality impacts in the event of a dump failure in that area.

Waste dump F is a small dump which would be associated with the haul road to the North Hill pit. The maximum dump height would be approximately 106 m (350 ft). The dump would be located nearly 610 m (2000 ft) from Cabin Creek and would not likely be a threat to the creek. This dump was not discussed by Golder Associates (1981).

Golder Associates (1981) discussed several measures for protection of the creeks. Where soft organic surface soils are present within the proposed foundation area of the dumps, these organic soils should be stripped and removed to expose the underlying competent overburden soils or bedrock. If these organic soils were removed, the possibility of mudflow occurrences during dump development would be remote. However, to protect the creeks from slide debris, it is proposed in the Stage II EA that protective berms be constructed at the toe of Dump C along Cabin Creek and at the toe of Dump D along Howell Creek. Although the company has not indicated plans in its Stage II proposal to construct a berm at the toe of Dump B south of Cabin Creek, the MDC assumes such a berm would be constructed for reasons stated above.

The protective berms would be constructed concurrently with the development of the dumps and would be maintained at a distance of approximately 90 m (300 ft) ahead of the fall line (projected to the bottom of the slope). The protective berms would be approximately 30 m (100 ft) wide and 10 m (33.8 ft) high. These berms would help protect against escape of slide debris into drainage courses should a failure on an advancing dump face develop into a mudflow. It is important, however, to recognize that berms can protect against encroachment of dumped material and small failures, but will not contain a major slide.

As shown on the various cross-sections, the development of the waste dumps would result in construction of a series of benches with the interbench slopes at the angle of repose of approximately 37°. These slopes would be reduced to 26° to facilitate revegetation of the completed dumps. This slope reduction would improve the overall stability of the dumps. Golder Associates (1981) estimated that this slope reduction would result in a safety factor of 1.5 for shallow failure surfaces. This would be high enough to preclude near-surface creep movements which could hamper root system establishment.

Implementation of the measures proposed (Golder Associates 1981) should adequately protect Cabin and Howell Creeks from potential slides during and after waste dump development. The dumps generally would have increased stability as they approached the creeks. Proper development of the dumps and maintenance of the protective berms should afford additional protection for the creeks. The reduction of the slopes for reclamation would further enhance stability of the dumps. Although the possibility of slide debris reaching Cabin Creek or Howell Creek would exist, proper construction and management should virtually eliminate the chance of this happening.

6.6.3 Consequences of Waste Dump Failure

The consequences of waste dump failures and the areas where they are most likely to affect water quality are discussed below in qualitative terms. It is not feasible to quantitatively estimate the probability of these events occurring or their effect on Cabin or Howell Creeks.

Waste Dumps B, C, and D, are the most critical. Failures there would be the most likely to affect water quality. Dump D begins on steeper slopes, but the majority of the toe area is on gentle slopes adjacent to Howell Creek and the factors of safety increase to two or greater in this area. A failure which would affect water quality in Howell Creek is unlikely.

Waste Dumps B and C are located adjacent to Cabin Creek. Both of these dumps have safety factors ranging from 1.5 to 2.0 in the toe areas of the dumps near Cabin Creek. Dump B would be more likely than Dump C to have a failure which could affect the water quality of Cabin Creek. This would be due to steeper slopes in the upper reaches of Dump B and the presence of organic materials and associated seeps in portions of the foundation area (planned to be excavated) of Dump B.

If waste dump failures occurred, materials could be carried beyond the protective berms and into the creeks. A failure reaching Cabin Creek or Howell Creek could contribute large amounts of suspended solids to the stream and divert flow until the channel readjusts. The volume of material from this type of event may or may not be large enough to temporarily block flow of the stream. Movement of a large volume of waste material near the stream, however, could potentially cross the protective berm and dam the stream. This would eliminate or severely reduce downstream flow until the dam breached. Flow would then increase substantially (similar to a flood flow) carrying with it large amounts of suspended solids. The levels of suspended solids would likely remain elevated until the stream channel adjusted to a new state of equilibrium between flow volume and channel size.

7. REFERENCES

Barfield, B.J., R.C. Warner, and C.T. Haan. 1981. Applied hydrology and sedimentology for disturbed areas. Oklahoma Technical Press. 603 pp.

B.C. Ministry of Environment, Terrestrial Studies Branch. 1977. Terrain map for 82G/2 at 1:50,000 scale.

British Columbia Ministry of Environment, Water Investigations Branch. 1978. Kootenay air and water quality study, phase II. B.C. Minister of Environment file no. 0322512-1. 289 pp.

B.C. Ministry of Environment, Pollution Control Board. 1979. Pollution control objectives for the mining, smelting and related industries of British Columbia. 15 pp.

B.C. Research and Norecol Environmental Consultants Ltd. 1982. Sage Creek Coal Stage II Environmental Assessment: text. Prepared for Sage Creek Coal Limited (also cited as Stage II EA).

B.C. Research and Norecol Environmental Consultants Ltd. 1982. Sage Creek Coal Stage II Environmental Assessment: Appendices - part 1. Prepared for Sage Creek Coal Limited.

B.C. Research and Norecol Environmental Consultants Ltd. 1982. Sage Creek Coal Stage II Environmental Assessment: Appendices - part 2. Prepared for Sage Creek Coal Limited.

Christie, R.L., and R.L. Kenny. 1980. Phosphate exploration in the southern Canadian Rockies. Second draft of report, Institute of Sedimentary and Petroleum Geology, Geological Survey of Canada, Calgary, Alberta. 37 pp. plus 8 figures.

Crippen Consultants. 1981. Sage Creek Coal access road design study route alignment. Prepared for Sage Creek Coal Limited, Vancouver, B.C. 33 pp. plus appendices.

Dames and Moore. 1976. Geotechnical investigation, proposed open pits, Flathead River valley, British Columbia. Prepared for Sage Creek Coal Limited. 77 pp. with supporting maps, figures, and diagrams.

Emerson, K., R.C. Russo, R.E. Lund, and R.V. Thurston. 1975. Aqueous ammonia equilibrium calculations: effect of pH and temperature. Journal of Fisheries Resource Board of Canada Ltd. 32(12):2379-2383.

Fording Coal Limited. 1985, 1984, 1983, and 1982. Annual Effluent Reports for Permit PE425 for 1984, 1983, 1982, and 1981.

Fording Coal Limited. 1985. Kilmarnock dragline proposal environmental impact assessment.

Gibson, D.W. 1985. Stratigraphy, sedimentology and depositional environments of the coal-bearing Jurassic-Cretaceous Kootenay Group, Alberta and British Columbia. Geological Survey of Canada. Bulletin 357. 108 pp.

Golder Associates. 1981. Stability of proposed waste dumps, Sage Creek property, Flathead River valley, British Columbia. Prepared for Sage Creek Coal Limited, Vancouver, B.C. 22 pp. plus appendices.

Grieve, D.A. 1985. Coal fields of the East Kootenay Region, southeastern British Columba. Coal in Canada. Edited by T.H. Patching. Canadian Institute of Mining and Metallurgy. Special Volume 31. 203-211 pp.

Hydrocan Engineering Continental Ltd. 1983. Appendix B, Regional Flood Frequency Analyses, Prepared for Esso Minerals Canada, Corbin Creek conveyance section, Byron Creek Collieries, Corbin, B.C.

Inland Waters Directorate. 1983. Historical streamflow summary, British Columbia, 1982, Ottawa, Canada.

Klohn Leonoff Consultants Ltd. 1981a. Drainage plan for Sage Creek Coal southeastern British Columbia: final report. Report for Norecol Environmental Consultants Ltd. 32 pp. plus appendices.

Klohn Leonoff Consultants Ltd. 1981b. Tailings dam feasibility study. Prepared for Sage Creek Coal Limited, Vancouver, B.C. 15 pp. plus appendices.

McDonald, L.E. 1982. Sediment production during the spring of 1980 and 1981 in the vicinity of Fording Coal Limited surface coal mining operations. B.C. Ministry of Environment, Waste Management Branch. 43 pp.

McDonald, L.E. 1984. Nutrient/algal growth trends in the Elk River Basin - interim report: 1984. B.C. Ministry of Environment, Waste Management Branch. 51 pp.

Nagpal, N.K. 1982. The effect on water quality of explosives use in surface mining. Volume 3: Nitrogen release from coal and mine waste. B.C. Ministry of Environment. 30 pp.

Nordin, R.N. 1982. The effect on water quality of explosives use in surface mining. Volume 2: The effect on algal growth. B.C. Ministry of Environment. 34 pp.

Norecol Environmental Consultants Ltd. 1985. Phosphorus from operating surface coal mines. Report prepared for the Environmental Protection Service, Mining, Mineral, and Metallurgical Process Division. Hull, Quebec.

Norecol Environmental Consultants Ltd. 1982. Preliminary environmental assessment of 230-kV transmission line route to Sage Creek Coal mine site. Prepared for Sage Creek Coal Limited. Vancouver, B.C. 98 pp.

Pacific Hydrology Consultants Ltd. 1982. Sage Creek Coal Stage II environmental assessment - groundwater study. Report for Sage Creek Coal Limited.

Pommen, L.W. 1983. The effect on water quality of explosive use in surface mining, volume 1: nitrogen sources, water quality and prediction and management of impacts. B.C. Ministry of Environment. 149 pp.

Qamar, A.I., and M.C. Stickeny. 1983. Montana earthquakes, 1869-1979: Historical seismicity and earthquake hazard. Montana Bureau of Mines and Geology Memoir 51. 79 pp.

Schultz, B. 1984. Surface water quality of the Stillwater State Forest and Swan River State Forest, 1976-1983. Montana Department of State Lands, Forestry Division. 11 pp. with appendices.

Sheehan, S.W., G.L. Ennis, R.L. Hallam, A.L. Smith and T.M. Tuominen. 1985. A water quality study of the Flathead River Basin in British Columbia prior to proposed coal mining (data report). Regional report, Water Quality Branch, Inland Waters Directorate, Pacific and Yukon Region. 260 pp.

Smith, A.L., G.L. Ennis, S.W. Sheehan, and T.M. Tuominen. 1985. A water quality study of the Akamina-Kishinena watershed and other tributaries to the Flathead River in British Columbia subjected to logging. Regional report, Water Quality Branch, Inland Waters Directorate, Pacific and Yukon Region. 91 pp.

Sowers, G.B. and G.F. Sowers. 1970. Introductory soil mechanics and foundations. Third edition. McMillan Publishing Company Inc.

Telfer, L. 1933. Phosphate in the Canadian Rockies. Canadian Institute of Mining and Metallurgy Bulletin 260: 566-605.

Toews, D.A.A. and M.J. Brownlee. 1981. An handbook for fish habitat protection on forest lands in British Columbia. Department of Fisheries and Oceans, Canada. 173 pp.

U.S. Environmental Protection Agency (EPA). 1983. Compilation of air pollutant emission factors, AP-42. Chapter on fugitive dust sources, pp. 11.2-1-11.2-2. Research Triangle Park, North Carolina, U.S.A..

U.S. National Oceanic and Atmospheric Administration. 1985. Climatological data, annual summary, Montana 1985. 88:13, ISSN 0145-0395. 37 pp.

8. APPENDICES

8.1 APPENDIX 1

Flathead River International Study Board Directive: The Mine.

FLATHEAD RIVER INTERNATIONAL STUDY BOARD DIRECTIVE

THE MINE

27 August 1985

PURPOSE

To provide all Technical Committees with Board policy regarding minesite design, specifications to be used in assessing impacts on water quantity and quality in the Flathead Basin.

BACKGROUND

Sage Creek Coal project design has not been finalised. The Stage II design was approved-in-principle by the B.C. Government in February 1984 subject to a number of conditions. Normally the company would take these conditions into account when completing final design, required before various permits and licences can be authorised and final permission to proceed is granted. This occurs at the end of Stage III in B.C.'s Mine Development approval process.

The B.C. Government has developed a detailed framework of regulations and guidelines under the Coal Act Regulations (see page 3 of "Legal and Administrative Arrangements for Regulating and Monitoring Coal Development in British Columbia"); under the Waste Management Act and the Water Act (see page 7, op.cit.); and under the Fisheries Act (Canada) (see page 12, op.cit.). This framework guides the final design process during Stage III.

DISCUSSION

Because the mine's development plan is still in the conceptual design phase (Stage II) it will not be possible to estimate precisely the impacts on water quantity and quality downstream in the Flathead system without making specific assumptions regarding final design.

The Board's policy on this matter is to develop two minesite cases to allow a range of potential inputs to be evaluated on water dependent resources of the Flathead basin.

The first example is called the "most desirable" case, under which it is assumed that all components of minesite design will operate up to the design frequencies specified in the various regulations and guidelines noted above and specified later in this directive.

The second example is named an "operational" case, under which possible failures to achieve full and consistent compliance with all regulations and guidelines will be assumed based on experience with existing operating mine developments in the Elk River Valley and reasonable assumptions about problems caused by "extreme events" that exceed the conditions specified in the above-mentioned regulations and guidelines, and the site-specific situation at Sage Creek.

The Board would like to approve these two design statements outlined above for distribution to the other Technical Committees in advance of the Workshop to be held in Kalispell, Montana on November 19th and 20th.

Accordingly, the Board makes the following directives:

1. The Minesite Development Committee shall develop a "most desirable" minesite case for Sage Creek based on the Stage II design and the further assumption that all conditions specified in the B.C. Government's regulations and detailed guidelines associated with coal mine development will be met. These include:

   - Guidelines for Design, Construction, Operation, and Abandonment of Tailings Impoundments (EMPR);
   - Guidelines for Mine Dumps (EMPR);
   - Guidelines for Approval of Main Surface Haul Roads Regularly Used for the Transportation of Minerals or Wastes at Mines (EMPR);
   - Mine Reclamation Guidelines (EMPR);
   - Pollution Control Objectives for the Mining, Smelting, and Related Industries of B.C. (governing air, solid, and liquid waste discharges at minesites, preparation plants, construction camps) (MOE);
   - Water Licences and Approvals governing all surface water diversion and settling ponds (MOE);
   - Guidelines for stream crossings (MOE).

2. The Minesite Development Committee shall also prepare an "operational" case for Sage Creek based on possible failures to achieve all the above-mentioned regulations. In developing this case, the Committee shall assemble existing information on the actual performance of operating mines in the Elk Valley. The Committee shall also identify any parameters that might affect water quantity and quality in Cabin and Howell Creeks and the Flathead River at the International Boundary that were not already identified in the "most desirable" case. Furthermore it will identify possible "extreme events" that exceed conditions outlined in various regulations, and the water quantity and quality of point and non-point discharges off the minesite, as well as stream channel morphology.

   The Committee should use its collective judgements based on practical experience in managing coal developments in developing this "operational" case. It should provide the Board with its rationale regarding how and why specific design conditions were assumed.

3. These statements of minesite cases shall be prepared and distributed to the Board no later than October 31, 1985.

The statement shall include design specifications for:

- minesite water management measures;
- waste treatment at processing plant and construction camps;
- blasting procedures;
- mine waste disposal and dump stability;
- coal handling and dust suppression;
- reclamation measures;
- construction of powerlines and roads.

It shall cover the mine construction, operation, and abandonment phases.

4. Where the Minesite Development Committee feels it is unable to specify design conditions and/or estimate water quantity or quality resulting from point and non-point discharges off the minesite, or potential changes to stream channel morphology, it should notify the Board Co-Chairmen immediately. This notification should outline the nature of the uncertainties and suggest measures for addressing them.

5. The Board requests the Minesite Development Committee advise it of any problems in meeting the October 31st deadline as soon as possible and provide an estimate of the resources (staff, expertise, funds) it requires to complete these assignments.

Approved: August 27, 1985.

J.A.Posewitz,
U.S. Co-Chairman,

E.M.Clark,
Canadian Co-Chairman,

Flathead River International Study Board

8.2 APPENDIX 2

Coal Refuse Sample Analysis

Reject coal is sent to a separate refuse dump at the Line Creek mine. It is expected that a similar approach would be used by Sage Creek Coal Limited at the proposed Cabin and Howell Creeks mine site. In the case of Line Creek the tailings, which normally go to a tailings pond, are dried by filters and mixed with the coarse coal waste rejects, which are then placed on the dump in 15 cm (6 in) layers and compacted. A grab sample from the Line Creek refuse dump was taken to evaluate the quality of groundwater moving through the refuse dump.

Table 1 presents the analytical results on the solid sample. This sample was treated as a coal sample in that everything but mercury was determined on the ash (64.3 weight percent) after combustion.

Table 2 presents leachate and extract data. Columns 1, 2, and 3 are the result of batch leaching, in triplicate, of 2.5 g of the pulverized grab sample in 250 ml water (a 1.0 weight percent slurry). Samples in the first 2 columns had their water pH adjusted 3 times weekly (total of 9 times) for 30 days. Column 1 shows the greatest release of alkaline earth elements and most heavy metals for the adjustment of pH to 5.0. Unfortunately, the pH-adjusted samples were not filtered immediately after the last pH adjustment as indicated by the pH values at the bottom of columns 1 and 2; consequently, spike recovery data are invalid. However, most recoveries were acceptable. Aluminum, nickel, and zinc dropped to or near to the detection levels in the pH 9 spike; these losses were probably a function of the pH, representing precipitation as hydroxides.

Column 3, which was simply a distilled water leach solution, is most representative of the quantity of easily leachable material, while the soil paste extract (column 4) indicates the maximum concentration which occurs in the first pore volume of leachate for most constituents.

The soil paste extract concentrations show that initial concentrations of nitrogen, sulphate, and chloride are quite high; however, dissolved concentrations from Montana overburden materials tested in leach columns show logarithmic decreases, assymptotically approaching a stable value, and it is expected that similar declines in dissolved constituents will occur with coal refuse materials.

Table 1. Coal Refuse Sample Analysis. Ash Content = 64.3 Weight Percent. Only the Ash was Analyzed.

Major Constituents	Wt. & (Ash)	Calculated Wt. % of Total	Calculated Oxide Wt. % of Total
Ca	12.2	7.8	11.
Mg	1.8	1.2	1.9
Na	0.26	0.17	0.22
K	1.2	0.77	0.93
Al	4.5	2.9	5.5
Fe	1.4	0.90	1.2

Minor Constituents	ppm (Ash)	Trace Constituent[a]	ppb
Cd	0.93		
Cr	65.	Hg	0.22
Cu	16.		
Li	26.		
Mo	<8.		
Ni	22.		
Pb	<16.		
Sr	220.		
Ti	1700.		
V	113.		
Zn	95.		
Zr	48.		

[a] Based upon total sample weight, not the ashed sample.

Table 2. Coal refuse sample leachate and extract analysis (dissolved: in mg/L)

	pH=5 Leachate[a]	pH=9 Leachate[a]	Distilled H_2O Leachate[a]	Soil Paste Extract[b]
Ca	149.	3.5	6.8	172.
Mg	7.8	0.2	0.4	26.3
Na	1.4	13.2[c]	1.1	242.
K	1.0	0.8	0.8	21.3
Fe	<.002	0.042	<.002	0.007
Mn	0.26	0.001	<.001	0.110
SiO_2	2.1	3.9	1.9	11.6
HCO_3	36.8	20.6	24.7	22.0
Cl	1.25	1.2	1.08	620.
SO_4	1.2	1.1	0.8	106.
N[d]	10.3	0.14	0.10	24.2
F	0.1	0.1	<.1	0.9
Al	<.03	0.44	0.147	<.030
Ag	<.002	0.008	0.003	<.002
B	<.02	<.02	0.013	0.180
Cd	<.002	<.002	<.002	<.002
Cr	<.002	0.003	<.002	<.002
Cu	0.017	0.005	0.002	0.030
Li	<.002	0.005	0.002	0.014
Mo	<.02	<.02	<.02	0.020
Br	<.1	<.1	<.1	<.1
Ni	<.01	<.01	<.01	0.01
P	<.1	<.1	<.1	<.1
O-P	<.1	<.1	<.1	<0.1
Sr	0.155	0.009	0.014	0.43
Ti	0.017	0.004	0.002	0.021
V	<.001	0.012	0.004	<.001
Zn	0.012	0.006	<.003	0.035
Zr	<.004	0.007	0.003	<.004
Anal pH	6.5	8.7	6.4	7.0

[a] These leachates were prepared by mixing 2.5 grams (g) of refuse material in 250 ml of water.

[b] This extract was taken from a water-saturated soil paste.

[c] HNO_3 and NaOH were used to adjust pH. The acid or base strength multiplied by the total volume was subtracted out. However, a lab error in volume or strength may have occurred as this Na value is not consistent with other leachate Na:K ratios.

[d] Total inorganic nitrogen.

8.3 APPENDIX 3

Legal and Administrative Arrangements for Regulating and Monitoring Coal Development in British Columbia

Note: On August 14, 1986 the Ministry of Environment became Ministry of Environment and Parks. Forests and Lands portions of Lands, Parks and Housing have been combined to form Ministry of Forests and Lands. The Ministry of Agriculture has been changed to the Ministry of Agriculture and Fisheries. However, for purposes of this report the original titles have been retained.

LEGAL AND ADMINISTRATIVE ARRANGEMENTS FOR REGULATING AND MONITORING COAL DEVELOPMENT IN BRITISH COLUMBIA

MINISTRY OF ENERGY, MINES AND PETROLEUM RESOURCES (MEMPR)

1. Ministry Goals and Objectives
2. Key Regulatory Statutes
   a) Coal Act
   b) Mines Act
3. Guidelines for Coal Development

MINISTRY OF ENVIRONMENT (MOE)

1. Relevant Statutes Administered by MOE
   a) Ministry of Environment Act
   b) Environment Management Act
   c) Waste Management Act
   d) Water Act
   e) Wildlife Act

2. Relevant Forms of Regulation
   a) Waste Management Program
   b) Fisheries and Wildlife Management Programs
   c) Fisheries Act (B.C.)
   d) Federal Fisheries Act

3. MOE Administrative Requirements
   a) Administrative Requirements Under the Waste Management Act
   b) Water Act Administrative Requirements

MINISTRY OF FORESTS (MOF)

1. Relevant Statutes Administered by MOF
2. Ministry Goals With Respect to Mining
3. Relevant Forms of Regulation

MINISTRY OF LANDS, PARKS AND HOUSING (MLPH)

1. Relevant Statutes Administered by MLPH
2. Ministry Goals With Respect to Mining
3. Relevant Forms of Regulation

GUIDELINES FOR COAL DEVELOPMENT

ATTACHMENTS: Copies of Relevant Statutes, Regulations and Guidelines for the Regulation and Monitoring of Coal Mining Developments in B.C.

MINISTRY OF ENERGY, MINES AND PETROLEUM RESOURCES

- Coal Act
- Coal Act Regulations
- Coal Act Regulations Amendments
- Coal Amendment Act, 1982
- Coal Amendment Act, 1985
- Summary of Coal Act Requirements in B.C.
- Mines Act
- Mines Regulation
- Mines Regulation Amendment
- Coal Mines Regulation
- Mineral Act
- Guidelines for Approval of Main Surface Haul Roads Regularly Used for the Transportation of Mineral or Waste at Mines
- Guidelines for Mine Dumps
- Guidelines for the Design, Construction, Operation and Abandonment of Tailings Impoundments
- Mine Reclamation Guidelines
- Guidelines for Coal Exploration

MINISTRY OF ENVIRONMENT

- Ministry of Environment Act
- Environment Management Act
- Waste Management Act
- Waste Management Regulation
- Waste Management Act Amendment
- Pollution Control Objectives for the Mining, Smelting and Related Industries of B.C.
- Water Act
- Water Act Amendment
- How to Obtain a Water Licence in B.C.
- How to Obtain Approval Under the Water Act in B.C.
- Wildlife Act
- Wildlife Act Amendment
- Fisheries Act (B.C.)
- Firearms Act

GUIDELINES FOR COAL DEVELOPMENT

MINISTRY OF ENERGY, MINES AND PETROLEUM RESOURCES

LEGAL AND ADMINISTRATIVE ARRANGEMENTS FOR THE REGULATION AND MONITORING OF COAL MINING DEVELOPMENTS IN BRITISH COLUMBIA BY THE MINISTRY OF ENERGY, MINES AND PETROLEUM RESOURCES

1. Ministry Goals and Objectives:

The Ministry's overall strategy for the coal sector is to develop and implement comprehensive policies and programs which will encourage the discovery, development and production of coal resources in a manner which is beneficial to British Columbia. In order to implement this strategy, the MEMPR pursues various policy objectives:

- to promote the orderly and rational development of provincial coal resources in a manner which contributes to the achievement of provincial goals for employment and industrial and business development;

- to encourage and facilitate the process of discovery and renewal of provincial coal resources through various geoscience programs, and to assure the availability of adequate coal lands for this purpose;

- to administer title to provincial coal resources in an efficient, effective and equitable manner;

- to ensure that provincial coal resources are explored for, developed and produced in a manner which is consistent both with worker and public health and safety and with subsurface resource conservation;

- through both internal and inter-agency activities, to encourage the maximizing of social benefits and the minimizing of adverse environmental and socio-economic impacts associated with coal exploration, development and production; and

- to cooperate in the pursuit of provincial objectives for land use and resource management and allocation, both through participation in multi-Ministry initiatives and through the enforcement of appropriate procedures and standards for access development, surface use and reclamation.

2. Key Regulatory Statutes:

Relevant statutes administered by the MEMPR:

- Coal Act; RSBC 1979
- Mines Act; BC 1980

(a) Coal Act

The Coal Act regulates the issuance of title to coal resources in B.C.

Exploration rights are granted to private parties under a coal licence, which is issued pursuant to S.17. The licence is renewable annually, subject to either the completion and reporting of work requirememts or the payment of a rental 'in lieu' (S.18). On a licence, the licencee may explore for and develop coal, and may mine small quantities for testing purposes. Following receipt, MEMPR may refer coal licence applications to other government agencies prior to deciding whether or not to issue the licence.

For full-scale coal production, a coal lease must be obtained, pursuant to S.24. The MEMPR Minister may require plans and studies to be submitted before a lease is issued (S.24(2)(d)). The scope of potential information requirements is listed in S.18 of the Coal Act Regulations. The Coal Guidelines Review Process is the normal working policy procedure by which the Province solicits and reviews this information.

A coal lease is not issued to a private party until a project has obtained approval-in-principle and is at Stage III of the Coal Guidelines Review Process.

(b) Mines Act

The Mines Act regulates all types of on-site mining-related activities in British Columbia, the primary purpose being to ensure:

- that the proposed mining system takes due account of health and safety requirements;
- that other subsurface resources will not be wasted or needlessly sterilized by the proposed mining system; and
- that disturbances of lands and watercourses will be property reclaimed to a final acceptable condition.

The Act provides the legal framework for extensive and detailed regulations (the Mines Regulation and the Coal Mines Regulation) and also for a series of technical guidelines:

- the Guidelines for Coal Exploration;
- the Guidelines for the Design, Construction, Operation and Abandonment of Tailings Impoundments;
- the Guidelines for Mine Dumps'
- the Guidelines for Approval and Main Surface Haul Roads Regularly Used for the Transportation or Mineral or Waste at Mines; and
- the Mine Reclamation Guidelines.

Before production can proceed from a coal mine, the Chief Inspector of Mines must approve the proposed mine plan under S.6, taking into account health and safety considerations and the minimizing of resource wastage and sterilization. An outline of the information requirements for this approval is presented on pages 25 and 26 of the Guidelines for Coal Development.

Before mining activities commence, a mining company must also obtain a reclamation permit (Ss. 7 and 30). Applications must be reviewed by an inter-Ministry Reclamation Advisory Committee before the MEMPR Minister decides whether or not to issue a permit (S.8). A bond for the reclamation program must be posted in accordance with S.9. Non-compliance with permitting or bonding requirements may cause cancellation of the reclamation permit (S.11). Information requirements for a reclamation permit application are summarized on page 26 of the Guidelines for Coal Development, and in S.37 of the Coal Mines Regulation.

The objectives of these two major approvals are to ensure collectively that mining methods are safe, that subsurface resources are conserved and that environmental disturbance is minimized. These approvals are finalized and issued at Stage III of the Coal Guidelines Review Process, following approval-in-principle. However, significant progress must normally be achieved on the mine plan and reclamation program during Stages I and II, prior to approval-in-principle, since only then is it possible to determine reliably that potential impacts can be managed to reduce them to acceptable levels.

3. Guidelines for Coal Development:

Since 1980, MEMPR has been the lead Ministry for the Coal Guidelines Review Process, which is set out in the Guidelines for Coal Development (ELUC, March, 1976). These guidelines and a summary statement of their purpose and procedures are attached.

MINISTRY OF ENVIRONMENT

LEGAL AND ADMINISTRATIVE ARRANGEMENTS FOR THE REGULATION AND MONITORING OF COAL MINING DEVELOPMENTS IN BRITISH COLUMBIA BY THE MINISTRY OF ENVIRONMENT

1. Relevant statutes administered by the Ministry of Environment:

- Ministry of Environment Act; 1980
- Environment Management Act; 1981
- Waste Management Act; 1982
- Waste Management Regulation;
- Special Waste Regulation (pending)
- Water Act; 1979 (Consolidated March 18, 1983)
- Wildlife Act; 1982
- Firearms Act; 1966
- Fisheries Act; 1979 (Consolidated December 1, 1983)
- Fisheries Act (Canada). RSC 1970 c.f. 14

(a) Ministry of Environment Act

The mandate of the Ministry of Environment as stated in the Ministry of Environment Act includes: "to encourage and maintain an optimum quality environment through specific objectives for the management and protection of land, water, air, and living resources of the province", and to "manage, protect, and conserve all water, land, air, plant life and animal life, having regard to the economic and social benefits they may confer on the Province".

(b) Environment Management Act

The Environment Management Act is designed to enable the Ministry of Environment to effectively manage and protect the environment of British

Columbia. The Act provides the framework for the orderly development and implementation of environmental plans, policies, procedures and administrative processes.

The Environment Management Act, Section 2, outlines the duties, powers and functions of the Minister relative to the policy formulation, planning, management, protection and enhancement of the environment. This Section provides a process for the preparation and publication of environment management plans for specific areas of the Province which may include measures related to flood control, drainage, soil conservation and the management of water, fisheries, aquatic life, wildlife, waste or air.

Section 3 empowers the Minister to require the submission of an environmental impact assessment if he feels that a proposal may have a detrimental environmental impact and that there is insufficient information available to assess the impact through other impact assessment procedures (such as the Guidelines for Mine Development).

Under Section 4.(1), the Minister may declare that an existing or proposed activity has or may have a detrimental environmental impact and, under Section 4.(3), may make an interim order restricting, modifying or prohibiting the activity. Such an order can remain in effect for a period no longer than 15 days but can be extended for a further period of time by order of the Lieutenant Governor in Council (Cabinet).

If the Minister considers it necessary, he may order a public inquiry with respect to the environment under Section 7 of the EMA.

Finally, Section 11 of the Act establishes an Environmental Appeal Board to hear appeals to decisions under other environmental legislation, such as the Water Act or the Waste Management Act.

(c) The Waste Management Act makes provision for the following:- prohibitions of, and permits or approvals for, discharge of waste to air, land and water; special waste storage, transportation and disposal; spill prevention and contingency planning; amendment of permits and approvals; variance orders; abandonment; enforcement; appeals to Director and Appeal Board; and regulations. Regulations include application requirements for permit, duties of applicant (e.g. time designated for posting and content), time designated for objectors to respond, etc.

"Waste" includes (a) air contaminants, (b) litter, (c) effluent, (d) refuse, (e) special waste and (f) any other substanstance designated by the Lieutenant Governor in Council. "Environment" means the air, land, water and all other external conditions or influences under which man, animals and plants live or are developed.

For the purposes of this Act, introduction of a waste into the environment means depositing the waste on or in or allowing or causing the waste to flow or seep on or into any land or water, or allowing or causing the waste to be emitted into the air.

(d) The Water Act, Section 2, states that "the property in and the right to the use and flow of all the water at any time in a stream in the Province are for all purposes vested in the Crown in right of the Province, except only in so far as private rights have been established under licenses issued or approvals given under this or a former Act". Section 4 lists the rights for the diversion, use, and storage of water, or the alteration of a stream or channel, which can be acquired under licence. Approvals can be issued under Section 7 of the Water Act for non-recurrent use of water for a period not exceeding six months and for changes in or about a stream.

(e) The Wildlife Act provides for the management and protection of fish and wildlife populations and to some degree for the protection, management and enchancement of fish and wildlife habitat. Section 2 states that all wildlife belongs to the Province unless it has been lawfully killed. The Minister may, under Section 3 of the Wildlife Act, acquire land or enter into agreements with others for the purpose of access to, or management or protection of wildlife.* In conjunction with wildlife management plans developed under the EMA, the Minister may designate land with very high existing or potential values for wildlife as a wildlife management area under Section 4 of the Wildlife Act. Where he requires land as essential habitat for threatened or endangered species of wildlife, the Minister may designate land within a wildlife management area as a critical wildlife area (Section 5.(1)). The Minister may also designate land as a wildlife sanctuary (Section 5.(2)).

Under Section 7 it is considered an offence to conduct an activity that has negative impact on wildlife or wildlife habitat in a wildlife management area, except as authorized by regulations or a permit. A permit may be issued by the regional manager where the applicant has complied with Section 3 of the EMA and provided an acceptable environmental impact assessment of the activity. In the case of mining projects it is likely that these sections would apply primarily to the exploration and predevelopment phase until a decision on approval in principle has been made.

2. Relevant Forms of Regulation:

The Ministry of Environment, through its various Programs, issues the following types of licences, permits or approvals for mine developments:

* As used in Sections 3, 4, 5, 7 and 8 of the Wildlife Act, the term "wildlife" includes fish.

a) Waste Management Program:

The Waste Management Program regulates the quantity and quality of solid, liquid and gaseous waste discharges from mining operations to land, water or air through the issuance of Waste Management Permits. Proponents are expected to comply with permit terms and conditions, which are set in accordance with objectives specified in the "Pollution Control Objectives for the Mining, Smelting and Related Industries of B.C." 1979. These objectives have been formulated following ecological, health, technological and economic considerations. Each Waste Management Permit establishes project and site specific effluent, emission or solid waste discharge objectives for parameters of concern. Such discharge objectives are currently used as the basis for assessment and review of pollution abatement facilities to ensure the maintenance of ambient air and water quality.

In addition, the Ministry of Environment is currently developing ambient air and water quality objectives for specified air management units and waterbodies in British Columbia, based on the protection of designated air and water uses in each area. These provisional non-regulatory objectives provide a statement of MOE policy regarding levels of air and water quality for the continued suitability of air and water for a variety of uses. Consequently, the ambient objectives will provide a context both for discharge objectives and for any improvement in abatement facilities that may be required through the waste management permitting process.

Permits are required for the emission of air contaminants from mining operations and related offsite project components (e.g. emissions from crushing and screening, roasting, concentrate drying, washplant, camp incinerators). Permits are also required for the discharge of minesite and related offsite effluent (e.g. collection and treatment of minesite contaminated runoff in settling ponds, pilot plant operations, tailings slurry discharge to the tailings pond and collection and treatment of plant site contaminated runoff, tailings, pond overflows, domestic effluent from the camp's or expanded community sewage treatment plant). Refuse permits are required to authorize discharge of putrescible and non-putrescible refuse to land and subsequent treatment (e.g., washplant discharge of coarse refuse and plant rejects, camp or expanded community refuse, disposal of construction debris).

While the disposal of preparation plant rejects (coarse refuse and tailings) requires Waste Management Permits, overburden dumps do not. They are considered part of the mining operation and are under the sole jurisdiction of the Ministry of Energy, Mines and Petroleum Resources. Where there are suspended solids or leachate concerns, the Waste Management Branch may also require permits.

Under Section 9, a manager may approve the introduction of waste into the environment or the storage of a special waste for a period of 12 months or less without issuing a permit. An example of an Approval for a temporary discharge is an experimental small-scale milling operation, with the qualification that a subsequent extended or expanded operation would require permits.

A manager may issue his approval subject to requirements for the protection of the environment that he considers advisable. In such instances the Waste Manager may specify certain terms and conditions which are then attached to the permit or approval as required, (studies, plans, alterations, monitoring or treatments) including financial security in the form of performance bonds. Approvals are legal decisions similar to permits and as such are subject to appeal.

Permits and Approvals may be amended, subject to the Waste Management Act and the Regulations.

b) Fisheries and Wildlife Management Programs:

The participation of the Fisheries and Wildlife Management Programs in the Mine Development Review Process is primarily program-oriented and not regulatory in nature. However, staff of these programs regularly participate on various referral processes of other regulatory agencies, including the Ministry's own Waste and Water Management Branches. Through these referral processes, the Fish and Wildlife Programs provide recommendations on the issuance of permits, licences and approvals to mitigate impacts on fish or wildlife populations and habitats.

However, not all direct mine development impacts on fish and wildlife resources can be adequately mitigated by terms and conditions accompanying licenses, approvals, and permits. Mitigatory strategies including population and habitat enhancement for identified lost resources, are developed largely through negotiations with individual companies and in accordance with established compensation/mitigation guidelines. Management activity requirements are then attached as conditions to the approval-in-principle for the project.

During the assessment of the environmental impacts of a mine development it may be necessary to capture or to kill wildlife. Permits are required for such activities under Section 20 of the Wildlife Act.

The Ministry will, upon request, close certain areas of land to discharge of firearms, using regulation under Section 12 of the Firearms Act. Areas in and around minesites are usually closed to hunting for safety purposes.

(c) The Fisheries Act (R.S.B.C. 1981, Chap. 137) - Section 28(1) states that "Every person who commences the construction of any dam or other hydraulic project that will use, divert, obstruct or impound or change the nature, flow or course of any river or stream or otherwise utilize any of the waters of the Province, shall provide fish passes, fish ladders, fish ways or other fish protective devices as the Ministry requires for the safe and adequate passage of fish over, around or through the dam or other hydraulic project."

(d) The Federal Fisheries Act (R.S.C., C. F-14) - Section 34 states that "The Governor in Council may make regulations for carrying out the purposes and provisions of this Act and, in particular, but without restricting the generality of the foregoing, may make regulation"

a. for the proper management and control of the seacoast and inland fisheries.

Letter or Agreement (June 3, 1983) between Canada and the Province sets out responsibility for setting regulations for freshwater fisheries by the Province subject to passage by Order in Council under Section 34 of the Fisheries Act.

Other sections of the Federal Fisheries Act are also applicable as follows:

20 - Construction of fishways
28 - Fish guards - screening
30 - Prohibition of destruction of fish except through fishing
31 - Harmful alteration of fish habitat
33(2) - Deposition of a deleterious substance

3. Ministry of Environment Administrative Requirements:

a) Administrative Requirements Under the Waste Management Act:

With the issuance of permits under the Waste Management Act, permittees and Waste Management Branch staff fall into an operation/enforcement mode based on permit conditions, that can be divided into the following categories:

i) Limits and Objectives

Each point source discharge may be assigned a maximum emission or discharge limit based on Pollution Control Objectives set for the province, or based on other documents, if required. The company is legally bound to meeting these limits.

ii) Monitoring

Company Monitoring

The permittee is required, by permit, to conduct a monitoring program at both point source and receiving environment stations designed to evaluate the achievement of meeting limits or objectives as specified above.

Waste Management Branch Monitoring

Monitoring is broken into two categories here. Those programs designed to witness, check, calibrate or split sample (to ensure data quality control), constitute the Ministry's major sampling emphasis with industry. The other category of sampling is usually on a large scale program basis designed for further assessment of a drainage basin or airshed.

iii) Reporting and Assessment

Permittees are required to tabulate and submit monitoring data on a quarterly basis along with a summary of non-compliance. The industry operators also are required to submit an annual report that tabulates or graphs the year's data showing trends, environmental impact areas (i.e. those results greater than objectives), and proposed or completed changes in control works.

iv) Inspection and Enforcement

Inspection by Waste Management staff is done on a bi-monthly basis during freshet and monthly the remainder of the year. Enforcement follow-up may be based on the results of inspection trips, quarterly reports or the annual reports. Enforcement follows the philosophy of negotiation for improvements to meet the conditions of the permit or to improve the permit requirements, based on assessments made for impact. Prosecution remains as the final tool for achieving compliance, short of a Stop Order from the Minister.

b) Water Act Administrative Requirements:

The right to the use and flow of all water at any time in a stream in the province are for all purposes vested in the provincial government (Water Act). A water licence or an approval may be issued by the Water Management Branch, Ministry of Environment, which specifies the conditions under which a right to use water or make alterations in and about a stream is granted.

All major instream works are authorized via a licence. At any time after the licence has been issued, the individual, company or agency constructing the works may be ordered to repair, alter, or remove the works. The individual, company or agency may also be required to set up a monitoring system and provide reports on a regular basis to ensure the works are performing as agreed to at the time the licence was issued.

MINISTRY OF FORESTS

LEGAL AND ADMINISTRATIVE ARRANGEMENTS FOR THE REGULATION AND MONITORING OF COAL MINING DEVELOPMENTS IN BRITISH COLUMBIA BY THE MINISTRY OF FORESTS

1. Relevant statutes administered by the Ministry of Forests:

   - Ministry of Forests Act
   - Forest Act
   - Regulations
   - MOF Protection Manual

2. Ministry Goals with Respect to Mining:

   - to salvage timber values in mining areas;
   - to plan access so that blocks of timber are not isolated and rendered inoperable;
   - to accommodate timber and mining development through road access development;
   - to reclaim land for forestry and range purposes where practicable.

3. Relevant Forms of Regulation:

   Free Use Permits
   Licence to Cut
   Road Permits
   Special Use Permits
   Burning Permits
   Instructions for disposal of Slash and Snags
   Particularly applicable to full disposal of roadside slash.
   Fire Equipment Inspection

MINISTRY OF LANDS, PARKS AND HOUSING

LEGAL AND ADMINISTRATIVE ARRANGEMENTS FOR THE REGULATION AND MONITORING OF COAL MINING DEVELOPMENTS IN BRITISH COLUMBIA BY THE MINISTRY OF LANDS, PARKS AND HOUSING

1. Relevant statutes administered by the Ministry of Lands, Parks and Housing:

   - Ministry of Lands, Parks and Housing Act
     Sections 5 and 9(1)

   - Land Act
     All sections are relevant to the administration and allocation of Crown Land to the mining industry

   - Park Act
     Sections 3(1c), 8, 9, 18(c) and 25

   - Ecological Reserve Act

2. Ministry Goals and Respect to Mining:

   Ministry policy and objectives pertaining to Crown Land administration for mining purposes include:

   (a) Provide Land Act tenure for the temporary use of Crown Land.

   (b) Allocate Crown Land in conjunction with the management and regulatory requirements of the Ministry of Energy, Mines and Petroleum Resources and the Ministry of Environment.

   (c) Establish pricing for use of Crown Land based on appraised market value for marketing/refining facilities, and a standard nominal fee for primary recovery and enhancement facilities.

(d) Provide variable terms of tenure recognizing and limited to the different requirements of exploration and development.

(e) Utilize the Ministry's inter-agency referral process and other mechanisms to reduce conflicts between exploration and development activities and adjacent uses and the environment.

3. Relevant Forms of Regulation:

Land Act

- General (Section 10) Licence re: temporary occupation of Crown Land
- Licence of Occupation (Section 36)
- Lease Dispositions
- Right of Way or Easement (roadways and access)
- Quarrying Land approvals/permits (borrow pits)

Park Act

Authorization of nonconforming use to occur within a Park (Class B) or recreation area.

- Park Use Permit
- Resource Use Permit

Ecological Reserve Act

GUIDELINES FOR COAL DEVELOPMENT

GUIDELINES FOR COAL DEVELOPMENTS

1. Background

The Guidelines for Coal Development were issued in March of 1976 by the Government of British Columbia's Environment and Land Use Committee (ELUC). This Committee currently consists of eight Cabinet Ministers in the following portfolios:

- Environment (Chairman)
- Lands, Parks and Housing
- Agriculture and Food
- Energy, Mines and Petroleum Resources
- Forests
- Municipal Affairs
- Transportation and Highways
- Industry and Small Business Development

The ELUC approved some important changes to the review process in 1984. However, the Sage Creek Coal Project obtained Stage II approval-in-principle and entered Stage III before the changes. For this reason, the following material describes the Coal Guidelines Review Process (CGRP) in its earlier form.

2. What is Coal Guidelines Review Process?

- Non-legislative (working policy) review procedures.
- Applied to all new coal mines from end of exploration phase to permit issuance/construction start-up phase.
- Also applied to major expansions/modifications of existing coal mines by working policy since 1980.
- published document:
  Guidelines for Coal Development (ELUC, March, 1976).

3. What are CGRP's Basic Goals?

- To facilitate and expedite sound, publicly-acceptable mining ventures in B.C.
- To provide a comprehensive, credible and widely understood procedure for project review/approval.
- To ensure effective coordination and realistic staging of company/ government contact.
- To provide early notification of mining proposals.
- To make possible early identification and acceptable management of potentially significant environmental, financial and community impacts.
- To ensure systematic, consistent application of government policies, regulations and information requirements.

4. Who are the Main Actors in the CGRP?

4.1 Developer (Mining Company)

- Approaches MEMPR (lead agency) with conceptual proposal.
- Provides information on request (in prospectus, Stage I and Stage II reports).

4.2 Lead Agency (Ministry of Energy, Mines and Petroleum Resources)

- Primary contact for industry.
- Chairs Coal Guidelines Steering Committee, advises it of project proposals.
- Provides technical coordination, support services for review process.

4.3 Coal Guidelines Steering Committee

- Consists of six key Ministries (senior-level public servants).
- Liaison between company and review agencies.
- Routine logistical coordination and procedural decisions.
- Consolidates agency information requests, review comments.
- Reports, makes recommendations to ELUTC/ELUC.

4.4 Technical Working Committees (MTC and SECC)

- Technical/biophysical aspects handled by Minesite Technical Committee.
- Socio-economic aspects handled by Socio-Economic Coordinating Committee.
- Streamline relationship between Steering Committee and review agencies.
- Assist in focussing key technical issues for Steering Committee.
- Perform specialized technical analysis for Steering Committee.

4.5 Provincial Review Agencies (see Attachment #1)

- Liaise with companies both formally (through Steering Committee) and informally (direct discussions).
- Responsible for ensuring that mines are consistent with individual agency policy/technical requirements.
- Grouped in two major areas of concern:
  - biophysical/technical/regulatory
  - socio-economic/community/manpower
- Participation of three types (see Attachment #1):
  - regulatory, resource management
  - non-regulatory, resource management of service delivery
  - technical, advisory (non-management).

4.6 ELUTC/ELUC

- ELUC is Cabinet Committee
- Environment and Land Use Technical Committee consists of Deputy Ministers of Ministers on ELUC.
- Responsible for resolution of major policy/technical issues.
- Grant Stage II approvals-in-principle.

4.7 Federal Agencies (see attachment #1)

- By working policy, involved in provincial review process rather than organizing separate review.
- Concerned primarily with matters under federal jurisdiction (National Parks, anadromous fish, marine environments, Native Indian groups).

4.8 Local Governments

- Feedback through Ministry of Municipal Affairs.

4.9 General Public and Interest Groups

- Proponents responsible for public consultations.
- All formal submissions to Steering Committee are public documents.
- Government review comments are in the public domain after approval-in-principle decision.

5. What Issues does the CGRP Address?

5.1 Project Description

- Proponent provides project particulars at appropriate levels of detail, depending on review stage.

- Mining Plan:
  - geological data
  - pits/shafts, waste dumps, stockpiles
  - milling/preparation process
  - plans for reclamation, waste management, water management
- Ancillary developments:
  - access (road, rail)
  - power supply
  - port facilities
  - workforce housing (camps, off-site housing, etc.)
- Review of project alternatives
- Tentative development schedule

5.2 <u>Impact Assessment</u>

- Potential environmental and socio-economic impacts
- Impact management measures
- See attachment #1 for agency input management responsibilities

5.3 <u>Regulatory Activities</u>

- Attachment #1 indicates key regulatory statutes.

6. <u>How is CGRP Staged?</u>

- See attachment #2
- Stage I
  - preliminary project description
  - preliminary impact assessment
- Stage II
  - detailed project description
  - detailed impact assessment/impact management planning
  - leads to Stage II approval-in-principle
- Stage III
  - licencing/permitting
  - non-regulatory conditions on approval-in-principle

7. What is Stage II Approval-in-Principle?

- expression of conditional support by government review agencies.
- not issued until:
  - all major policy issues resolved;
  - all major technical issues known to be resolvable by economically affordable means.

8. What is Status of Sage Creek Coal Project?

- from perspective of British Columbia Government, is at Stage III (licencing stage)
- received Stage II approval-in-principle from ELUC in February, 1984.
- outstanding environmental concerns are deemed manageable from a provincial perspective.

8.4 APPENDIX 4

Inventory of Chemicals Stored and Used
at an Existing Elk Valley Mine
(information received in July, 1985)

GROUP I - PETROLEUM PRODUCTS

CHEMICAL	STORAGE FACILITY OR TYPE OF PACKAGING	NORMAL INVENTORY AT MINE SITE	QUANTITY USAGE ANNUAL BASIS
Kerosene	Bulk-2 tanks, 90,000 litres each	100,000 litres	72,000 litres
Oil	Bulk-1 tank, 68,000 litres	30,000 litres	327,000 litres
Gasoline	Bulk-68,000-litre tank Fuel station-20,000-litre tank	45,000 litres	$27x10^6$ litres
Diesel	5 mobile trucks-3 with 4,500 litre tanks; 1 with 13,600 litre tank; 1 with 9,000 litre tank	--------	---------
Diesel	Bulk-4 tanks, 90,000 litres each	180,000 litres	$31x10^6$ litres
Diesel	Fuel station-2 tanks 45,000 litres each	30,000 litres	------
Diesel	Fuel Station-2 tanks 45,000 litres each	30,000 litres	------
Diesel	Fuel station-2 tanks 45,000 litres each	30,000 litres	------
Diesel	Fuel station-1 tank 136,000 litres	100,000 litres	-------
Motor Oil 30 Winter	Bulk-2 tanks, 27,000 litres each	30,000 litres	227,000 litres
Motor Oil 40 summer	Bulk-2 tanks, 27,000 litres each	30,000 litres	291,000 litres
Motor Oil 5W-30	Bulk-2 tanks, 27,000 litres each	30,000 litres	577,000 litres
Grease	Bulk-tank, 37,000 litres	20,000 litres	10,000 litres
Grease	Bulk-tank, 37,000 litres	20,000 litres	10,000 litres
Grease	Bulk-tank, 31,000 litres	20,000 litres	80,000 kilograms
Grease	Bulk-tank, 31,000 litres	20,000 litres	97,000 kilograms

GROUP I - PETROLEUM PRODUCTS (continued)

CHEMICAL	STORAGE FACILITY OR TYPE OF PACKAGING	NORMAL INVENTORY AT MINE SITE	QUANTITY USAGE ANNUAL BASIS
Motor Oil (Winter) 10-30W	20-litre pail; 5 fuel trucks 450-litre tank each	17 pails	400 litres (See bulk)
Motor Oil (Summer) 15-40W	20-litre pail; 5 fuel trucks 450 litre-tank each	17 pails	400 litres (See bulk)
Motor/hy-draulic Oil 40W	20-litre pail; 5 fuel trucks 450-litre tank each	20 pails	960 litres (See bulk)
Hydraulic Oil (Compressor)	205-litre drum 20-litre pail	4 drums 23 pails	2,400 litres
Hydraulic Oil	20-litre pail 205-litre drum	12 pails 4 drums	4,000 litres
Hydraulic Oil	20-litre pail	12 pails	40 litres
Hydraulic Oil	20-litre pail	8 pails	120 litres
Hydraulic Oil	20-litre pail	4 pails	80 litres
Hydraulic Oil	20-litre pail	8 pails	80 litres
Hydraulic Oil	20-litre pail	7 pails	12,000 litres
Hydraulic Oil	205-litre drum	2 drums	2,000 litres (to (be discontinued)
Gear Oils	205-litre drum	23 drums	60,000 litres
Gear Lube	205-litre drum	16 drums	500,000 litres

GROUP I - PETROLEUM PRODUCTS (continued)

CHEMICAL	STORAGE FACILITY OR TYPE OF PACKAGING	NORMAL INVENTORY AT MINE SITE	QUANTITY USAGE ANNUAL BASIS
Automatic Transmission Oil	205-litre drum 20-litre pails	8 drums 45 pails	2,000 litres 2,000 litres
Transmission and Hydraulic Fluid	20-litre pail	35 pails	4,000 litres
Compressor Oil	20-litre pail	3 pails	340 litres
Brake Fluid	20-litre pail	43 pails	3,300 litres
Moly Lubricant	17-kilogram drum	3 drums	300 kilograms
Moly Lubricant	54-kilogram drum	2 drums	100 kilograms
Grease	54-kilogram drum	1 drum	300 kilograms
Industrial Oil	20-litre pail	2 pails	40 litres
Hydraulic Oil	20-litre pail	4 pails	80 litres
Open Gear Lubricant	205-litre drum	2-8 drums	5,000 litres
Lube	205-litre drum	17 drums	20,000 litres
Preservation Oil	205-litre drum	6 drums	7,000 litres
Grease	205-litre drum	8 drums	Backup to bulk
Grease	205-litre drum	4 drums	backup to bulk
Grease	205-litre drum	4 drums	Backup to bulk
Methyl Hydrate	205-litre drum	5 drums	5,000 litres

GROUP I - PETROLEUM PRODUCTS (continued)

CHEMICAL	STORAGE FACILITY OR TYPE OF PACKAGING	NORMAL INVENTORY AT MINE SITE	QUANTITY USAGE ANNUAL BASIS
Ether	24 cans/case	10 cases	2,500 cases
Transformer Coolant	205-litre drum	8 drums	3,000 litres
Kerosene	205-litre drum	10 drums	2,500 litres
Varsol	205-litre drum	20 drums	60,000 litres
Tanner Gas	205-litre drum	2 drums	5,000 litres
Methyl Hydrate	205-litre drum	3-13 drums	8,000 litres
Methanol	Bulk tank-45,000 litres	30,000 litres	225,000 litres

GROUP II - SOLVENTS/CLEANERS

CHEMICAL	STORAGE FACILITY OR TYPE OF PACKAGING	NORMAL INVENTORY AT MINE SITE	QUANTITY USAGE ANNUAL BASIS
Degreaser Solvent	20-litre pail	5 pails	1,200 litres
Xylene	4-litre can	3 cans	12 litres
Toluene	4-litre can	6 cans	120 litres
Paint Removal Toluene	205-litre drum	1 drum	205 litres
Paint Asphalt and Plastic Stripper	205-litre drum	1-6 drums	6,000 litres
Paint Thinner-Petroleum Spirits	20-litre pail	21 pails	600 litres
Conditioner Acidic	1-litre can	3 cans	9 litres
Hydrochloric Acid	4-litre can	7 cans	4 litres
Solvent Cleaner	205-litre drum	4 drums	6,000 litres
Alkaline Steam Cleaner	205-litre drum	4 drums	6,000 litres
Cleaner	205-litre drum	1 drum	800 litres
Electric Motor Cleaner	205-litre drum	1 drum	1,200 litres
Degreaser and Emulsifier	205-litre drum	2 drums	6,000 litres
Phenolic Germicidal Detergent	20-litre pail	5 pails	1,200 litres

GROUP III - MISCELLANEOUS

CHEMICAL	STORAGE FACILITY OR TYPE OF PACKAGING	NORMAL INVENTORY AT MINE SITE	QUANTITY USAGE ANNUAL BASIS
Frother-Alcohol Methylisobutyl Carbanial	Bulk tank-68,000 litres	40,000 litres	85,000 litres
Antifreeze	Bulk tank-68,000 litres	40,000 litres	100,000 litres
Antifreeze	3 fuel stations-20,000-litre tanks	See bulk	See bulk
Acrylamine Polymer	205-litre drum	8 drums	25,000 litres
Polyacrylate Acrylamine Polymer	Bulk tank-47,000 litres Mix tank @ 1.5%-13,600 litres	30,000 litres	120,000 litres
Perchloryl Ethylene	205-litre drum	1 drum	400 litres
Sodium Hydroxide	205-litre drum	1 drum	200 litres
Polymer	205-litre drum	2 drums	400 litres
Polymer	205-litre drum	6 drums	2,000 litres
Polymer	205-litre drum	4 drums	800 litres
Glycol	205-litre drum	2 drums	4,000 litres
Sulphuric Acid	20-litre box	9 boxes	4,000 litres
Antifreeze	16-litre box	30 boxes	10,000 litres
Acid	50-kilogram container	1 container	100 kilograms
Acid Scale Remover	50-kilogram container	4 containers	300 kilograms
Fire Retardant	20-litre can	2 cans	4 cans

GROUP III - MISCELLANEOUS (continued)

CHEMICAL	STORAGE FACILITY OR TYPE OF PACKAGING	NORMAL INVENTORY AT MINE SITE	QUANTITY USAGE ANNUAL BASIS
Drill Collar Compound	20-kilogram pail	47 pails	1,000 kilograms
Rotary Drill Compound	18-kilogram bag	4 bags	less than 1 bag
Bentonite Clay	20-litre pail	2 pails	varies
Drilling Fluid Polymer	20-litre pail	13 pails	varies
Urethane	16-kilogram case	2 cases	120 kilograms
Elec. Cording on Cables	4-liter container	6 containers	32 liters
Tank liner-Slightly Alkaline	5-kilogram case	16 cases	5 kilograms
Aggregate with Hardener Resin	20-kilogram case	3 cases	60 kilograms
Phosphate Acid (Inhibits Lime Scale)	45-kilogram container	1 container	1 kilogram

GROUP IV - PESTICIDES

CHEMICAL	STORAGE FACILITY OR TYPE OF PACKAGING	NORMAL INVENTORY AT MINE SITE	QUANTITY USAGE ANNUAL BASIS
Fungicide	20-litre pail	4 pails	Less than 1 pail
Fungicide-Oxine Benzoate	4-litre container	1 container	Less than 1 container
Herbicide-Bromacil	4-litre container	2 containers	Less than 1 container
Herbicide-Paraquat	1-litre container	12 containers	Less than 1 container
Herbicide-Simazine 80%	2-kilogram bag	2 bags	Less than 1 bag
Herbicide-Chloroxuron 50%	2.7-kilogram bag	8 bags	Less than 1 bag
Insecticide-Diazinon (Organo-phosphate)	4.5-litre bottle	1 bottle	Less than 1 bottle
Insecticide-Malathion (Organo-phosphate)	4.5-litre bottle	1 bottle	Less than 1 bottle
Herbicide-Glyphosphate	4-litre container	1 container	Less than 1 container

GROUP V - HIGH EXPLOSIVES

CHEMICAL	STORAGE FACILITY OR TYPE OF PACKAGING	NORMAL INVENTORY AT MINE SITE	QUANTITY USAGE ANNUAL BASIS
High Explosives		45,000 kilograms maximum LICENSED	Information not available
Variety of detonators and relays and primer cord		9,000 kilograms maximum LICENSED	Information not available

GROUP VI - C.I.L. PLANT - EXPLOSIVE MAKE-UP

CHEMICAL	STORAGE FACILITY OR TYPE OF PACKAGING	NORMAL INVENTORY AT MINE SITE	QUANTITY USAGE ANNUAL BASIS
Sodium Dichromate	50-kilogram bag	20 bags	Information not available
Sodium Bicarbonate	25-kilogram bag	20 bags	Information not available
Zinc Nitrate	135-kilogram drum	10 drums	Information not available
Urea	25-kilogram bag	100 bags	Information not available
Lignosol (Ground Wood)	25-kilogram bag	100 bags	Information not available
Guar	25-kilogram bag	50 bags	Information not available
Guar	20-kilogram bag	50 bags	Information not available
Sodium Nitrate	25-kilogram bag	50 bags	Information not available
Aluminum Oxide	25-kilogram bag	10 bags	Information not available
Aluminum	-----	20,000 kilograms	Information not available
Calcium Nitrate	Bulk	75,000 kilograms	Information not available
Ammonium Nitrate	Bulk	20,000 kilograms	Information not available
Ammonium Nitrate	Bulk	50,000 kilograms	Information not available
Ammonium Nitrate	Bulk	50,000 kilograms	Information not available

GROUP VI - C.I.L. PLANT - EXPLOSIVE MAKE-UP (continued)

CHEMICAL	STORAGE FACILITY OR TYPE OF PACKAGING	NORMAL INVENTORY AT MINE SITE	QUANTITY USAGE ANNUAL BASIS
Ammonium Nitrate 83%	Bulk Tank	35,000 kilograms	Information not available
Ammonium Nitrate-Slurry	Tank	20,000 kilograms	Information not available
Ammonium Nitrate-Slurry	Tank	20,000 kilograms	Information not available
Paint Thinner	20-liter pail	1 pail	Information not available
Enamel Reducer	20-liter pail	1 pail	Information not available
Petroleum Solvent	205-litre drum	Less than 1 drum	Information not available
Kerosene	205-litre drum	Less than 1 drum	Information not available
Motor Oil	205-litre drum	2 drums	Information not available
Automatic Transmission Oil	205-litre drum	2 drums	Information not available
Diesel Fuel-No. 2	Bulk tank-68,000 litres	45,000 litres	Information not available
Diesel	Bulk tank-9,000 litres	4,500 litres	Information not available
Gasoline	Bulk tank-9,000 litres	3,000 litres	Information not available
Furnace Oil	Bulk tank-9,000 litres	4,500 litres	Information not available
Amine	20-litre container	1 container	Information not available

GROUP VI - C.I.L. PLANT - EXPLOSIVE MAKE-UP (continued)

CHEMICAL	STORAGE FACILITY OR TYPE OF PACKAGING	NORMAL INVENTORY AT MINE SITE	QUANTITY USAGE ANNUAL BASIS
Polyphosphate-Slightly Alkaline	205-litre drum	1 drum	Information not available
Catalyzed Sodium Sulphite	40-kilogram container	1 container	Information not available
Sulphuric Acid	20-litre case	5 cases	Information not available
Calcium Nitrate	Rail car	170,000 kilograms per rail car	Information not available
Ammonium Nitrate	Bulk	50,000 kilograms	Information not available

8.5 APPENDIX 5

Groundwater Quality Sample Results
in the Project Area

MONTANA BUREAU OF MINES AND GEOLOGY
BUTTE,MONTANA 59701 (406)496-4101

WATER QUALITY ANALYSIS
LAB NO. 84Q0667

STATE		COUNTY	
LATITUDE-LONGITUDE	49D05'52"N 114D33'03"W	SITE LOCATION	00N 00W 00
UTM COORDINATES	Z N E	MBMG SITE	N-FORK
TOPOGRAPHIC MAP		STATION ID	490552114330301
GEOLOGIC SOURCE	* * *	SAMPLE SOURCE	TEST HOLE
DRAINAGE BASIN		LAND SURFACE ALTITUDE	4375. FT < 10
AGENCY + SAMPLER	MBMG*RAN	SUSTAINED YIELD	
BOTTLE NUMBER	75-R-01	YIELD MEAS METHOD	
DATE SAMPLED	25-JUL-84	TOTAL DEPTH OF WELL	
TIME SAMPLED	17:30 HOURS	SWL ABOVE(-) OR BELOW GS	FLOWING
LAB + ANALYST	MBMG*FNA	CASING DIAMETER	6 IN
DATE ANALYZED	16-AUG-84	CASING TYPE	STEEL
SAMPLE HANDLING	4220	COMPLETION TYPE	*
METHOD SAMPLED	GRAB	PERFORATED INTERVAL	
WATER USE	RESEARCH		

SAMPLING SITE BRITISH COLUMBIA, CANADA
GEOLOGIC SOURCE

	MG/L	MEQ/L		MG/L	MEQ/L
CALCIUM (CA)	57.7	2.88	BICARBONATE (HCO3)	296.2	4.85
MAGNESIUM (MG)	26.2	2.16	CARBONATE (CO3)	0.	
SODIUM (NA)	1.6	.07	CHLORIDE (CL)	.2	.01
POTASSIUM (K)	1.2	.03	SULFATE (SO4)	12.8	.27
IRON (FE)	.79	.04	NITRATE (AS N)	1.22	.09
MANGANESE (MN)	.018	.00	FLUORIDE (F)	<.1	
SILICA (SIO2)	7.3		PHOSPHATE TOT (AS P)		
TOTAL CATIONS		5.18	TOTAL ANIONS		5.21

STANDARD DEVIATION OF ANION-CATION BALANCE (SIGMA) .152

CALCULATED DISSOLVED SOLIDS	254.93	TOTAL HARDNESS AS CACO3	251.91
SUM OF DISS. CONSTITUENT	405.22	FIELD HARDNESS AS CACO3	
FIELD CNDUCTVY, MICROMHOS	446.	TOTAL ALKALINITY AS CACO3	242.93
LAB CNDUCTVY, MICROMHOS	450.	FIELD ALKALINITY AS CACO3	256.
FIELD PH	6.75	RYZNAR STABILITY INDEX	7.40
LABORATORY PH	7.30	LANGLIER SATURATION INDEX	-.05
ADJUSTED SODIUM AD. RATIO		SODIUM ADSORPTION RATIO	.04

PARAMETER	VALUE	PARAMETER	VALUE
FIELD TEMP. AIR	32.0 C	FIELD TEMP. WATER	7.0 C
ALUMINUM, DISS (UG/L-AL)	<30.	NICKEL,DISS (UG/L AS NI)	<10.
SILVER, DISS(UG/L AS AG)	<2.	PHOSPHATE,TO,DIS(MG/L-P)	<.1
BORON,DISS (UG/L AS B)	<20.	STRONTIUM,DISS (UG/L-SR)	340.
CADMIUM,DISS(UG/L AS CD)	<2.	TITANIUM DIS(UG/L AS TI)	7.
CHROMIUM, DISS (UG/L-CR)	<2.	VANADIUM,DISS(UG/L AS V)	<1.
COPPER,DISS (UG/L AS CU)	3.	ZINC, DISS (UG/L AS ZN)	<3.
LITHIUM,DISS(UG/L AS LI)	20.	ZIRCONIUM DIS(UG/L - ZR)	<4.
MOLYBDENUM,DISS(UG/L-MO)	<20.	O-PHOSPHATE,DISS(MG/L-P)	<.1
BROMIDE,DISS(MG/L AS BR)	<.1	ARSENIC,DISS(UG/L AS AS)	.3
SULFIDE,TOTAL(MG/L AS S)	<.1	SELENIUM, DISS (UG/L-SE)	.2
DISSLD SOLIDS(CALC MG/L)	255.		

REMARKS: TRICKLES OVER TOP OF CASING * WATER FROM KOOTENAY FM

EXPLANATION: MG/L = MILLIGRAMS PER LITER, UG/L = MICROGRAMS PER LITER, MEQ/L = MILLIEQUIVALENTS PER LITER. FT = FEET, MT = METERS. (M) = MEASURED, (E) = ESTIMATED, (R) = REPORTED. TR = TOTAL RECOVERABLE. TOT = TOTAL. BIO = BIOLOGICALLY AVAILABLE. SIGMA INCLUDES AL, CU, SR, ZN, AND H+ IF REPORTED.

OTHER AVAILABLE DATA QW WA S2 WI OW PW AT OTHER
OTHER FILE NUMBERS:

LAST EDIT DATE: 29-JAN-87 BY: TP *JKS
PROCESSING PROGRAM: F1730P V4 (12/19/86) PRINTED: 13-FEB-87

PERCENT MEQ/L (FOR PIPER PLOT)

CA	MG	NA	K	CL	SO4	HCO3	CO3
56.0	42.0	1.4	.6	.1	5.2	94.8	.0

NOTE: IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 84Q0667

MONTANA BUREAU OF MINES AND GEOLOGY
BUTTE,MONTANA 59701 (406)496-4101

WATER QUALITY ANALYSIS
LAB NO. 84Q0668

STATE		COUNTY	
LATITUDE-LONGITUDE	49D06'07"N 114D32'53"W	SITE LOCATION	00N 00W 00
UTM COORDINATES	Z N E	MBMG SITE	N-FORK
TOPOGRAPHIC MAP		STATION ID	490607114325301
GEOLOGIC SOURCE	124KSNN* * *	SAMPLE SOURCE	TEST HOLE
DRAINAGE BASIN		LAND SURFACE ALTITUDE	4415. FT < 10
AGENCY + SAMPLER	MBMG*RAN	SUSTAINED YIELD	
BOTTLE NUMBER	75-R02A	YIELD MEAS METHOD	
DATE SAMPLED	25-JUL-84	TOTAL DEPTH OF WELL	120.0 FT (M)
TIME SAMPLED	12:30 HOURS	SWL ABOVE(-) OR BELOW GS	3.0 FT (M)
LAB + ANALYST	MBMG*FNA	CASING DIAMETER	6 IN
DATE ANALYZED	16-AUG-84	CASING TYPE	STEEL
SAMPLE HANDLING	4220	COMPLETION TYPE	*
METHOD SAMPLED	BAILED	PERFORATED INTERVAL	
WATER USE	RESEARCH		

SAMPLING SITE BRITISH COLUMBIA, CANADA
GEOLOGIC SOURCE

	MG/L	MEQ/L			MG/L	MEQ/L
CALCIUM (CA)	8.9	.44	BICARBONATE	(HCO3)	303.	4.97
MAGNESIUM (MG)	4.7	.39	CARBONATE	(CO3)	0.	
SODIUM (NA)	99.9	4.35	CHLORIDE	(CL)	.2	.01
POTASSIUM (K)	1.4	.04	SULFATE	(SO4)	9.2	.19
IRON (FE)	.023	.00	NITRATE	(AS N)	.20	.01
MANGANESE (MN)	.066	.00	FLUORIDE	(F)	.1	.01
SILICA (SIO2)	2.6		PHOSPHATE TOT	(AS P)		
TOTAL CATIONS		5.22	TOTAL ANIONS			5.18

STANDARD DEVIATION OF ANION-CATION BALANCE (SIGMA) -.224

CALCULATED DISSOLVED SOLIDS	276.55	TOTAL HARDNESS AS CACO3	41.56
SUM OF DISS. CONSTITUENT	430.28	FIELD HARDNESS AS CACO3	
FIELD CNDUCTVY, MICROMHOS	467.	TOTAL ALKALINITY AS CACO3	248.51
LAB CNDUCTVY, MICROMHOS	460.	FIELD ALKALINITY AS CACO3	266.
FIELD PH	8.37	RYZNAR STABILITY INDEX	8.09
LABORATORY PH	8.22	LANGLIER SATURATION INDEX	.06
ADJUSTED SODIUM AD. RATIO		SODIUM ADSORPTION RATIO	6.74

PARAMETER	VALUE	PARAMETER	VALUE
FIELD TEMP. AIR	34. C	FIELD TEMP. WATER	19.5 C
ALUMINUM, DISS (UG/L-AL)	<30.	NICKEL,DISS (UG/L AS NI)	<10.
SILVER, DISS(UG/L AS AG)	<2.	PHOSPHATE,TO,DIS(MG/L-P)	<.1
BORON,DISS (UG/L AS B)	50.	STRONTIUM,DISS (UG/L-SR)	320.
CADMIUM,DISS(UG/L AS CD)	<2.	TITANIUM DIS(UG/L AS TI)	<1.
CHROMIUM, DISS (UG/L-CR)	<2.	VANADIUM,DISS(UG/L AS V)	<1.
COPPER,DISS (UG/L AS CU)	<2.	ZINC, DISS (UG/L AS ZN)	<3.
LITHIUM,DISS(UG/L AS LI)	30.	ZIRCONIUM DIS(UG/L - ZR)	<4.
MOLYBDENUM,DISS(UG/L-MO)	<20.	O-PHOSPHATE,DISS(MG/L-P)	<.1
BROMIDE,DISS(MG/L AS BR)	<.1	ARSENIC,DISS(UG/L AS AS)	.1
SULFIDE,TOTAL(MG/L AS S)	<.1	SELENIUM, DISS (UG/L-SE)	.3
DISSLD SOLIDS(CALC MG/L)	277.		

REMARKS: SHOULD RESAMPLE WITH A PUMP * WATER FROM KISHENEN FM
LAB: APPROXIMATELY 1 MG/L NO2

EXPLANATION: MG/L = MILLIGRAMS PER LITER, UG/L = MICROGRAMS PER LITER, MEQ/L = MILLIEQUIVALENTS PER LITER. FT = FEET, MT = METERS. (M) = MEASURED, (E) = ESTIMATED, (R) = REPORTED. TR = TOTAL RECOVERABLE. TOT = TOTAL. BIO = BIOLOGICALLY AVAILABLE. SIGMA INCLUDES AL, CU, SR, ZN, AND H+ IF REPORTED.

QW WA S2 WI OW PW AT OTHER
OTHER AVAILABLE DATA
OTHER FILE NUMBERS:

LAST EDIT DATE: 29-JAN-87 BY: TP *JKS
PROCESSING PROGRAM: F1730P V4 (12/19/86) PRINTED: 13-FEB-87

PERCENT MEQ/L (FOR PIPER PLOT)

CA	MG	NA	K	CL	SO4	HCO3	CO3
8.5	7.4	83.3	.7	.1	3.7	96.2	.0

NOTE: IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 84Q0668

MONTANA BUREAU OF MINES AND GEOLOGY
BUTTE,MONTANA 59701 (406)496-4101

WATER QUALITY ANALYSIS
LAB NO: 84Q0669

STATE		COUNTY	
LATITUDE-LONGITUDE	49D06'33"N 114D32'56"W	SITE LOCATION	00N 00W 00
UTM COORDINATES	Z N E	MBMG SITE	N-FORK
TOPOGRAPHIC MAP		STATION ID	490633114325601
GEOLOGIC SOURCE	* * *	SAMPLE SOURCE	TEST HOLE
DRAINAGE BASIN		LAND SURFACE ALTITUDE	4400. FT < 10
AGENCY + SAMPLER	MBMG*RAN	SUSTAINED YIELD	
BOTTLE NUMBER	75-R-03	YIELD MEAS METHOD	
DATE SAMPLED	25-JUL-84	TOTAL DEPTH OF WELL	
TIME SAMPLED	14:30 HOURS	SWL ABOVE(-) OR BELOW GS	FLOWING
LAB + ANALYST	MBMG*FNA	CASING DIAMETER	6 IN
DATE ANALYZED	16-AUG-84	CASING TYPE	STEEL
SAMPLE HANDLING	4220	COMPLETION TYPE	*
METHOD SAMPLED	GRAB	PERFORATED INTERVAL	
WATER USE	RESEARCH		

SAMPLING SITE BRITISH COLUMBIA, CANADA
GEOLOGIC SOURCE

	MG/L	MEQ/L		MG/L	MEQ/L
CALCIUM (CA)	49.6	2.48	BICARBONATE (HCO3)	274.3	4.50
MAGNESIUM (MG)	25.2	2.07	CARBONATE (CO3)	0.	
SODIUM (NA)	4.4	.19	CHLORIDE (CL)	.2	.01
POTASSIUM (K)	1.5	.04	SULFATE (SO4)	8.8	.18
IRON (FE)	.42	.02	NITRATE (AS N)	.13	.01
MANGANESE (MN)	.018	.00	FLUORIDE (F)	.2	.01
SILICA (SIO2)	7.7		PHOSPHATE TOT (AS P)		
TOTAL CATIONS		4.81	TOTAL ANIONS		4.70

STANDARD DEVIATION OF ANION-CATION BALANCE (SIGMA) -.648

CALCULATED DISSOLVED SOLIDS	233.29	TOTAL HARDNESS AS CACO3	227.57
SUM OF DISS. CONSTITUENT	372.46	FIELD HARDNESS AS CACO3	
FIELD CNDUCTVY, MICROMHOS	424.	TOTAL ALKALINITY AS CACO3	224.97
LAB CNDUCTVY, MICROMHOS	415.	FIELD ALKALINITY AS CACO3	208.
FIELD PH	6.98	RYZNAR STABILITY INDEX	7.45
LABORATORY PH	7.45	LANGLIER SATURATION INDEX	-.00
ADJUSTED SODIUM AD. RATIO		SODIUM ADSORPTION RATIO	.12

PARAMETER	VALUE	PARAMETER	VALUE
FIELD TEMP. AIR	34.0 C	FIELD TEMP. WATER	9.0 C
ALUMINUM, DISS (UG/L-AL)	30.	NICKEL,DISS (UG/L AS NI)	<10.
SILVER, DISS(UG/L AS AG)	6.	PHOSPHATE,TO,DIS(MG/L-P)	.2
BORON,DISS (UG/L AS B)	60.	STRONTIUM,DISS (UG/L-SR)	560.
CADMIUM,DISS(UG/L AS CD)	<2.	TITANIUM DIS(UG/L AS TI)	8.
CHROMIUM, DISS (UG/L-CR)	6.	VANADIUM,DISS(UG/L AS V)	9.
COPPER,DISS (UG/L AS CU)	10.	ZINC, DISS (UG/L AS ZN)	7.
LITHIUM,DISS(UG/L AS LI)	39.	ZIRCONIUM DIS(UG/L - ZR)	10.
MOLYBDENUM,DISS(UG/L-MO)	20.	O-PHOSPHATE,DISS(MG/L-P)	.2
BROMIDE,DISS(MG/L AS BR)	<.1	ARSENIC,DISS(UG/L AS AS)	.3
SULFIDE,TOTAL(MG/L AS S)	<.1	SELENIUM, DISS (UG/L-SE)	.3
DISSLD SOLIDS(CALC MG/L)	233.		

REMARKS: TRICKLE FLOW OUT HOLE BELOW TOC * WATER FROM KOOTENAY FM *

EXPLANATION: MG/L = MILLIGRAMS PER LITER, UG/L = MICROGRAMS PER LITER, MEQ/L = MILLIEQUIVALENTS PER LITER. FT = FEET, MT = METERS. (M) = MEASURED, (E) = ESTIMATED, (R) = REPORTED. TR = TOTAL RECOVERABLE. TOT = TOTAL. BIO = BIOLOGICALLY AVAILABLE. SIGMA INCLUDES AL, CU, SR, ZN, AND H+ IF REPORTED.

QW WA S2 WI OW PW AT OTHER
OTHER AVAILABLE DATA
OTHER FILE NUMBERS:

LAST EDIT DATE: 29-JAN-87 BY: TP *JKS
PROCESSING PROGRAM: F1730P V4 (12/19/86) PRINTED: 13-FEB-87

PERCENT MEQ/L (FOR PIPER PLOT)

CA	MG	NA	K	CL	SO4	HCO3	CO3
51.7	43.3	4.0	.8	.1	3.9	96.1	.0

NOTE: IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 84Q0669

MONTANA BUREAU OF MINES AND GEOLOGY
BUTTE,MONTANA 59701 (406)496-4101

WATER QUALITY ANALYSIS
LAB NO. 84Q0670

STATE		COUNTY	
LATITUDE-LONGITUDE	49D05'55"N 114D33'17"W	SITE LOCATION	00N 00W 00
UTM COORDINATES	Z N E	MBMG SITE	N-FORK
TOPOGRAPHIC MAP		STATION ID	490555114331701
GEOLOGIC SOURCE	* * *	SAMPLE SOURCE	TEST HOLE
DRAINAGE BASIN		LAND SURFACE ALTITUDE	4440. FT < 10
AGENCY + SAMPLER	MBMG*RAN	SUSTAINED YIELD	
BOTTLE NUMBER	75-R-12	YIELD MEAS METHOD	
DATE SAMPLED	25-JUL-84	TOTAL DEPTH OF WELL	
TIME SAMPLED	11:30 HOURS	SWL ABOVE(-) OR BELOW GS	FLOWING
LAB + ANALYST	MBMG*FNA	CASING DIAMETER	6 IN
DATE ANALYZED	16-AUG-84	CASING TYPE	STEEL
SAMPLE HANDLING	4220	COMPLETION TYPE	*
METHOD SAMPLED	GRAB	PERFORATED INTERVAL	
WATER USE	RESEARCH		

SAMPLING SITE BRITISH COLUMBIA, CANADA
GEOLOGIC SOURCE

	MG/L	MEQ/L		MG/L	MEQ/L
CALCIUM (CA)	63.6	3.17	BICARBONATE (HCO3)	304.	4.98
MAGNESIUM (MG)	22.	1.81	CARBONATE (CO3)	0.	
SODIUM (NA)	3.7	.16	CHLORIDE (CL)	.2	.01
POTASSIUM (K)	.9	.02	SULFATE (SO4)	11.9	.25
IRON (FE)	2.95	.16	NITRATE (AS N)	.06	.00
MANGANESE (MN)	.050	.00	FLUORIDE (F)	<.1	
SILICA (SIO2)	7.6		PHOSPHATE TOT (AS P)		
TOTAL CATIONS		5.33	TOTAL ANIONS		5.23

STANDARD DEVIATION OF ANION-CATION BALANCE (SIGMA) -.530

CALCULATED DISSOLVED SOLIDS	262.71	TOTAL HARDNESS AS CACO3	249.36
SUM OF DISS. CONSTITUENT	416.96	FIELD HARDNESS AS CACO3	
FIELD CNDUCTVY, MICROMHOS	474.	TOTAL ALKALINITY AS CACO3	249.33
LAB CNDUCTVY, MICROMHOS	457.	FIELD ALKALINITY AS CACO3	256.
FIELD PH	6.83	RYZNAR STABILITY INDEX	7.53
LABORATORY PH	6.96	LANGLIER SATURATION INDEX	-.28
ADJUSTED SODIUM AD. RATIO		SODIUM ADSORPTION RATIO	.10

PARAMETER	VALUE	PARAMETER	VALUE
FIELD TEMP. AIR	30.0 C	FIELD TEMP. WATER	8.0 C
ALUMINUM, DISS (UG/L-AL)	<30.	NICKEL,DISS (UG/L AS NI)	<10.
SILVER, DISS(UG/L AS AG)	<2.	PHOSPHATE,TO,DIS(MG/L-P)	<.1
BORON,DISS (UG/L AS B)	<20.	STRONTIUM,DISS (UG/L-SR)	400.
CADMIUM,DISS(UG/L AS CD)	<2.	TITANIUM DIS(UG/L AS TI)	7.
CHROMIUM, DISS (UG/L-CR)	<2.	VANADIUM,DISS(UG/L AS V)	<1.
COPPER,DISS (UG/L AS CU)	<2.	ZINC, DISS (UG/L AS ZN)	3.
LITHIUM,DISS(UG/L AS LI)	17.	ZIRCONIUM DIS(UG/L - ZR)	<4.
MOLYBDENUM,DISS(UG/L-MO)	<20.	O-PHOSPHATE,DISS(MG/L-P)	<.1
BROMIDE,DISS(MG/L AS BR)	<.1	ARSENIC,DISS(UG/L AS AS)	.5
SULFIDE,TOTAL(MG/L AS S)	<.1	SELENIUM, DISS (UG/L-SE)	.4
DISSLD SOLIDS(CALC MG/L)	263.		

REMARKS: LEFT GRAY RESIDUE ON FILTER; FLOW ABOUT 3 GPM * WATER FROM KOOTENAY FM

EXPLANATION: MG/L = MILLIGRAMS PER LITER, UG/L = MICROGRAMS PER LITER, MEQ/L = MILLIEQUIVALENTS PER LITER. FT = FEET, MT = METERS. (M) = MEASURED, (E) = ESTIMATED, (R) = REPORTED. TR = TOTAL RECOVERABLE. TOT = TOTAL. BIO = BIOLOGICALLY AVAILABLE. SIGMA INCLUDES AL, CU, SR, ZN, AND H+ IF REPORTED.

QW WA S2 WI OW PW AT OTHER
OTHER AVAILABLE DATA
OTHER FILE NUMBERS:

LAST EDIT DATE: 29-JAN-87 BY: TP *JKS
PROCESSING PROGRAM: F1730P V4 (12/19/86) PRINTED: 13-FEB-87

PERCENT MEQ/L (FOR PIPER PLOT)

CA	MG	NA	K	CL	SO4	HCO3	CO3
61.4	35.0	3.1	.4	.1	4.7	95.3	.0

NOTE: IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 84Q0670

MONTANA BUREAU OF MINES AND GEOLOGY — WATER QUALITY ANALYSIS
BUTTE,MONTANA 59701 (406)496-4101 — LAB NO: 84Q0671

STATE		COUNTY	
LATITUDE-LONGITUDE	49D06'22"N 114D32'56"W	SITE LOCATION	00N 00W 00
UTM COORDINATES	Z N E	MBMG SITE	N-FORK
TOPOGRAPHIC MAP		STATION ID	490622114325601
GEOLOGIC SOURCE	* * *	SAMPLE SOURCE	TEST HOLE
DRAINAGE BASIN		LAND SURFACE ALTITUDE	4500. FT < 10
AGENCY + SAMPLER	MBMG*RAN	SUSTAINED YIELD	
BOTTLE NUMBER	7443	YIELD MEAS METHOD	
DATE SAMPLED	25-JUL-84	TOTAL DEPTH OF WELL	
TIME SAMPLED	15:30 HOURS	SWL ABOVE(-) OR BELOW GS	FLOWING
LAB + ANALYST	MBMG*FNA	CASING DIAMETER	6 IN
DATE ANALYZED	16-AUG-84	CASING TYPE	STEEL
SAMPLE HANDLING	4220	COMPLETION TYPE	*
METHOD SAMPLED	GRAB	PERFORATED INTERVAL	
WATER USE	RESEARCH		

SAMPLING SITE BRITISH COLUMBIA, CANADA
GEOLOGIC SOURCE

	MG/L	MEQ/L		MG/L	MEQ/L
CALCIUM (CA)	44.6	2.23	BICARBONATE (HCO3)	229.8	3.77
MAGNESIUM (MG)	21.3	1.75	CARBONATE (CO3)	0.	
SODIUM (NA)	.6	.03	CHLORIDE (CL)	.2	.01
POTASSIUM (K)	1.	.03	SULFATE (SO4)	14.8	.31
IRON (FE)	.65	.03	NITRATE (AS N)	.06	.00
MANGANESE (MN)	.014	.00	FLUORIDE (F)	.1	.01
SILICA (SIO2)	6.5		PHOSPHATE TOT (AS P)		
TOTAL CATIONS		4.07	TOTAL ANIONS		4.08

STANDARD DEVIATION OF ANION-CATION BALANCE (SIGMA) .104

CALCULATED DISSOLVED SOLIDS	203.02	TOTAL HARDNESS AS CACO3	199.03
SUM OF DISS. CONSTITUENT	319.62	FIELD HARDNESS AS CACO3	
FIELD CNDUCTVY, MICROMHOS	398.	TOTAL ALKALINITY AS CACO3	188.47
LAB CNDUCTVY, MICROMHOS	355.	FIELD ALKALINITY AS CACO3	180.
FIELD PH	7.25	RYZNAR STABILITY INDEX	7.87
LABORATORY PH	7.28	LANGLIER SATURATION INDEX	-.29
ADJUSTED SODIUM AD. RATIO		SODIUM ADSORPTION RATIO	.01

PARAMETER	VALUE	PARAMETER	VALUE
FIELD TEMP. AIR	34.0 C	FIELD TEMP. WATER	6.0 C
ALUMINUM, DISS (UG/L-AL)	<30.	NICKEL,DISS (UG/L AS NI)	<10.
SILVER, DISS(UG/L AS AG)	<2.	PHOSPHATE,TO,DIS(MG/L-P)	.4
BORON,DISS (UG/L AS B)	<20.	STRONTIUM,DISS (UG/L-SR)	270.
CADMIUM,DISS(UG/L AS CD)	<2.	TITANIUM DIS(UG/L AS TI)	2.
CHROMIUM, DISS (UG/L-CR)	<2.	VANADIUM,DISS(UG/L AS V)	<1.
COPPER,DISS (UG/L AS CU)	<2.	ZINC, DISS (UG/L AS ZN)	35.
LITHIUM,DISS(UG/L AS LI)	12.	ZIRCONIUM DIS(UG/L - ZR)	<4.
MOLYBDENUM,DISS(UG/L-MO)	<20.	O-PHOSPHATE,DISS(MG/L-P)	.2
BROMIDE,DISS(MG/L AS BR)	.1	ARSENIC,DISS(UG/L AS AS)	.3
SULFIDE,TOTAL(MG/L AS S)	<.1	SELENIUM, DISS (UG/L-SE)	.4
DISSLD SOLIDS(CALC MG/L)	203.		

REMARKS: CAPPED AND FLOWING APPROXIMATELY 3 GPM * WATER FROM KOOTENAY FM *

EXPLANATION: MG/L = MILLIGRAMS PER LITER, UG/L = MICROGRAMS PER LITER, MEQ/L = MILLIEQUIVALENTS PER LITER. FT = FEET, MT = METERS. (M) = MEASURED, (E) = ESTIMATED, (R) = REPORTED. TR = TOTAL RECOVERABLE. TOT = TOTAL. BIO = BIOLOGICALLY AVAILABLE. SIGMA INCLUDES AL, CU, SR, ZN, AND H+ IF REPORTED.

OTHER AVAILABLE DATA: QW WA S2 WI OW PW AT OTHER
OTHER FILE NUMBERS:

LAST EDIT DATE: 29-JAN-87 BY: TP *JKS
PROCESSING PROGRAM: F1730P V4 (12/19/86) PRINTED: 13-FEB-87

PERCENT MEQ/L (FOR PIPER PLOT)

CA	MG	NA	K	CL	SO4	HCO3	CO3
55.2	43.4	.6	.6	.1	7.6	92.5	.0

NOTE: IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 84Q0671

MONTANA BUREAU OF MINES AND GEOLOGY
BUTTE,MONTANA 59701 (406)496-4101

WATER QUALITY ANALYSIS
LAB NO. 84Q0672

STATE		COUNTY	
LATITUDE-LONGITUDE	49D06'06"N 114D33'15"W	SITE LOCATION	00N 00W 00
UTM COORDINATES	Z N E	MBMG SITE	N-FORK
TOPOGRAPHIC MAP		STATION ID	490606114331501
GEOLOGIC SOURCE	* * *	SAMPLE SOURCE	TEST HOLE
DRAINAGE BASIN		LAND SURFACE ALTITUDE	4600. FT < 10
AGENCY + SAMPLER	MBMG*RAN	SUSTAINED YIELD	
BOTTLE NUMBER	75-D03A	YIELD MEAS METHOD	
DATE SAMPLED	25-JUL-84	TOTAL DEPTH OF WELL	
TIME SAMPLED	16:30 HOURS	SWL ABOVE(-) OR BELOW GS	FLOWING
LAB + ANALYST	MBMG*FNA	CASING DIAMETER	6 IN
DATE ANALYZED	16-AUG-84	CASING TYPE	STEEL
SAMPLE HANDLING	4220	COMPLETION TYPE	*
METHOD SAMPLED	GRAB	PERFORATED INTERVAL	
WATER USE	RESEARCH		

SAMPLING SITE BRITISH COLUMBIA, CANADA
GEOLOGIC SOURCE

	MG/L	MEQ/L		MG/L	MEQ/L
CALCIUM (CA)	53.3	2.66	BICARBONATE (HCO3)	254.2	4.17
MAGNESIUM (MG)	22.4	1.84	CARBONATE (CO3)	0.	
SODIUM (NA)	.5	.02	CHLORIDE (CL)	.1	.00
POTASSIUM (K)	.5	.01	SULFATE (SO4)	19.	.40
IRON (FE)	.52	.03	NITRATE (AS N)	.08	.01
MANGANESE (MN)	.037	.00	FLUORIDE (F)	<.1	
SILICA (SIO2)	6.3		PHOSPHATE TOT (AS P)		
TOTAL CATIONS		4.56	TOTAL ANIONS		4.57

STANDARD DEVIATION OF ANION-CATION BALANCE (SIGMA) .012

CALCULATED DISSOLVED SOLIDS	227.95	TOTAL HARDNESS AS CACO3	225.28
SUM OF DISS. CONSTITUENT	356.93	FIELD HARDNESS AS CACO3	
FIELD CNDUCTVY, MICROMHOS	442.	TOTAL ALKALINITY AS CACO3	208.48
LAB CNDUCTVY, MICROMHOS	407.	FIELD ALKALINITY AS CACO3	210.
FIELD PH	7.18	RYZNAR STABILITY INDEX	7.56
LABORATORY PH	7.34	LANGLIER SATURATION INDEX	-.11
ADJUSTED SODIUM AD. RATIO		SODIUM ADSORPTION RATIO	.01

PARAMETER	VALUE	PARAMETER	VALUE
FIELD TEMP. AIR	32. C	FIELD TEMP. WATER	6.0 C
ALUMINUM, DISS (UG/L-AL)	<30.	NICKEL,DISS (UG/L AS NI)	<10.
SILVER, DISS(UG/L AS AG)	<2.	PHOSPHATE,TO,DIS(MG/L-P)	<.1
BORON,DISS (UG/L AS B)	60.	STRONTIUM,DISS (UG/L-SR)	53.
CADMIUM,DISS(UG/L AS CD)	<2.	TITANIUM DIS(UG/L AS TI)	6.
CHROMIUM, DISS (UG/L-CR)	2.	VANADIUM,DISS(UG/L AS V)	4.
COPPER,DISS (UG/L AS CU)	3.	ZINC, DISS (UG/L AS ZN)	14.
LITHIUM,DISS(UG/L AS LI)	5.	ZIRCONIUM DIS(UG/L - ZR)	<4.
MOLYBDENUM,DISS(UG/L-MO)	30.	O-PHOSPHATE,DISS(MG/L-P)	<.1
BROMIDE,DISS(MG/L AS BR)	<.1	ARSENIC,DISS(UG/L AS AS)	.4
SULFIDE,TOTAL(MG/L AS S)	<.1	SELENIUM, DISS (UG/L-SE)	.5
DISSLD SOLIDS(CALC MG/L)	228.		

REMARKS: FLOWS APPROXIMATELY 1 GPM OUT OF 1 INCH PIPE * WATER FROM KOOTENAY FM

EXPLANATION: MG/L = MILLIGRAMS PER LITER, UG/L = MICROGRAMS PER LITER, MEQ/L = MILLIEQUIVALENTS PER LITER. FT = FEET, MT = METERS. (M) = MEASURED, (E) = ESTIMATED, (R) = REPORTED. TR = TOTAL RECOVERABLE. TOT = TOTAL. BIO = BIOLOGICALLY AVAILABLE. SIGMA INCLUDES AL, CU, SR, ZN, AND H+ IF REPORTED.

OTHER AVAILABLE DATA QW WA S2 WI OW PW AT OTHER
OTHER FILE NUMBERS:

LAST EDIT DATE: 29-JAN-87 BY: TP *JKS
PROCESSING PROGRAM: F1730P V4 (12/19/86) PRINTED: 13-FEB-87

PERCENT MEQ/L (FOR PIPER PLOT)

CA	MG	NA	K	CL	SO4	HCO3	CO3
58.7	40.7	.5	.3	.1	8.7	91.3	.0

NOTE: IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 84Q0672

MONTANA BUREAU OF MINES AND GEOLOGY
BUTTE,MONTANA 59701 (406)496-4101

WATER QUALITY ANALYSIS
LAB NO. 84Q0673

STATE		COUNTY	
LATITUDE-LONGITUDE	49D06'35"N 114D32'56"W	SITE LOCATION	00N 00W 00
UTM COORDINATES	Z N E	MBMG SITE	N-FORK
TOPOGRAPHIC MAP		STATION ID	490635114325601
GEOLOGIC SOURCE	* * *	SAMPLE SOURCE	TEST HOLE
DRAINAGE BASIN		LAND SURFACE ALTITUDE	4450. FT < 10
AGENCY + SAMPLER	MBMG*RAN	SUSTAINED YIELD	
BOTTLE NUMBER	7435	YIELD MEAS METHOD	
DATE SAMPLED	25-JUL-84	TOTAL DEPTH OF WELL	
TIME SAMPLED	14:00 HOURS	SWL ABOVE(-) OR BELOW GS	FLOWING
LAB + ANALYST	MBMG*FNA	CASING DIAMETER	6 IN
DATE ANALYZED	16-AUG-84	CASING TYPE	STEEL
SAMPLE HANDLING	4220	COMPLETION TYPE	*
METHOD SAMPLED	GRAB	PERFORATED INTERVAL	
WATER USE	RESEARCH		

SAMPLING SITE BRITISH COLUMBIA, CANADA
GEOLOGIC SOURCE

	MG/L	MEQ/L		MG/L	MEQ/L
CALCIUM (CA)	44.1	2.20	BICARBONATE (HCO3)	244.5	4.01
MAGNESIUM (MG)	20.9	1.72	CARBONATE (CO3)	0.	
SODIUM (NA)	7.1	.31	CHLORIDE (CL)	.2	.01
POTASSIUM (K)	1.2	.03	SULFATE (SO4)	15.9	.33
IRON (FE)	.27	.01	NITRATE (AS N)	.21	.01
MANGANESE (MN)	.016	.00	FLUORIDE (F)	.1	.01
SILICA (SIO2)	7.9		PHOSPHATE TOT (AS P)		

TOTAL CATIONS 4.28 TOTAL ANIONS 4.36

STANDARD DEVIATION OF ANION-CATION BALANCE (SIGMA) .444

CALCULATED DISSOLVED SOLIDS	218.33	TOTAL HARDNESS AS CACO3	196.14
SUM OF DISS. CONSTITUENT	342.39	FIELD HARDNESS AS CACO3	
FIELD CNDUCTVY, MICROMHOS	460.	TOTAL ALKALINITY AS CACO3	200.53
LAB CNDUCTVY, MICROMHOS	380.	FIELD ALKALINITY AS CACO3	218.
FIELD PH	7.11	RYZNAR STABILITY INDEX	7.64
LABORATORY PH	7.46	LANGLIER SATURATION INDEX	-.09
ADJUSTED SODIUM AD. RATIO		SODIUM ADSORPTION RATIO	.22

PARAMETER	VALUE	PARAMETER	VALUE
FIELD TEMP. AIR	34.0 C	FIELD TEMP. WATER	6.0 C
ALUMINUM, DISS (UG/L AL)	<30.	NICKEL,DISS (UG/L AS NI)	<10.
SILVER, DISS(UG/L AS AG)	<2.	PHOSPHATE,TO,DIS(MG/L-P)	.5
BORON,DISS (UG/L AS B)	60.	STRONTIUM,DISS (UG/L-SR)	620.
CADMIUM,DISS(UG/L AS CD)	<2.	TITANIUM DIS(UG/L AS TI)	2.
CHROMIUM, DISS (UG/L-CR)	<2.	VANADIUM,DISS(UG/L AS V)	<1.
COPPER,DISS (UG/L AS CU)	<2.	ZINC, DISS (UG/L AS ZN)	<3.
LITHIUM,DISS(UG/L AS LI)	35.	ZIRCONIUM DIS(UG/L - ZR)	<4.
MOLYBDENUM,DISS(UG/L-MO)	<20.	O-PHOSPHATE,DISS(MG/L-P)	.2
BROMIDE,DISS(MG/L AS BR)	.1	ARSENIC,DISS(UG/L AS AS)	.3
SULFIDE,TOTAL(MG/L AS S)	<.1	SELENIUM, DISS (UG/L-SE)	.3
DISSLD SOLIDS(CALC MG/L)	218.		

REMARKS: WELL FLOWS A TRICKLE * WATER FROM KOOTENAY FM

EXPLANATION: MG/L = MILLIGRAMS PER LITER, UG/L = MICROGRAMS PER LITER, MEQ/L = MILLIEQUIVALENTS PER LITER. FT = FEET, MT = METERS. (M) = MEASURED, (E) = ESTIMATED, (R) = REPORTED. TR = TOTAL RECOVERABLE. TOT = TOTAL. BIO = BIOLOGICALLY AVAILABLE. SIGMA INCLUDES AL, CU, SR, ZN, AND H+ IF REPORTED.

QW WA S2 WI OW PW AT OTHER
OTHER AVAILABLE DATA
OTHER FILE NUMBERS:

LAST EDIT DATE: 29-JAN-87 BY: TP *JKS
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PERCENT MEQ/L (FOR PIPER PLOT)

CA	MG	NA	K	CL	SO4	HCO3	CO3
51.6	40.3	7.2	.7	.1	7.6	92.3	.0

NOTE: IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 84Q0673

MONTANA BUREAU OF MINES AND GEOLOGY
BUTTE, MONTANA 59701 (406)496-4101

WATER QUALITY ANALYSIS
LAB NO: 84Q0688

STATE		COUNTY	
LATITUDE-LONGITUDE	49D05'34"N 114D32'10"W	SITE LOCATION	00N 00W 00
UTM COORDINATES	Z N E	MBMG SITE	N-FORK
TOPOGRAPHIC MAP		STATION ID	490534114321001
GEOLOGIC SOURCE	* * *	SAMPLE SOURCE	STREAM
DRAINAGE BASIN		LAND SURFACE ALTITUDE	4285. FT < 10
AGENCY + SAMPLER	MBMG*RAN	WATER FLOW RATE	
BOTTLE NUMBER	HOWELL	FLOW MEAS METHOD	
DATE SAMPLED	31-JUL-84	STAFF GAGE	
TIME SAMPLED	16:00 HOURS	STREAM STAGE	
LAB + ANALYST	MBMG*FNA	DEPTH TO SAMPLE	
DATE ANALYZED	16-AUG-84	TOTAL DEPTH OF WATER	
SAMPLE HANDLING	7120	STREAM WIDTH	55. FT
METHOD SAMPLED	FLOW COMPOSITE		
WATER USE	UNUSED		

SAMPLING SITE HOWELL CREEK * BRITISH COLUMBIA, CANADA
DRAINAGE BASIN

	MG/L	MEQ/L		MG/L	MEQ/L
CALCIUM (CA)	42.5	2.12	BICARBONATE (HCO3)	166.	2.72
MAGNESIUM (MG)	8.	.66	CARBONATE (CO3)	0.	
SODIUM (NA)	.5	.02	CHLORIDE (CL)	<.1	
POTASSIUM (K)	<.1		SULFATE (SO4)	6.	.12
IRON (FE)	<.002		NITRATE (AS N)	.06	.00
MANGANESE (MN)	.001	.00	FLUORIDE (F)	<.1	
SILICA (SIO2)	4.8		PHOSPHATE TOT (AS P)		

TOTAL CATIONS 2.80 TOTAL ANIONS 2.84

STANDARD DEVIATION OF ANION-CATION BALANCE (SIGMA) .324

CALCULATED DISSOLVED SOLIDS	143.63	TOTAL HARDNESS AS CACO3	139.05
SUM OF DISS. CONSTITUENT	227.86	FIELD HARDNESS AS CACO3	
FIELD CNDUCTVY, MICROMHOS	252.	TOTAL ALKALINITY AS CACO3	136.14
LAB CNDUCTVY, MICROMHOS	252.8	FIELD ALKALINITY AS CACO3	
FIELD PH	7.18	RYZNAR STABILITY INDEX	7.31
LABORATORY PH	8.16	LANGLIER SATURATION INDEX	.42
ADJUSTED SODIUM AD. RATIO		SODIUM ADSORPTION RATIO	.01

PARAMETER	VALUE	PARAMETER	VALUE
FIELD TEMP. AIR	30. C	FIELD TEMP. WATER	13.5 C
ALUMINUM, DISS (UG/L-AL)	<30.	NICKEL,DISS (UG/L AS NI)	<10.
SILVER, DISS(UG/L AS AG)	<2.	PHOSPHATE,TO,DIS(MG/L-P)	<.1
BORON,DISS (UG/L AS B)	60.	STRONTIUM,DISS (UG/L-SR)	54.
CADMIUM,DISS(UG/L AS CD)	<2.	TITANIUM DIS(UG/L AS TI)	6.
CHROMIUM, DISS (UG/L-CR)	<5.	VANADIUM,DISS(UG/L AS V)	<1.
COPPER,DISS (UG/L AS CU)	<2.	ZINC, DISS (UG/L AS ZN)	<3.
LITHIUM,DISS(UG/L AS LI)	<2.	ZIRCONIUM DIS(UG/L ZR)	<4.
MOLYBDENUM,DISS(UG/L-MO)	<20.	O-PHOSPHATE,DISS(MG/L-P)	<.1
BROMIDE,DISS(MG/L AS BR)	.2	ARSENIC,DISS(UG/L AS AS)	.7
MERCURY,DISS(UG/L AS HG)	<.04	SEDIMENT, TOTAL (MG/L)	2.1
DISSLD SOLIDS(CALC MG/L)	144.		

REMARKS: CLEAR AND COLD
CHANNEL IS ABOUT 55 FEET WIDE WHERE SAMPLED AND FLOWS VERY SWIFTLY;
MAXIMUM DEPTH 1.8 FEET

EXPLANATION: MG/L = MILLIGRAMS PER LITER, UG/L = MICROGRAMS PER LITER, MEQ/L = MILLIEQUIVALENTS PER LITER. FT = FEET, MT = METERS. (M) = MEASURED, (E) = ESTIMATED, (R) = REPORTED. TR = TOTAL RECOVERABLE. TOT = TOTAL. BIO = BIOLOGICALLY AVAILABLE. SIGMA INCLUDES AL, CU, SR, ZN, AND H+ IF REPORTED.

QW WA S2 WI OW PW AT OTHER
OTHER AVAILABLE DATA
OTHER FILE NUMBERS:

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PERCENT MEQ/L (FOR PIPER PLOT)

CA	MG	NA	K	CL	SO4	HCO3	CO3
75.7	23.5	.8	.0	.0	4.4	95.9	.0

NOTE: IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 84Q0688

MONTANA BUREAU OF MINES AND GEOLOGY
BUTTE, MONTANA 59701 (406)496-4101

WATER QUALITY ANALYSIS
LAB NO. 84Q0689

STATE		COUNTY	
LATITUDE-LONGITUDE	49D05'33"N 114D32'14"W	SITE LOCATION	00N 00W 00
UTM COORDINATES	Z N E	MBMG SITE	N-FORK
TOPOGRAPHIC MAP		STATION ID	490533114321401
GEOLOGIC SOURCE	* * *	SAMPLE SOURCE	STREAM
DRAINAGE BASIN		LAND SURFACE ALTITUDE	4290. FT < 10
AGENCY + SAMPLER	MBMG*RAN	WATER FLOW RATE	
BOTTLE NUMBER	CABIN C	FLOW MEAS METHOD	
DATE SAMPLED	31-JUL-84	STAFF GAGE	
TIME SAMPLED	17:00 HOURS	STREAM STAGE	
LAB + ANALYST	MBMG*FNA	DEPTH TO SAMPLE	
DATE ANALYZED	16-AUG-84	TOTAL DEPTH OF WATER	
SAMPLE HANDLING	5120	STREAM WIDTH	22. FT (M)
METHOD SAMPLED	FLOW COMPOSITE		
WATER USE			

SAMPLING SITE CABIN CREEK * BRITISH COLUMBIA, CANADA
DRAINAGE BASIN

	MG/L	MEQ/L		MG/L	MEQ/L
CALCIUM (CA)	37.2	1.86	BICARBONATE (HCO3)	161.	2.64
MAGNESIUM (MG)	10.4	.86	CARBONATE (CO3)	0.	
SODIUM (NA)	1.	.04	CHLORIDE (CL)	.2	.01
POTASSIUM (K)	.2	.01	SULFATE (SO4)	9.9	.21
IRON (FE)	<.002		NITRATE (AS N)	.22	.02
MANGANESE (MN)	.002	.00	FLUORIDE (F)	.1	.01
SILICA (SIO2)	5.2		PHOSPHATE TOT (AS P)		
TOTAL CATIONS		2.76	TOTAL ANIONS		2.87

STANDARD DEVIATION OF ANION-CATION BALANCE (SIGMA) .740

CALCULATED DISSOLVED SOLIDS	143.73	TOTAL HARDNESS AS CACO3	135.69
SUM OF DISS. CONSTITUENT	225.42	FIELD HARDNESS AS CACO3	
FIELD CNDUCTVY, MICROMHOS	249.	TOTAL ALKALINITY AS CACO3	132.04
LAB CNDUCTVY, MICROMHOS	249.3	FIELD ALKALINITY AS CACO3	
FIELD PH	8.22	RYZNAR STABILITY INDEX	7.40
LABORATORY PH	8.21	LANGLIER SATURATION INDEX	.40
ADJUSTED SODIUM AD. RATIO		SODIUM ADSORPTION RATIO	.03

PARAMETER	VALUE	PARAMETER	VALUE
FIELD TEMP. AIR	30.0 C	FIELD TEMP. WATER	17.5 C
ALUMINUM, DISS (UG/L-AL)	<30.	NICKEL,DISS (UG/L AS NI)	<10.
SILVER, DISS(UG/L AS AG)	<2.	PHOSPHATE,TO,DIS(MG/L-P)	<.1
BORON,DISS (UG/L AS B)	<20.	STRONTIUM,DISS (UG/L SR)	76.
CADMIUM,DISS(UG/L AS CD)	<2.	TITANIUM DIS(UG/L AS TI)	4.
CHROMIUM, DISS (UG/L-CR)	<2.	VANADIUM,DISS(UG/L AS V)	<1.
COPPER,DISS (UG/L AS CU)	<2.	ZINC, DISS (UG/L AS ZN)	<3.
LITHIUM,DISS(UG/L AS LI)	<2.	ZIRCONIUM DIS(UG/L - ZR)	<4.
MOLYBDENUM,DISS(UG/L-MO)	<20.	O-PHOSPHATE,DISS(MG/L-P)	<.1
BROMIDE,DISS(MG/L AS BR)	.2	ARSENIC,DISS(UG/L AS AS)	.9
MERCURY,DISS(UG/L AS HG)	<.04	SEDIMENT, TOTAL (MG/L)	1.9
DISSLD SOLIDS(CALC MG/L)	144.		

REMARKS: THIS STREAM WAS NOT FLOWING NEARLY AS SWIFTLY AS HOWELL CREEK

EXPLANATION: MG/L = MILLIGRAMS PER LITER, UG/L = MICROGRAMS PER LITER, MEQ/L = MILLIEQUIVALENTS PER LITER. FT = FEET, MT = METERS. (M) = MEASURED, (E) = ESTIMATED, (R) = REPORTED. TR = TOTAL RECOVERABLE. TOT = TOTAL. BIO = BIOLOGICALLY AVAILABLE. SIGMA INCLUDES AL, CU, SR, ZN, AND H+ IF REPORTED.

OTHER AVAILABLE DATA QW WA S2 WI OW PW AT OTHER
OTHER FILE NUMBERS:

LAST EDIT DATE: 29-JAN-87 BY: TP *JKS
PROCESSING PROGRAM: F1730P V4 (12/19/86) PRINTED: 13-FEB 87

PERCENT MEQ/L (FOR PIPER PLOT)

CA	MG	NA	K	CL	SO4	HCO3	CO3
67.3	31.0	1.6	.2	.2	7.2	92.6	.0

NOTE: IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 84Q0689

8.6 APPENDIX 6

Memo of 1982-05-07 from L. Pommen to
R. Rocchini Concerning the Effects of
Explosives on Water Quality

Province of British Columbia Ministry of Environment ASSESSMENT AND PLANNING DIVISION

MEMORANDUM

To: R. Rocchini, P.Eng.,
Acting Head, Services Unit,
Aquatic Studies Branch,
Ministry of Environment,
765 Broughton Street,
Victoria, British Columbia.

Date: May 7, 1982.

File: 0317511-15-d

RE: SAGE CREEK COAL PROJECT-STAGE II SUBMISSION

As requested by J. Arber of the Assessment Branch, and J.D. McDonald, Chairman, Coal Guidelines Steering Committee, the above submission was reviewed and the following comments were prepared on the water quality aspects.

Conclusions

My responses to the 3 questions posed by the Chairman of the Coal Guidelines Steering Committee in his memorandum of March 9, 1982 are:

(i) Stage II approval-in-principle could be granted.

(ii) There are no outstanding issues that must be resolved before granting Stage II approval-in-principle.

(iii) The outstanding Stage II type concerns raised in this memorandum could be deferred to Stage III, if this is acceptable to the Water Management, Waste Management, and Fish and Wildlife Branches.

1. Groundwater Quality

The groundwater that will be encountered during mining was of good quality for the parameters that were measured. An important parameter that was not measured in groundwater is barium. Barium was reported to be relatively high in surface water (up to 2.0 mgL^{-1}), and this was attributed to groundwater discharge from barite (barium sulphate) deposits (Text, p. 3-45). It is thus possible that the groundwater that will be discharged from the pits during mining may have elevated barium concentrations, although the barium content of the materials to be mined was low (0.05 to 0.1%, Appendix 4.3.5.1). The quantity of groundwater that will be pumped from the pits is substantial (0.45 - 0.68 m^3s^{-1}, total for both pits, Text p. 3-38) and thus it may have an effect on surface water quality when discharged if it is high in barium. In addition, the drinking water supply for the mine will be obtained from wells.

It is noted that further groundwater studies will be conducted during Stage III (Text, p.4-79). It is recommended that these studies include the measurement of dissolved and total barium in the groundwater that will be pumped from the pits, and in the groundwater that will be used for the drinking water supply. The results, and a discussion of any impacts and needed mitigative measures should be submitted to the Ministry of Environment.

2. The Effects of Explosives on Water Quality

(a) Summary

The effects of explosives on water quality have not been well addressed in the Stage II submission. The potential impacts and proposed mitigative measures have not been well defined. This is due in part to the lack of information on this subject, but the consultants have not availed themselves of the information that is available within the Ministry of Environment.

My assessment is that the effects of explosives on water quality due to the project will not be as minor as has been predicted, but that the impacts should be manageable if some additional mitigative measures are used. Consequently, rather than recommending further work on this issue during Stage II, I have outlined the shortcomings of the Stage II submission, and presented my assessment of probable impacts and needed mitigation for consideration during Stage III.

(b) Impact Prediction

The effect of nitrogen losses from explosives use on water quality was modelled using the QUAL II water quality model. Minor increases in inorganic nitrogen were predicted in Cabin Creek (0.26 $mgL^{-1}N$) and Howell Creek downstream from Cabin Creek (0.15 $mgL^{-1}N$). The modelling has the following shortcomings:

- the nitrogen inputs to water from the mine were an order of magnitude too low. The QUAL II printouts in Appendix 4.3.2-1 indicate that inputs of about 37. $kgd^{-1}N$ were used. A 5% nitrogen loss would result in 160 000 $kgy^{-1}N$ input to water (Text, p. 4-28), or about 440 $kgd^{-1}N$.

- the streamflows used were too high. A flow of about 4. m^3s^{-1} at the mouth of Howell Creek was used to represent summer low flow conditions. The flow records for the Flathead River at Flathead (1, 2) suggest that the average summer (June through September) low flows in Howell Creek at the mouth should be about 2. m^3s^{-1}, and that the minimum summer low flows should be about 1. m^3s^{-1} (i.e. 7 day average June - September low flow with a 10 year return period).

  In addition, the minimum flow of the year was not modelled to indicate the maximum nitrogen concentrations that could be expected. The minimum flows in Howell Creek at the mouth should be about 0.6 m^3s^{-1} based on Flathead River flows (i.e. 7 day average annual low flow with a 10 year return period).

- modelling was only conducted to the mouth of Howell Creek. Modelling should have also been conducted on the Flathead River at least to the international boundary in view of the importance of predicting impacts on U.S. waters.

- the nitrogen inputs from the mine were assumed to enter only Cabin and Howell Creeks. This is a rather conservative assumption because a substantial portion of the mine drainage will enter the Flathead River directly, such as the effluent from settling ponds #1 and #3.

- the assumptions used in modelling were poorly documented, and are probably not comprehensible to anyone who is not familiar with the QUAL II model.

My prediction of inorganic nitrogen increases in the receiving waters under worst conditions is:

Assumptions

- 5% loss of nitrogen in explosives, evenly distributed over the year (i.e. $\sim$440 $kgd^{-1}N$). (Losses at Fording Coal were 6% in 1979-80)

- low flows in the Flathead River of 4.8 m^3s^{-1} in summer (10 year - 7 day low flow, June - September) and 2.8 m^3s^{-1} in winter (10 year - 7 day annual low flow).

- low flows in Howell Creek downstream from Cabin Creek of 1 m^3s^{-1} in summer and 0.6 m^3s^{-1} in winter.

Calculations

Flathead River: Summer: N increase $= \frac{440}{4.8 \times 86.4} = 1.1\ mgL^{-1}N$

Winter: N increase $= \frac{440}{2.8 \times 86.4} = 1.8\ mgL^{-1}N$

Howell Creek: Summer: N increase $= \frac{440}{1.0 \times 86.4} = 5.1\ mgL^{-1}N$

Winter: N increase $= \frac{440}{0.6 \times 86.4} = 8.5\ mgL^{-1}N$

The above N increases in Howell Creek are overestimates because not all of the N will be discharged to Howell and Cabin Creeks; some of it will be discharged directly to the Flathead River. The maximum N increases in Howell Creek would lie somewhere between 1.8 and 8.5 $mgL^{-1}N$. The inorganic nitrogen would probably be almost entirely as nitrate with minor amounts of nitrite and ammonia, because the proposed water management system would allow almost complete nitrification of explosives - contaminated mine drainage. The use of mitigation techniques as outlined in Section 2(c) below would reduce the inorganic nitrogen increases predicted above.

The impact of increasing nitrate levels in the receiving waters would probably be moderate to heavy increases in benthic algal growth downstream from the settling pond discharges. At Fording Coal Ltd., moderate increases in benthic algal growth were experienced in the Fording River downstream from settling pond discharges, despite very low dissolved ortho-phosphorus levels (< 3 ugL^{-1}) in the Fording River upstream from the mine. Phosphorus levels in Howell Creek upstream from Cabin Creek are similar to those in the Fording River, and thus moderate increases in benthic algal growth could occur downstream from settling pond #4. The dissolved ortho-phosphorus levels in Cabin Creek, upstream from Howell Creek, are relatively high at times (7 to 38 μgL^{-1}, Tables 8 and 9, Appendix 3.3.3-1), and nitrogen appears to be the limiting algal nutrient (N:P = 5:1 or less). Consequently, heavy increases in benthic algal growth could occur in Cabin Creek downstream from settling pond #2.

The reaches of Cabin and Howell Creeks immediately downstream from settling ponds #2 and #4 are bull trout spawning areas (Map 3.3.6-1), and moderate to heavy increases in algal growth may be detrimental to spawning and egg survival. Consideration should be given to relocating the discharges from ponds #2 and #4 to minimize the amount of spawning area affected. Moving the decant and spillway for pond #2 further downstream on Cabin and Howell Creeks would place them downstream from most of the known redds. Consideration should be given to eliminating the discharges to Howell Creek from pond #4 by diverting the water to pond #3 and the Flathead River, thus avoiding a discharge immediately upstream from a large number of redds.

(c) Mitigation Measures

The mitigation measures that would be used to minimize the effects of nitrogen losses from explosives use are generally not well-defined. Dewatering of the pits so that blasting can be conducted under dry conditions is a key factor in minimizing nitrogen losses. The Pacific Hydrology Consultants 1982 report [3] states that wet conditions may be expected during mining unless measures are taken to dewater the mining area. The discussion of dewatering on p. 2-15 and p. 4-24 suggests that dewatering will be done, but a clear commitment to dewater and maximize dry blasting conditions should be made by the company. If the predicted 80% AN/FO, 20% slurry explosives usage (p. 2-15) is achieved, and the slurry is loaded into holes that are free of standing water, then the nitrogen losses should be less than the 5% value used in Section 2(b).

Control of nitrogen losses from explosives storage, blending and handling facilities is another key factor in minimizing impacts, but the location, nature and the spill control and wastewater management plans for these facilities is not described in the report. The company should supply this information to the Waste Management Branch, and these facilities should be brought under Pollution Control permit.

The report states that if nitrogen concentrations in mine drainage "become threatening" further treatment will be applied to reduce nitrogen concentrations (p. 2-49 and p. 4-29). Reduction of ammonia and nitrite concentrations can be achieved relatively easily in settling ponds by nitrification to nitrate . Nitrate can be removed by biological denitrification, but it could be very expensive and difficult to use given the potentially large volumes of mine drainage, and the low ambient temperatures during much of the year. Emphasis should be placed on minimizing nitrogen losses to water through dewatering and spill control, rather than on nitrogen removal methods.

Consideration should be given to maximizing the amount of nitrogen-rich water from pits, spoil piles and explosives facilities that is discharged to the tailing pond for use as make-up water.

Consideration should be given to relocating the discharge from ponds #2 and #4 as outlined in Section 2(b).

3. Miscellaneous

(a) p. 2-42, 2nd last line: overflow velocity should be 5×10^{-5} m/sec not 5×10^{5} m/sec.

(b) Appendix 3.3.3-5: dissolved zinc values are µg/L not mg/L.

(c) Appendix 4.3.5-1: The results of the acid production potential tests (Table 1) is missing.

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References

1. Inland Waters Directorate, Pacific Region, Water Survey of Canada, Low Flows in British Columbia, June - September 7-day Averages, August 1973, Vancouver, B.C.

2. Inland Waters Directorate, Pacific Region, Water Survey of Canada, Low Flows in British Columbia, Annual 7-day Averages, Volume 1, January 1974, Vancouver, B.C.

3. Pacific Hydrology Consultants Ltd., Sage Creek Coal Limited, Stage II Environmental Assessment, Groundwater Study, March 1982.

8.7 APPENDIX 7

Settling Pond Failures at Line Creek

A. MDC Evaluation

B. Bulletin of Ministry of Energy, Mines, and Petroleum Resources

A. MDC EVALUATION

This Appendix has been written to provide information on three topics with respect to settling pond failures at the Crows Nest Resources Line Creek Operation during the week of May 26, 1986.

1. <u>Probable Causes of Failure</u>

At 0325h, May 28 two interior dykes and the spillway dyke of the three cell settling pond known as Pond 4 washed out. Peak flows in West Line Creek above the pond were 0.80 m^3/s and 0.94 m^3/s for May 28 and 29, respectively. The pond is designed to withstand the 200-year flood flow calculated to be 24.7 m^3/s. The interior or baffle dykes have no defined spillway and are designed to discharge over their entire length during high flows.

The breaching of the dykes is related to one or more of the following (Crippen Consultants Ltd. 1986):

i) unevenly constructed dyke crests or uneven settlement of dyke crests causing concentration of flow, excessive velocities, and failure of the rip-rap;
ii) inadequate thickness of rip-rap or filter layer on the spillway dyke;
iii) the use of shale as rip-rap, which disintegrated and resulted in subsidence, leading to concentration of flow; and/or
iv) inadequate filtering between the baffle dyke common fill and the Type B rip-rap.

There is no evidence that the failure of the Pond 4 dykes was due to instability of the dyke section or piping (Crippen Consultants Ltd. 1986).

One interior dyke and the spillway dyke of Pond 6 failed on May 26. This failure is believed to have been caused by one or more of the same factors as outlined above.

2. <u>Impacts of Failure on the Receiving Environment</u>

The only assessment of impacts done to date is the evaluation of total suspended solids (TSS) concentration grab samples and flow data collected at selected monitoring sites during the week of May 26 (Strosher 1986). Highlights of that review are as follows.

Highest TSS concentrations in Line Creek upstream and downstream of the mine were 306 mg/L and 3180 mg/L, respectively; these were both recorded on May 26. Peak concentrations measured in the Fording River upstream and downstream of Line Creek were 534 mg/L and 1040 mg/L, respectively; these were both recorded on May 27. Flows peaked on May 29 in all gauged streams in the area with flow rates which have not been exceeded since 1974.

Total suspended solids loading (over background concentrations of TSS in Line Creek) increased by a factor of 10 in the downstream Line Creek site on three of four sample days. By comparison, upstream to downstream station results from river reaches where no coal mines exist showed TSS loading increased by a factor of 1.5 to 2.5. The substantial increase in Line Creek is attributed mainly to the pond failures.

3. <u>Possibility of Pond Failure at the Sage Creek Coal Limited Site</u>

The interior or baffle dykes at Line Creek had no defined spillway and are designed to discharge over their entire length either by flow through or overtopping during high flows. This design fact is germane to the probable causes of failure outlined in 1 above. Any uneven dyke crest will concentrate flows and contribute to erosion since no one part of the dyke is designed to handle the concentration of flow (see Part B for discussion and recommendations by MEMPR regarding this type of design).

No other settling ponds in the Elk Valley, or at the Sage Creek Coal Limited site, have this type of spillway design. That is, all are designed with specific exterior spillways that concentrate the flow at one specific decant point. Examples include concrete spillways, and corrugated metal pipe decants with inverts equipped with T-skimming devices that are located approximately 1 m (3.3 ft) below the crest of the dyke. None of this type have failed.

Because of the considerable differences in settling pond design between those that failed at Line Creek and those proposed at the Sage Creek Coal Limited site, it is concluded that, from the standpoint of design, it would be unreasonable to consider additional risk of failure of the proposed Sage Creek Coal Limited settling ponds in light of the recent failures at Line Creek. However, the MDC recognises that there may be other reasons for pond failure in addition to design. It is understood that the Province of British Columbia is continuing its investigations into the causes of the settling pond failure at Line Creek. The B.C. Government is also investigating improvements to the approval and inspection process required to reduce the probability of such failures in the future.

Crippen Consultants Ltd. 1986. Report on failure of dykes at Line Creek Settling Ponds. Prepared for Crows Nest Resources Ltd., Sparwood, B.C. 22 pp.

Strosher, M.M. 1986. Total suspended solids concentrations and loading estimates in the upper Elk basin during the week of May 26, 1986. B.C. Ministry of Environment and Parks, Waste Management Branch. 17 pp.

Province of
British Columbia

Ministry of
Energy, Mines and
Petroleum Resources

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B.

BULLETIN

In the Spring of 1986 a number of low dykes at a mine in the East Kootenays were washed away during high flows. The dykes had been designed to serve as overflow weirs, but they failed to meet the criteria of design. The purpose of this bulletin is to warn owners of similar overflows of the dangers inherent in the design.

The dykes in question were less than ten metres in height and were composed of a well compacted mixture of grain sizes ranging from fine particles to cobbles. Overlying this granular core was a layer of dumped rip rap which was spread over the narrow crest and downstream slopes along the entire length of dyke. No provision was made to direct excess flows into spillways or low sections of the dyke; instead, the entire length of dyke was intended to serve as an overflow weir. Even though these dykes had been expected to handle flows exceeding 20 cu. metres per second, several washouts resulted when flows peaked at one-tenth of the design values.

Although the precise mechanism of failure is not known, it has been postulated that the overflows concentrated in preferred channels among the coarse particles of the rip rap and eroded the underlying fine particles in the core. This undermining continued at these weak points until a breach developed. In some places most of the dyke was washed away in a very short period of time.

Mining operators of similar structures should provide spillways through natural ground around their dykes or ensure that flows pass over ground either lined with reinforced concrete or protected by heavy rip rap underlain by an inverted filter. Designers of new installations should eschew such overflow dykes in favour of proper spillways or overflow structures such as concrete weirs or stoplog chutes.

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