BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

HAT CREEK PROJECT

British Columbia Hydro and Power Authority - Hat Creek Project - Environmental Protection Monitoring and Reclamation - December 1980

ENVIRONMENTAL IMPACT STATEMENT REFERENCE NUMBER: 27

B. C. HYDRO AND POWER AUTHORITY

HAT CREEK PROJECT

ENVIRONMENTAL PROTECTION, MONITORING AND RECLAMATION

THERMAL GENERATION PROJECTS DIVISION

December 1980

HAT CREEK PROJECT

ENVIRONMENTAL PROTECTION, MONITORING AND RECLAMATION

1.0 INTRODUCTION

Environmental protection is an integral part of all phases of the Hat Creek thermal powerplant development. Extensive studies to define and document environmental conditions in the region and to assess mitigation measures have been carried out and are continuing. It is planned that an environmental group would be established at the Hat Creek site prior to the start of construction activities. This group would plan and implement the environmental protection programmes before and during construction, throughout the operating life of the powerplant and after decommissioning. The site environmental group would function without interruption from the pre-construction period to after decommissioning of the powerplant, providing continuity to the environmental protection activities.

The major responsibilities of the site environmental group would include monitoring and control of construction activities to minimise local environmental impact, control of dust and noise emissions, control of erosion and surface drainage, control of air emissions and implementation of environmental quality monitoring and land reclamation programmes. These environmental programmes and the manpower and organisation of the group which would carry them out are described in this document.

2.0 ENVIRONMENTAL PROTECTION

2.1 Introduction

The on-site environmental protection programme would commence with site construction activities five years before the in-service date. An environmental group would be established at site immediately prior to the start of construction activities. The size and diversity of this group would increase as the project activities expand. This group would remain through the construction, operating and decommissioning phases to provide complete continuity throughout the life of the project. Assistance would be obtained from B.C. Hydro's head office environmental group or from outside consultants to provide additional expertise in specialised areas.

A major initial responsibility of the site environmental group would be the maintenance and protection of local environmental conditions during the construction phase. Comprehensive environmental protection plans would be developed during detailed design of the site construction activities. At this time it is not possible to describe in detail the organisation and procedures that would be followed. However, a general outline of the major environmental protection activities during construction has been prepared.

2.2 Major Activities

The environmental protection group would provide for an environmental perspective during the development of detailed design. They would develop contingency plans designed to cope with accidental hazards, such as spills of oil and fuels and coordinate emergency procedures with the regulatory authorities.

Monitoring of the air, water and land environments would be carried out prior to and during construction. The environmental protection group would continually compile and evaluate the data from the monitoring programmes and implement any additional remedial measures necessary to protect the local environment.

A partial listing of environmental protection activities to be carried out by the on-site group would include the following:

- ensure the implementation of dust control programmes;
- monitor surface runoff and erosion;
- operation of drainage, sedimentation lagoons;
- arrange for installation of additional or temporary drainage control facilities as required in areas which cannot be serviced by the main lagoons;
- ensure that disturbances to land and waterbodies are minimized and implement any immediate remedial measures necessary;
- supervise operation of the sewage treatment and disposal facilities:
- ensure satisfactory disposal of garbage and construction debris;
- assist with the commissioning of Hat Creek and other surface water diversion systems;
- carry out reclamation of disturbed areas;
- monitor noise emissions and implement procedures to control unacceptable noise;
- coordinate site activities for the environmental monitoring programmes;
- coordinate site programmes with regulatory authorities and other government agencies;
- prepare periodic reports describing the on-site environmental protection activities.

3.0 ENVIRONMENTAL MONITORING

3.1 INTRODUCTION

The impact assessment of the proposed Hat Creek coal mine and thermal powerplant predicts that a number of environmental impacts would occur and that these would be mitigated to acceptable levels with proper design and operation of the facilities. However, the prediction of environmental effects is not precise and the responses of natural systems to pollutants are presently not completely understood. Therefore, extensive environmental monitoring would be carried out in the Hat Creek region to quantify and document the actual effects of the mine and powerplant development on the environment. Knowledge of these effects would provide an early warning of significant environmental changes and form the basis for the evaluation and mitigation of any unacceptable impacts.

The environmental monitoring program would be initiated before development begins to provide adequate baseline information against which the results of future monitoring could be compared. During the site preparation and construction phase, the effects of construction activities would be documented to provide a basis for effective mitigation of impacts. Monitoring during operation of the mine and powerplant would serve two major purposes. Firstly, the data obtained would provide a means of ensuring that the project is operated in compliance with permits and licences. Secondly, the effects of the operation on the local and regional environments would be documented and assessed by comparison with pre-operation baseline conditions, and, if necessary, appropriate remedial measures could then be taken based on the extent of these effects.

The environmental monitoring program has been designed to document conditions in representative sectors of the atmospheric, terrestrial and aquatic environments. It is not practical to monitor all aspects of the receiving environment in all areas that may be affected by the powerplant development, given the practical constraints of cost, data management and site accessibility. Representative parameters and monitoring sites have been selected for study, based on:

- the possible effects of the development as predicted in the environmental impact assessment studies;
- knowledge of the existing local and regional environments;
- studies conducted at similar developments in the United States and Canada;
- federal and provincial pollution control guidelines for such developments.

It is expected that the monitoring procedures and the locations of some sites would be modified as the project proceeds to reflect the results obtained during the early stages of the monitoring program and the changes in the development during detailed design and operation.

The monitoring before and during construction and during the initial years of plant operation would be most extensive to create a firm data base. As the operation proceeds and the environmental effects become known, it is expected that the extent of monitoring would be decreased. However, additional studies would be carried out if the monitoring results indicated these were warranted to more thoroughly document specific environmental effects.

3.2 ATMOSPHERIC RESOURCES

Meteorological data has been recorded in the Hat Creek Valley since 1959. The volunteer climate station established by the Atmospheric Environmental Service has provided a daily record of temperature extremes and precipitation.

In 1974 B.C. Hydro established a network of meteorological stations to gather data for the initial project design phase. The data provided the information necessary to better define local meteorology. Since 1977 various additional meteorological and air quality stations have been established. Many of these stations and the parameters measured will continue to operate through the construction and operational phases of the project.

Extensions to the air quality and meteorological monitoring programme will occur as a result of increased project activity. Additional particulate monitoring will take place during construction. During the operational phase continuous monitoring of powerplant emissions will be carried out to demonstrate compliance with permit requirements. Also an expanding system of ambient air analysers will continuously record concentrations of sulphur dioxide and other contaminants in the local area.

Monitoring programmes for air quality and meteorological parameters will also provide data for correlating project emissions with terrestrial and water resource impacts. The following sections will specify the parameters and implementation plan for the proposed air quality and meteorological monitoring network.

3.2.1 Existing Monitoring Programmes

Table 3.1a depicts the meteorological and air quality parameters that have been collected thus far. Figure 3.1 shows the locations of sampling sites referred to in Table 3.1a.

The eight station network established in 1974 measures wind run, wind direction, temperature and relative humidity. In 1977 additional instrumentation was installed to monitor air quality and meteorological parameters. In 1978 a 100 meter tower was erected at the powerplant site. Air temperature, dew point temperature, wind speed and direction are being recorded at both the 10 meter and 100 meter levels. A U-V-W anemometer was installed at the 100 meter level in 1979 to collect data for the assessment of atmospheric stability.

Approximately three years of continuous SO_2, NO_x, O_3 and CO data have been collected. These measurements will be discontinued at sites 112 and 113 (Figure 3.1) until 1985, however, all other existing sites and parameters will remain unchanged.

3.2.2 Construction Monitoring

In additional to the monitoring network presently in operation a number of particulate monitors will be added to the network in 1981 to quantify fugitive dust emissions (Sites 114 to 116). Two years of background particulate data will be gathered prior to the start of construction in 1983. Table 3.1b and Figure 3.1 indicate the monitoring proposed for 1981 to 1985.

3.2.3 Operational Monitoring

Acceptable ambient air quality will be maintained as a result of reductions in powerplant stack emissions. Flue gas desulphurization units and high efficiency particulate collection devices will remove approximately 50% of the sulphur and 99.8% of the particulates generated by the coal combustion process. It is clearly impractical to install monitors at all individual locations in the area. Therefore, mainly those areas predicted to exhibit the highest concentrations of contaminants were selected as monitoring locations. Provided air quality at these locations is maintained it follows that the air quality at the less affected locations would be, at least equally well, maintained. Control stations would also be operated in areas predicted to be less affected by the powerplant emissions.

3.2.3.1 Ambient Monitoring Programmes

During 1985, the monitoring network will be expanded (Table 3.1c) Two years of preoperational data will be gathered prior to start up of the first boiler. Sulphur dioxide, the major air contaminant emitted from the powerplant, would be continuously monitored at eight stations in the Hat Creek vicinity. These are shown in Figure 3-1. The locations of these stations were selected with empahsis on those areas where it is predicted that SO_2 levels would be greatest and on areas near population centres. A mobile monitoring station capable of measuring SO_2 and wind parameters would be used to provide data intermediate to the fixed sites as required. Acoustic radar and minisonde equipment would supplement the U-V-W anemometer dispersion data for an improved understanding of local dispersion potential.

Sulphur dioxide concentrations and corresponding wind data would be transmitted to the plant site computer. These data and other continuous air quality data would be compiled and stored in the computer which would perform data editing, statistical evaluations and provide periodic summaries for use in the other monitoring programmes.

Continuous measurements of other less significant contaminants, nitrogen oxides, ozone and carbon monoxide, would be made at the Hat Creek Valley and Cornwall Mountain stations (Sites 106 and 112). This information, in addition to providing a continuous recording of these secondary parameters, would provide more comprehensive data for correlation and evaluation of the results from the other monitoring programmes. Visibility would be monitored at the Hat Creek Valley and Cornwall Mountain stations. These measurements would provide data on the effects of the mine and powerplant operations on local and regional visibility.

Total suspended particulate levels, a primary air quality contaminant of the project, would be measured using hi-volume samplers at the twelve locations shown in Figure 3-1. Six of these stations are located in the valley near to the mine and powerplant sites to monitor local conditions. Three stations, Cornwall Mountain, Chipuin Mountain and Arrowstone Hills, are in areas where particulate concentration due to the powerplant emissions are predicted to be greatest. One station is located 13 km north of the plant in a predominating downwind direction. The four remaining stations are in Cache Creek, Ashcroft, Marble Canyon and northwest of Carquille, near population centres.

Initially, 24-hour samples would be collected once every thirteen days at each location. Twice per year, at selected suspended particulate monitoring stations, particulate sizing would be done and the size fractions analysed for selected trace elements including As, Cd, Cr, Cu, F, Pb, Hg, V and Zn[2]. These analyses would be coordinated with trace element testing of stack emissions.

An extensive monitoring network would be established to measure dustfall, sulphation, corrosion and fluoridation. The majority of sampling would be in the areas of greatest impact of the air emissions, as predicted by the air emission modelling studies, and near to population centres. Some stations would also be located at distances greater than 25 km from the powerplant site to monitor long range transport of emissions. A number of the monitoring stations would be located at the vegetation monitoring sites to provide site-specific data for correlation with the vegetation assessments. The locations of these stations are shown in Figure 3-1. Analysis of sulphation, dustfall and fluoridation would be carried out monthly. Composite dustfall samples from selected sites would be analysed quarterly for trace elements. The corrosion samplers would be analysed annually.

All monitoring would be carried out using established standard procedures complete with an extensive quality assurance programme to establish and maintain the precision and accuracy of the air quality data.

3.2.3.2 Powerplant Emissions

Continuous measurement of the gaseous emissions from each boiler would provide data for the evaluation of the operational performance of the AQCS. Periodic measurement of gaseous and particulate emissions would also be utilised to evaluate the functioning of combustion and emission control equipment and to monitor compliance with pollution control permit requirements.

Monitoring Programme

Continuous stack monitors would record opacity and the levels of sulphur dioxide and nitrogen oxides in the emissions from each boiler. An ongoing quality assurance programme would ensure the accuracy and precision of the continuous source monitoring results. Additional periodic sampling would be carried out on each boiler stack to measure particulate, SO_2, $SO_4^{=}$,

NO_x, and solid and gaseous trace elements. A recognised independent consultant would be contracted to perform the periodic stack sampling for compliance purposes.

3.2.3.3 Noise

Noise levels would be monitored during both the construction and operation phases of the mine and powerplant.

Monitoring Programme

Ambient levels of noise would be recorded using a mobile unit. at five sites as shown in Figure 3-1. Three noise monitoring sites would be along Highway 12; at the junction with Hat Creek road, at a point about 3 km northwest of the junction and at another point about 10 km northeast of the junction. The other two monitoring sites would be near the valley meteorological station and close to the water intake structure in the Thompson River near Ashcroft. These monitoring sites were located based on predicted noise impacts and proximity to populated areas[3]. Monitoring was carried out at these sites during the environmental impact assessment studies.

Noise monitoring would commence one year before construction starts. Two measurements over 24-hour periods would be carried out at each of the five monitoring sites during each quarter to document conditions before construction begins. During the construction period, measurements would be made quarterly at each site and at other sites as required. During operation of the mine and powerplant noise measurements would initially be made quarterly and then annually.

At each monitoring site, day-night average sound levels (Ldn), equivalent sound levels (Leq), peak sound levels and statistical indices (Li), which represent the sound levels exceeded 1% of the time would be calculated. Sound level measurements would be in 'A' - weighted decibels, the unit of sound commonly used when dealing with the effects of noise on humans.

Noise emissions from major equipment would be monitored as a normal maintenance procedure during the construction and operation of the mine and powerplant development.

3.2.4 References

1. Environmental Research and Technology Inc. April 1978. Air Quality and Climatic Effects of the Proposed Hat Creek Project, Appendix C. Alternative Methods of Ambient Sulphur Dioxide Control. Document P-5074-F-C. Prepared for B.C. Hydro and Power Authority.

2. Environmental Research and Technology Inc. July 1978. Air Quality and Climatic Effects of the Proposed Hat Creek Project, Appendix F. The Influence of the Project on Trace Elements in the Ecosystem. Document P-5074-F-F.

3. Harford, Kennedy, Wakefield Ltd. August 1978. Hat Creek Project, Detailed Environmental Studies, Appendix E1 - Noise. Prepared for B.C. Hydro and Power Authority.

3.11

TABLE 3.1a

EXISTING HAT CREEK AMBIENT MONITORING 1980

PARAMETER (Instrument)	HAT CREEK SITE																										
	101	102	103	104	105	106	107	108	109	110	111 a	111 b	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126
				DISCONTINUED (1979)	DISCONTINUED (1977)		DISCONTINUED (1979)																				
Meteorological																											
1 Relative Humidity	X	X	X			X																					
2 Dew Point Temperature											X	X	X	X													
3 Temperature	X	X	X			X		X	X		X	X	X	X													
4 Precipitation								X	X		X		X	X													
5 Evaporation											X																
6 Barometric Pressure											X																
7 Wind Speed and Direction	X	X	X			X		X			X	X	X	X													
8 Dispersion Parameters (U-V-W or Bi-Vane)												X															
9 Light Intensity													X														
10 Upper Air Measurement (acoustic radar, minisonde or tethersonde.)																											
Air Quality																											
11 Visibility													X	X													
12 Sulphur dioxide (SO_2)													X	X													
13 Nitrogen Oxides (NO_x)													X	X													
14 Ozone (O_3)													X	X													
15 Carbon Monoxide (CO)														X													
16 Total Suspended Particulate (TSP)	X	X								X	X		X	X													
17 Dustfall	X	X	X			X		X		X	X		X	X													
18 Sulphation	X	X	X			X		X		X	X		X	X													
19 Corrosion	X	X	X			X		X		X	X		X	X													
20 Fluoridation	X	X	X			X		X		X	X		X	X													

TABLE 3.1b

PROPOSED HAT CREEK AMBIENT MONITORING 1981 to 1985

PARAMETER (instrument)	HAT CREEK SITE																										
	101	102	103	104	105	106	107	108	109	110	111 a	111 b	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126
				DISCONTINUED (1979)	DISCONTINUED (1977)		DISCONTINUED (1979)																				
Meteorological																											
1 Relative Humidity	X	X	X			X																					
2 Dew Point Temperature											X	X	X	X													
3 Temperature	X	X	X			X		X	X		X	X	X	X													
4 Precipitation								X	X		X		X	X													
5 Evaporation											X																
6 Barometric Pressure											X																
7 Wind Speed and Direction	X	X	X			X		X			X	X	X	X													
8 Dispersion Parameters (U-V-W or Bi-Vane)												X															
9 Light Intensity													X														
10 Upper Air Measurement (acoustic radar, minisonde or tethersonde.)																											
Air Quality																											
11 Visibility													X	X													
12 Sulphur dioxide (SO_2)																											
13 Nitrogen Oxides (NO_x)																											
14 Ozone (O_3)																											
15 Carbon Monoxide (CO)																											
16 Total Suspended Particulate (TSP)	X	X								X	X		X	X	O	O	O										
17 Dustfall	X	X	X			X		X		X	X		X	X	O	O	O										
18 Sulphation	X	X	X			X		X		X	X		X	X	O	O	O										
19 Corrosion	X	X	X			X		X		X	X		X	X			O										
20 Fluoridation	X	X	X			X		X		X	X		X	X	O	O	O										

X - parameters monitored prior to 1980.

O - parameters to be installed in 1981.

TABLE 3.1c

PROPOSED HAT CREEK AMBIENT MONITORING 1985 TO PLANT SHUTDOWN

PARAMETER (Instrument)	HAT CREEK SITE																										
	101	102	103	104	105	106	107	108	109	110	111 a	111 b	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126
Meteorological									LEMAN RANCH CLIMATE STATION																		
1 Relative Humidity																											
2 Dew Point Temperature											X	X	X	X													
3 Temperature						X		X			X	X	X	X													
4 Precipitation								X			X		X	X													
5 Evaporation											X																
6 Barometric Pressure											X																
7 Wind Speed and Direction						X		X			X	X	X	X			Δ			Δ	Δ	Δ	Δ				
8 Dispersion Parameters (U-V-W or Bi-Vane)												X															
9 Light Intensity													X														
10 Upper Air Measurement (acoustic radar, minisonde or tethersonde.)											Δ																
Air Quality			DISCONTINUED	DISCONTINUED	DISCONTINUED		DISCONTINUED		DISCONTINUED																		
11 Visibility						Δ							X														
12 Sulphur dioxide (SO_2)						Δ							Δ	Δ			Δ			Δ	Δ	Δ	Δ				
13 Nitrogen Oxides (NO_x)						Δ							Δ														
14 Ozone (O_3)						Δ							Δ														
15 Carbon Monoxide (CO)						Δ							Δ														
16 Total Suspended Particulate (TSP)	X	X				Δ				X			X	X	O		O			Δ	Δ	Δ					Δ
17 Dustfall	X	X				X		X		X	X		X	X	O	O	O	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
18 Sulphation	X	X				X		X		X	X		X	X	O	O	O	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
19 Corrosion	X	X				X		X		X	X		X	X			O										
20 Fluoridation	X	X				X		X		X	X		X	X	O	O	O	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
21 Noise		Δ									Δ				Δ		Δ										

X - parameters monitored prior to 1980
O - parameters to be installed in 1981
Δ - parameters to be installed in 1985

TABLE 3.1c (continued)

PROPOSED HAT CREEK AMBIENT MONITORING 1985 TO PLANT SHUTDOWN

PARAMETER (instrument)	HAT CREEK SITE										
	127	128	129	130	131	132	133	134	135	136	Mob-ile
Meteorological											
1 Relative Humidity											
2 Dew Point Temperature											
3 Temperature											
4 Precipitation											
5 Evaporation											
6 Barometric Pressure											
7 Wind Speed and Direction											Δ
8 Dispersion Parameters (U-V-W or Bi-Vane)											
9 Light Intensity											
10 Upper Air Measurement (acoustic radar, minisonde or tethersonde.)											
Air Quality											
11 Visibility											
12 Sulphur dioxide (SO_2)											Δ
13 Nitrogen Oxides (NO_x)											
14 Ozone (O_3)											
15 Carbon Monoxide (CO)											
16 Total Suspended Particulate (TSP)											
17 Dustfall	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ		
18 Sulphation	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ		
19 Corrosion							Δ		Δ		
20 Fluoridation	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ		
21 Noise										Δ	

3.3 TERRESTRIAL RESOURCES

Vegetation is one of the basic components of the terrestrial ecosystems and the aesthetic values of the Hat Creek region are dependent upon the maintenance of healthy vegetation. Adverse impacts on the vegetation would have repercussions in other biological and physical systems.

The objective of this terrestrial resource monitoring programme is to provide early warning of any potentially significant environmental degradation due to emissions from the powerplant. This would be accomplished by documenting changes, both qualitatively and quantitatively where possible, in the relative abundance, productivity and vigour of selected species and plant communities growing in the Hat Creek region.

Plants are the primary producers in an ecosystem. The health and competitive relationship of the members of a plant community are good indicators of the condition of the ecosystem. Monitoring of entire ecosystems is too complex to be undertaken on a practical basis at the present level of environmental understanding. Analysis of the vegetation successional pattern, as an indication of the condition of the ecosystem, is a more practical approach. This method, which has been extensively applied in forestry and range management, would be used in this monitoring programme.

Air pollution affects vegetation by altering the physical characteristics and physiological functioning of the plants. Pollution-induced vegetation injury is often difficult to recognise and quantify because of the interrelation of the pollutants with environmental factors such as frost, drought, insects and plant diseases. Consequently, this monitoring programme utilises a variety of techniques, both qualitative and quantitative to document the effects of air pollution on the vegetation in the Hat Creek region.

3.3.1 Native Vegetation

This phase of the overall monitoring programme focuses on sampling native plants from ecosystems in the areas of major influence of the development. Three sampling frequencies would be used. A periodic sampling interval of five years would be implemented to monitor in detail the successional status of the forest and grassland ecosystems. Monitoring for foliar trace element concentrations would initially be conducted on selected plots and species on an annual basis. To provide an early warning of any possible acute damage to the vegetation, it is proposed to visually inspect the permanent relevé plots used in the above 5-year interval programme twice a year.

The 5-year monitoring programme would commence six years before the start-up of the first boiler unit to provide two pre-operational surveys. The other native vegetation monitoring programmes would commence three years before start-up of the first boiler.

Selection of Plant Groups to be Monitored

Four plant groups have been selected for the native vegetation monitoring based on their life forms and value as indicators of air pollution. These include trees, understory vegetation,lichens and open range vegetation.

The sampling of trees for growth and productivity changes is a proven quantitative method used to measure the effects of chronic injury due to air pollutants. Trees generally are the first to receive fumigations because of their height and large area of foliage. Removal of air contaminants by trees reduces the concentration of pollutants reaching the lower vegetation strata.

Understory vegetation may be a less sensitive indicator of changes due to air emissions since the concentrations of contaminants may be reduced by the tree canopy. Methods utilised to examine understory vegetation would therefore concentrate on species mortality, changes in species composition and gross changes in the cover of individual species. These parameters also reflect general successional changes.

Studies have shown that most lichen species become less abundant or die out when exposed to relatively low levels of air pollutants. They are more sensitive to air pollution damage than bryphytes.[1] Lichens grow on rock, bark and soil surfaces. They have efficient gas absorption systems which are not protected by a cuticle or stomata. They absorb air pollutants at any time. Lichens absorb sulphur dioxide either directly or dissolved in rain water as sulphurous acid. The decline in abundance and diversity of lichen species has been used in other monitoring programmes as indicators of air pollution. Their monitoring is included in the five year interval relevé monitoring plots and in the annual trace element analyses.

Open range vegetation has been classed separately because of its importance as cattle range in the Hat Creek region. It lacks tree cover and is thus more exposed to air pollutants.

Selection of Sampling Areas

The major factors considered for selection of the areas where sample plots would be established were the ambient air quality data predicted by the modelling studies,[2] and the sensitivity, relative important, type and abundance of native vegetation.[3] To the extent practical, sample areas should be sufficiently numerous and suitably located to distinguish the effects of air pollution from other effects.

It is not proposed to sample all of the Hat Creek vegetation associations because of the diveristy of vegetation, elevated terrain and attendant inaccessibility and the large area of possible influence. However, a remote sensing monitoring programme using low level colour infra-red photography would be used to obtain data for remote areas.

Figure 3-2 shows the average annual concentrations of SO_2, predicted by the computer model of the Hat Creek region which was developed by ERT[2] after field experiments. Selection of the areas of native vegetation to be sampled was based on the results from this model. Annual average concentration predictions were supplemented with information on the frequency of 1-hour concentrations greater than 450 $\mu g/m^3$ to stratify the region into two major areas: those where possible injury was predicted to occur and those where no injury was predicted. The model also was used to predict seasonal and maximum episodal concentrations of SO_2 for the region. The highest seasonal and episodal SO_2 levels were predicted to occur in patterns similar to the annual average levels. Thus, predicted seasonal and episodal SO_2 occurrences as well as the predicted average annual SO_2 concentrations were incorporated into the selection of sampling areas.

The selection of the 1-hour SO_2 concentrations above 450 $\mu g/m^3$ as one of the criteria to stratify the region was based on data presented by Runeckles[19]. Utilizing dose/response relationships and predicted areas of possible vegetation injury, this information provided the best indication of where sampling locations should be established. This analysis showed that the elevated areas west and south of the plant site are prime sampling locations (Figure 3-2). Other areas would be sampled, but at a lower frequency. This would provide the necessary sampling distribution of all vegetation zones and provide data in areas that are presently predicted to have no vegetation injury.

Twenty vegetation associations were identified by TERA Consultants Limited[3] in the area within 25 km of the Hat Creek site, during the environmental impact assessment studies. Monitoring of all twenty associations would be difficult because of distribution, successional status, inaccessibility, and the large number of associations. The vegetation monitoring programme was developed by successive classification of the vegetation and related data as described below.

The vegetation associations were first grouped into biogeoclimatic zones considering species composition, soils and macroclimate. Three major biogeoclimatic zones resulted: the Engelmann spruce - subalpine fir zone; the Interior Douglas-fir zone, and the Ponderosa pine - bunchgrass zone. Table 3-2 shows how the larger and more important vegetation associations were grouped into the three biogeoclimatic zones.

TABLE 3.2

VEGETATION ASSOCIATIONS GROUPED INTO BIOGEOCLIMATIC ZONES

AND SAMPLING IMPORTANCE

Biogeoclimatic Zones	Sampling Importance
Engelmann Spruce - Subalpine Fir Zone	
Engelmann spruce - grouseberry	low
Engelmann spruce - grouseberry - pinegrass	low
Engelmann spruce - grouseberry - white rhododendron	low
Engelmann spruce - willow - red heather parkland	high
Engelmann spruce - grouseberry - lupine	high
Interior Douglas-fir Zone	
Douglas fir - pinegrass	low
Douglas fir - bunchgrass	high
Douglas fir - spirea - bearberry	low
Douglas fir - bunchgrass - pinegrass	low
Ponderosa Pine - Bunchgrass Zone	
Ponderosa pine - bunchgrass	low

The second step in determining the vegetation associations to be monitored, consisted of identifying associations in the three biogenclimatic zones that rated highly with respect to the following criteria: importance of the vegetation association in livestock and wildlife; number of plant species known to be sensitive to air pollution in each association; and the extent of the vegetation association. Vegetation associations that rated highly with respect to these criteria have the greatest need for monitoring and were assigned a high sampling association. Biogeoclimatic zones are shown in Figure 3-2.

Sampling areas were determined by overlaying the air quality information and the vegetation information on a map and selecting potential monitoring areas within each biogeoclimatic zone. Where possible, vegetation associations with a high sampling importance were selected for monitoring. This procedure produced the sampling locations listed in Table 3-3. The locations of these areas are shown in Figure 3-2. At each area, three replicate relevé plots would be established in forest vegetation and three in grassland vegetation. That is, at a sampling area where both grassland and forest are present there would be six relevés.

In addition to these sampling areas, a series of sampling plots would be established on a transect between McLean Lake and Cornwall Hills (Figure 3-2). The information derived from this sampling would be useful to determine any differential vegetation injury between areas of high and low SO_2 levels.

Table 3.3

CLASSIFICATION AND LOCATION OF SAMPLING AREAS

Biogeoclimatic Zone	Location	Number of Relevés
Engelmann Spruce - Subalpine Fir (ESSF) Zone	Cornwall Hills	6
	Chipuin Mountain	6
	Cairnes/Blustry Mountains	6
	Marble Range	3
	Mt. Martley	6
Interior Douglas-Fir (IDF) Zone	Arrowstone Hills	6
Ponderosa Pine - Bunchgrass (PPBG) Zone	Red Hill	6

Five-Year Monitoring Programme

Trees and Understory

a) Tree Canopy

Open and closed canopy forest stands cover more than 65 percent of the area that may be affected by the thermal powerplant stack emissions. In these areas, the upper canopy will be the first layer to intercept the emission plume, particulate fallout, and any acidic rainfall. Therefore, it is necessary to both monitor this layer over an extensive area and to sample it more intensively with judiciously located ground plots.

To detect and to monitor the effects of the stack emissions, chiefly sulphur dioxide and fluoride gases, on the vegetation over an extensive area, it is proposed to use the remote sensing technique that utilises low level colour infrared photography. Photographs would be taken in the late spring and later in the summer along pre-determined flight lines. The photographs, which would be taken every five years, would give a permanent record of the condition of the local vegetation. Detailed interpretation would be done, on selected frames in the strips of photographs, to determine the extent of injury, if any, from air emissions on the tree cover. Also information on the tree crown closure, number of dead trees, snags, and severity of insect and disease damage would be determined from the low level photography. The interpretation techniques have been documented by Murtha.[4] The interpreted data would give an understanding of the dynamics of the forest stand conditions. It should be noted that this technique of low level aerial photography does not guarantee that exactly all of the same trees would be repeatedly sampled; but the same forest stands would be repeatedly and accurately surveyed. The ground plots would allow repetitive sampling of individual trees.

b) Ground Plots

Data from existing B.C. Forest Service inventory plots, any permanent growth and yield plots, and any research plots that have already been established in the Hat Creek area would be examined. If feasible and warranted, these plots may be incorporated into the monitoring programme. However, it is not proposed to establish and maintain any new forest plots that would conform to the Ministry of Forests' specification. Instead, about forty vegetation plots would be established on a permanent basis. These plots, i.e. relevés, would be set up in accordance with the standard of the Vegetation Data Bank of the Terrestrial Studies Branch of the Ministry of the Environment. The general plot description includes information on slope, topographic position, surface configuration and aspect. A description of the area surrounding the releve would also be made. This description would list any additional species not present in the sampling area. Evidence of past fires, disease, erosion, animal usage, and phenological status of the vegetation at the time of sampling would also be recorded. A photographic record of selected portions of the relevés would be kept.

The optimum size for the ground plots could be determined using a nested plot technique.[5] However, it has been found in other vegetation studies of forested areas, that a plot size of 10m by 10m, i.e. 100 m^2, is sufficient to sample at least 90 percent of the species occurring in the area.

The location of the sampling areas is shown in Figure 3-2. The corners of the plots would be marked with permanent markers and a detailed access map with photographs would be prepared to document the exact location of each plot, so that future observations can be done on precisely the same plot areas.

The Terrestrial Studies Branch site description, vegetation description, and their short soil/vegetation description forms would be used for the data from the ground plots. These forms would be completed using the interpretations given in the Ministry of Environment manual. This provides explanations of the terminology and gives guidelines for the sampling procedures. Any modifications of these forms and procedures would be discussed with the Head of the Vegetation Section of the Terrestrial Studies Branch.

It is presently considered that it is not necessary, as part of this monitoring programme, to complete the detailed soil description form nor the mensuration page of the mensuration/wildlife form. The wildlife page of this form would be completed.

In addition to collecting the detailed relevé data, increment cores from two dominant trees of each species of the forested releves would be collected after the powerplant has been in operation for 5 years. The cores would be analysed using standard dendrochronological procedures.[6,7,8] These data would document any change in growth rates.

A collection of a herbarium set of voucher samples of each plant species would be made for the monitoring programme. These voucher samples would be kept at the Hat Creek environmental monitoring facilities.

Open Range Vegetation

In this study, range vegetation is defined as open grasslands without trees. Open range vegetation covers a large area in the Hat Creek region and is important to local cattle farming.[3]

Sampling areas would not be fenced to prevent disturbance from the grazing cattle. Relevé plots would be established and sampled in the same manner as described for the forest understory vegetation. Species composition, percent cover and vigour estimates would be recorded. General plot information including slope, aspect and elevation would be recorded. In addition, a measure of grassland productivity would be obtained by collecting biomass samples.

Annual Monitoring Programme

Trace Element Monitoring

Initially, trace element analysis of samples from vegetation growing in the Hat Creek would be carried out annually. These data would be correlated with those of the soils monitoring programme, Section 3.3.4. Ten sampling plots would be selected, from the sampling plots in the established 5-year monitoring programme, based on the species present and predicted levels of air contaminants. Extensive monitoring has been carried out in the Hat Creek region to determine background trace element levels in native vegetation and more data are being collected. Statistical tests would be used as a basis to establish the number of samples necessary to achieve reasonable sampling precision.

The trace elements to be monitored would include: As, B, Cd, Cr, Cu, F, Hg, Pb, Ni, Sn, U, V and Zn. These elements were selected after detailed assessment of the coal analyses and predicted emissions from the powerplant,[9,10] thorough review of the literature concerning toxicity and accumulation of trace elements in the environment,[9] evaluation of monitoring programmes conducted at major coal-fired powerplants in North America, and review of background trace element levels in the Hat Creek region.[9]

Four types of receptors were chosen to monitor these elements; trees, shrubs, grasses and lichens and mosses. These receptors represent the dominant or sensitive vegetation types in the Hat Creek region.

From these four groups of plants, a number of species were selected for analyses based on their sensitivity to various trace elements and on their abundance, distribution and importance in the Hat Creek region. One species in each group would be sampled at each site. The species to be sampled would include the following:

Trees

Ponderosa pine - *Pinus ponderosa*
Douglas-fir - *Pseudotsuga menziesii*

Shrubs

Willow	-	*Salix* spp. *
Western shadbush	-	*Amelanchier alnifolia*

Grasses

Pinegrass	-	*Calamagrositis rubescens*
Bluebunch Wheatgrass	-	*Agropyron spicatum*
Kentucky bluegrass	-	*Poa pratensis*

* Note: species not identified here but the same would be sampled each time.

Lichens and Mosses

Letharia vulpina

Parmelia spp.

Pleurozium schreberi

Standard sampling procedures would be followed to minimise sample contamination. About 200 g of fresh material would be collected and placed in labelled bags using acid-washed, stainless-steel scissors and plastic gloves. The season of sampling, plant height, exposure and vegetation species would be kept as constant as possible to minimise sample variation. In the case of trees, samples of the current and previous year's needles would be collected separately for independent analysis. In all other vegetation species, current growth would be sampled. Grass species would be clipped 3 cm above the soil surface to reduce soil contamination. Detailed notes would be made during sample collection to record such parameters as weather, dust and moisture on plants, condition of plants and other pertinent data.

At least three samples would be collected at each sampling plot. The trees and shrubs sampled would be selected randomly at each plot and permanently marked for future sampling. However, in the case of lichens and mosses, an adequate sample weight may be difficult to collect from one tree because of the limited amount of material present. As required, material from other trees of the same species would be collected and the sample size may be reduced.

Sampling would be carried out annually in the late summer at the same time as the semi-annual plot inspections. The annual vegetation trace element monitoring programme would commence two years before the start-up of the first power boiler.

The trace element analyses of the vegetation samples would be conducted on dried, pulverised material. Concentrations would be expressed on a dry weight basis. Washing for removal of contamination deposited on plant foliage would not normally be done.[11]

Semi-Annual Monitoring Programme

Visual Plot Inspection

The 5-year monitoring plots at the 12 sampling locations would be investigated twice a year for signs of foliar symptoms characteristic of damage by air pollutants. In addition, symptoms that could be attributed to insects or disease would also be identified. If required, samples would be collected and taken to the laboratory for more positive identification. This monitoring approach is designed to observe acute changes that could be attributed to air pollution injury or pathological problems. This provides an early warning of injury and a means of establishing reasons for changes that might occur during the 5-year interval between intensive surveys. The visual plot inspections would be conducted at the beginning and the end of each growing season, commencing two years before the operation of the first boiler unit.

3.3.2 Field Test Plots

The use of cultivated field test plots is an effective method of determining plant injury due to air pollutants. Indicator plants which have known sensitivities and symptoms characteristic of individual pollutants are used to evaluate air pollution effects. Such plants grown in managed field plots have proven valuable in many studies.[12,13,14,15].

The selection of indicator species is important. The following characteristics are desirable for any species selected as an indicator:

1. It should be sensitive to air pollutants at a level below the sensitivity of vegetation of economic, biological or aesthetic importance.
2. The injury by the air pollutant of interest should be characteristic and easily observed.
3. The species should be present throughout the growing season.

Based on these criteria, six plant species were chosen. Each is sensitive to airborne pollutants and threshold values are well documented.[19] The plants and the pollutant they are sensitive to are as follows:

Alfalfa (Medicago sativa) - Sulphur dioxide
Gladiolus (Gladiolus sp.) - Fluorine
Ponderosa pine (Pinus ponderosa) - Fluorine, sulphur dioxide
Tobacco (Nicotiana tabacum) - Ozone
White Bean (Phaseolus vulgaris) - Ozone, sulphur dioxide
Kentucky bluegrass (Poa pratensis) - Sulphur dioxide

These species would be planted in 12 m x 12 m fenced plots located at five sites as shown in Figure 3-2. The choice of these locations was made on the basis of the predicted SO_2 levels and local land use. Generally, plots would be located in areas where SO_2 levels are predicted to be the greatest, since vegetation in these areas would be the most likely to indicate air pollution damage. Field test plots located in the Semlin Valley and near Upper Hat Creek would be close to population centres and in areas where agricultural crops are grown. Air quality monitoring stations would be located at or close to each field test plot.

To reduce the effect of variable soil moisture and nutrient supply during the early stages of plant development, the plants would be prepared in greenhouses under uniform growing conditions. The seedlings would be moved to the prepared field plots as soon as the weather permits in the spring. Tree seedlings at least two years old would be transferred to the field plots in large pots.

The seedlings would be planted in one metre wide rows the length of the plot. Inspection for foliar injury on the sensitive indicator plants would be carried out on a 7 to 10 day interval throughout the growing season. A description of the types of foliar injury, if present, would be documented. A photographic record would also be kept.

The cultivated field test plot monitoring programme would commence two years prior to the operation of the first boiler unit.

3.3.3. Crop Surveys

Agricultural crops such as alfalfa, hay and corn are important in the Hat Creek region. Crop surveys would be carried out in the Hat Creek region on a bi-monthly basis during the growing season to identify any impacts due to air pollution.

To document changes in the condition of the local crops, regular inspection would be made at six areas: Upper Hat Creek; Lillooet; Semlin Valley; Bonaparte Valley and Thompson Valley near Ashcroft Manor; near Pavilion, and near Glen Fraser in the Fraser Valley. These locations were selected based on the predicted SO_2 levels and the types of crops grown in the region.

Visual inspections would be made through the growing season commencing two years before start-up of the first boiler unit. If some indication of crop stress is observed, a quantitative procedure to estimate the amount of injury would be carried out. This procedure would assess variables such as proportion of plants affected and extent of injury per plant. Crop yields are generally not affected unless 5% or more of the leaf area is necrotic.[16] If greater than 5% injury is found further studies would be conducted to determine the causes.

3.3.4 Soils

Emissions from the powerplant would be deposited on the surface soils in the region. These emissions would contain trace elements which could accumulate in the soils and in vegetation growing on these soils. This impact is not predicted to be significant. However, the actual patterns and rates of trace element deposition and transport mechanisms of the deposited trace elements in the terrestrial ecosystems are not well established. Thus monitoring of trace element levels in local and regional surface soils would be carried out to document changes and to provide data for correlation with the other environmental monitoring programmes.

Monitoring Programme

Mineral soils samples would be collected from the top 3 cm at the same 10 sampling plots as used for vegetation trace element monitoring. These sites would be located in areas of greatest deposition of air emissions from the powerplant, based on model predictions made by ERT[2], in areas judged to be sensitive to trace element deposition based on levels determined during the environmental assessment studies, and in some cases the sites are located at or close to air quality monitoring sites, so that close correlation of results would be possible.

At least five soil samples would be collected at each sampling plot to provide adequate data for statistical evaluation of the analytical results. Samples would be collected annually, in the late summer, using standard sampling procedures. Soil samples would be collected from the top 3 cm of mineral soils with plant litter excluded. At selected plots surface litter would be collected and analysed separately. The samples would be analysed for selected trace elements: As, B, Cd, Cr, Cu, F, Pb, Hg, Ni, Sn, U, V and Zn. Other significant soil parameters such as conductivity, pH, nutrients, sulphate and cation exchange capacity would be determined periodically. The soil monitoring programme would commence two years before the start-up of the first boiler.

3.3.5 Wildlife

The emissions from the powerplant would contain trace elements which would be deposited in the surrounding region. The actual deposition patterns of these trace elements and pathways of trace element accumulation in the environment are uncertain. The levels of selected trace elements would be monitored in two wildlife species to document existing levels and any changes that occur during operation of the powerplant.

(i) Ruffed Grouse

Ruffed grouse has been selected as the species to be monitored because they are abundant in the Hat Creek valley, they are classed as a game bird in terms of hunting regulations and they are easily shot or collected. They feed on a variety of grasses, shrubs, forbs and insects and would thus ingest trace elements from a number of possible sources. They are present year-round in the valley, and are localized in distribution.

Monitoring Program

Ruffed grouse would be shot in fall during the normal open season at five locations. Areas preferred for sampled birds would be in close proximity to a sampling point for vegetation and wherever possible, in the areas of highest emission impact. Iron or plastic shot would be used to prevent lead contamination of body tissues. At least 10 birds would be sampled in the first year to establish levels of variation and to determine a statistically adequate intensity for future sampling.

Shot birds would be autopsied immediately and the whole liver, kidneys and femurs removed and placed in separate polyethylene containers, labelled and frozen. Samples of primary feather would be taken from birds in the first year, to establish the usefulness of further sampling of these tissues as trace element indicators. Sample organs would be analyzed for arsenic (liver), cadmium (liver), chromium (liver), copper (liver), fluorine (bone), lead (kidney and liver), mercury (liver), vanadium (liver), zinc (liver), uranium (bone), tin (liver) and nickel (liver).

The ruffed grouse monitoring program would commence two years prior to the start-up of the first boiler.

(ii) Honeybees

Honeybees are known to accumulate fluorine in their body tissues and they have been used successfully as indicators of fluorine levels in the environment.[17,18] Local honeybees would be monitored to document the levels of fluorine, selenium and possibly other trace elements.

Monitoring Program

A hive would be established near the alfalfa fields in the Hat Creek Valley south of the powerplant site. In the late summer about 50 honeybees would be collected for analysis. The bees would be placed in an entomological killing jar and then transferred to a polyethylene container and frozen. In the laboratory, the bees would be pulverized, lyophilized and three sub-samples taken for analysis of fluorine and selenium content. For the first three years of the monitoring program, analyses for other trace elements would be undertaken to establish the usefulness of bees as trace element indicators. Monitoring would commence two years before start-up of the first boiler.

3.3.6 References

1. Showman, R.E. 1975. Lichens as indicators of air quality around a coal-fired power generating plant. Bryologist 78:1-6.

2. Environmental Research & Technology, Inc. April 1978. Air Quality and Climatic Effects of the Proposed Hat Creek Project, Appendix C. Alternate Methods of Ambient Sulfur Dioxide Control. Document P-5074-F-C. Prepared for B.C. Hydro and Power Authority.

3. The TERA Environmental Resource Analyst Ltd. 1978. Physical Habitat and Range Vegation Report - Impact Assessment. Detailed Hat Creek Environmental Studies. Prepared for B.C. Hydro and Power Authority Vancouver, B.C.

4. Murtha, P.A. 1972. A Guide to Air Plots Interpretation of Forest Damage in Canada. Canadian Forestry Service Publication No. 1292. Ottawa. 63 p.

5. Mueller-Dombois, D., and H. Ellenberg. 1974. Aims and Methods in Vegetation Ecology. John Wiley and Sons, New York. 547 p.

6. Hauas, P. and S. H. Uttunen. 1972. The Effect of Air Pollution on the Radial Growth of Scots Pine (Pinus sulvestris L.) Biol. Conv. 4(1): 361-368.

7. Linzon, S. N. 1971. Economic effects of sulfur dioxide on forest growth. J. Air Pollut. Control Assoc. 21:81-86.

8. Parker, M.L., H.W.F. Bunce, and J.H.G. Smith. 1974. The Use of X-ray Densitometry to Measure the Effects of Air Pollution on Tree Growth near Kitimat, B.C. Report to the Industrial Conference on Air Pollution and Forestry. Oct. 15-18, 1974. Czechoslovakia.

9. Environmental Research & Technology, Inc. July 1978. Air Quality and Climatic Effects of the Proposed Hat Creek Project, Appendix F. The Influence of the Project on Trace Elements in the Ecosystem, Document P-5074-F-F. Prepared for B.C. Hydro and Power Authority.

10. B.C. Hydro Report SE7933. Trace Elements in Coal and Effects of Redistribution in the Environment from the Proposed Hat Creek Project. December 1979.

11. Little, P. 1973. A Study of Heavy Metal Contamination of Leaf Surfaces. Environ. Poll. 5:159.

12. Daley, E.F. Use of Plants for Air Pollution Monitoring. J. Air Pollut. Control Assoc. 10, 198 (1960).

13. Heck, W.W. The Use of Plants as Indicators of Air Pollution. Intl. J. Air and Water Pollution, 10, 99 (1966).

14. Cole G.A. Air Pollution with Relation to Agronomic Crops II: Vegetation Survey Methods in Air Pollution Studies. Agronomy J. 50, 553 (1969).

15. Reinert, R.A., Heagle, A.S., Miller, J.R., and Geckeler, W.R. Field Studies of Air Pollution Injury to Vegetation in Cincinnati, Ohio. Plant Disease Reporter 54, 8 (1970).

16. Jacobson, J.S. and A.C. Hill, eds. 1970. Recognition of Air Pollution Injury to Vegetation: A Pictorial Atlas. Air Pollut. Control Assoc., Pittsburgh, Pennsylvania.

17. Committee on Biologic Effects of Atmospheric Pollutants. 1971. Biologic Effects of Atmospheric Pollutants: Fluorides. U.S. National Academy of Sciences. Washington, D.C.

18. Bromenshank, J.J. 1978. Investigation of the impact of coal-fired power plant emissions upon insects: entomological studies in the vicinity of Colstrip, Montana. In Preston, E.M. and R.A. Lewis (eds.). The Bioenvironmental Impact of a Coal-fired Power Plant. Third Interim Report, Colstrip, Montana. U.S. E.P.A. NTIS No. EPA-600/3-76-013. 521 pp.

19. Tera Environmental Rescurce Analyst Ltd. and Canadian Bio-Resources Consultants Ltd. Prepared by V. C. Runeckles - Hat Creek Project - Detailed Environmental Studies - Physical Habitat and Range Vegetation Report - Appendix F - Assessment of Impacts of Airborne Emissions on Vegetation - 1978.

3.4 WATER RESOURCES

3.4.1 Groundwater Quality

The mine and powerplant development would alter local groundwater flows and characteristics. Monitoring of local groundwaters would be conducted to document any changes quantitatively and to provide data for the operation of discharge control systems and design of any remedial measures needed.

Monitoring Programme

Eight groundwater monitoring wells would be installed in the vicinity of the mine and powerplant, as shown in figure 3-3. Most of these wells would be located downstream of dump embankments and coal and waste storage facilities in the direction of seepage flows to the groundwater table. Monitoring at these locations would document the effects of the project facilities on the local groundwater. Wells would be located further away to document the effects on the Marble Canyon and Hat Creek aquifers.

Three wells would be located at the Houth Meadows Dump; at the toe of the main embankment and at the toes of the northwest and northeast saddle embankments. A well would be located west of the ash dump runoff holding pond in the Medicine Creek Valley. As this area becomes a mine waste dump, after about year 15, a further well would be located at the toe of the waste dump embankment. A well would be located north of the coal blending and stocking facility.

A control well would be located in Marble Canyon to monitor groundwater conditions upstream of the Houth Meadows waste dump and a well would be placed at the eastern end of the Marble Canyon aquifer. Monitoring at these two locations would document the effects of the Houth Meadows dump on the Marble Canyon aquifer. A well would also be installed in the Hat Creek aquifer to measure the overall effect of the project on this resource.

Each well would be equipped with one or more piezometers and water sampling devices at various depths depending upon the well and groundwater locations.

Piezometer reading and water sampling and analyses would be done every two months during the first year of groundwater monitoring to assess seasonal variations. Thereafter, monitoring of the wells would be done about every four months: in the winter; during the spring freshet, and during low water near the end of summer. Monitoring would commence two years prior to the start of construction.

The groundwater samples would be analyzed for the following paramters, As, Cd, Ca, Cr, Cu, Fe, Pb, Mg, Hg, Na, U, V, Zn, Mn, Cl, F, SO_4, total PO_4, alkalinity, NO_2, NO_3, pH, conductivity, filtrable residue and non-filtrable residue. These parameters have been selected on the basis of predicted levels in the various seepages, on known toxicity data and parameters significant to uses of these waters, such as irrigation and domestic supply.

3.4.2 Surface Water Quality

Local surface waters are a multiple use resource. Air emissions from the mine and powerplant, seepages and drainage from the mine and waste disposal areas and wastewater discharges could alter existing surface water quality. Although this impact is predicted to be minor, monitoring would be conducted to document the effects such that remedial measures could be taken if required.

Monitoring Program

Seven surface water quality monitoring stations would be located as shown in Figure 3.4. Three stations would be located on Hat Creek; upstream of the development area, immediately downstream of the coal mine area and 10 km downstream of the mine area. Monitoring at these stations would document water quality conditions above and below the mine and powerplant site and any effects of the operation on Hat Creek.

Two stations would be located in the Bonaparte River, immediately upstream of the confluence with Hat Creek and 1 km downstream of the confluence to document any changes which may be caused by changes in the water quality in Hat Creek.

Monitoring stations would be located in Pavilion Lake where Pavilion Creek enters the lake and in Cornwall Creek at the outflow from McLean Lake. Pavilion Lake is an important nearby recreational area which receives drainage from the high ground to the northwest. McLean Lake, a large lake close to the powerplant site, is not predicted to be significantly affected by the development, however, monitoring would document any unforeseen changes.

Surface water quality monitoring would commence two years prior to the start of construction. During the first year Hat Creek would be monitored every two months. The Bonaparte River, and Hat Creek after the first year, would be monitored three times per year, in the winter, during the spring freshet and during the late summer low flow period. Pavilion Lake and Cornwall Creek, which are not readily accessible during the winter, would be monitored during the spring freshet and in late summer.

The three sampling times have been selected based on natural flow characteristics and water quality fluctuations and project design parameters. Background studies[1] indicate that during the low flow period in the winter and late summer, most of the flow into the rivers is from groundwater discharge. It is during these periods that any effects of the project on the local groundwaters would be most evident. During the spring freshet discharges from the sediment lagoons would be greatest and monitoring would document any effects. Water quality monitoring would be undertaken at other times as necessary based on wastewater discharges and the results of the continuous Hat Creek water quality monitoring programme.

The same parameters as measured in the groundwater quality programme would be measured in the surface water quality programme (see page 3-38). In addition, special samples would be collected for coliform and BOD_5 analyses. At the time of sampling in situ measurements of dissolved oxygen and temperature would be made.

Flow measurement stations would be installed in Hat Creek. One station would be located upstream of the maximum level of the headworks dam and the other would be downstream of the development area immediately southwest of Indian Reserve No. 1. Flows would be continuously recorded at these stations.

The water temperature in Hat Creek would be continuously recorded at the flow monitoring station locations above and below the development area during the summer months and at the north end of the open diversion canal. The environmental assessment studies predict that there could be a significant increase in temperature in Hat Creek diversion canal although temperatures below the project would be maintained at levels suitable for aquatic organism by the addition of cool water from the power-plant reservoir. Continuous monitoring during the summer months would provide accurate documentation of any increases in water temperatures due to the project.

At the Hat Creek monitoring station immediately upstream of Indian Reserve No. 1, pH, conductivity, turbidity and sodium concentrations would be continuously monitored by an automated analytical system. These would provide a detailed record of changes in water quality due to the project and enable correlation with the measured characteristics of wastewater discharges.

3.4.3. Wastewater Discharges

Water from project sedimentation ponds would be discharged into surface waters; the impact of such discharges is predicted to be minor. However, discharges would be monitored to provide a basis for any necessary remedial actions and for compliance with Pollution Control Permit requirements. Wastewater discharge data would also be used in the assessment of surface water quality data and in other environmental studies.

Monitoring Programme

The only discharges of wastewaters from the development to surface waters would be from the north valley sedimentation lagoons and the pit rim dam. The north valley sedimentation lagoons would treat surface runoff and seepage from surficial materials. The pit rim dam would collect runoff from areas downstream of the main diversion works and the sedimentation lagoons which treat surface runoff from Medicine Creek mine waste disposal area (See Fig. 3-3). The flow of discharges from the sedimentation lagoons and the pit rim reservoir would be measured and recorded continuously. Samples for analyses would be collected periodically based on discharge quantities. During construction, discharges from temporary lagoons and storage basins would be monitored as required.

The parameters measured would be the same as those measured in the groundwater quality monitoring programme.

3.4.4. Aquatic Biology

Construction of the diversion canal, wastewater discharges, seepages and drainage from the mine and waste disposal areas and air emissions from the powerplant could alter the water quality, fisheries and benthic habitats and populations in the Hat Creek system. Benthic organisms are sensitive to changes in water quality and reflect periodic as well as chronic modifications which may not be evident from periodic water quality monitoring. Fish are a significant resource in the Hat Creek-Bonaparte River system. Aquatic biological studies would document changes in fisheries and benthic conditions and provide a basis for any remedial actions required to safeguard local aquatic resources.

Monitoring Program

Fisheries, habitat condition and benthos sampling would be carried out at two stations in Hat Creek and two stations in the Bonaparte River. These stations and others were monitored during the environmental impact studies conducted by Beak[2] in 1976 and 1977. These were selected for continued monitoring based on their locations in representative areas and on results of the 1976 and 1977 studies. The locations of these five aquatic biological monitoring stations are shown in Figure 3-4.

The condition of the aquatic habitat would be noted at the time of the fish and benthos studies, particularly with respect to bottom sediments below the mine site. Observations would be made on substrate composition, bank stability and vegetation, stream width, depth, velocity and pool-riffle ratio at each station. These observations, plus the information on water quality will be monitored in the assessment of the quality of the aquatic habitat.

Benthic invertebrate samples would be obtained using a Surber sampler. Four replicate samples would be collected at each station. Each sample would be washed on a No. 30 sieve and retained sample preserved and stained. In the laboratory all macro-invertebrates would be sorted, enumerated and categorized into established pollution tolerance groupings. Selected samples would be further identified to genus and species, as possible, to provide more detailed data. Analysis of community structure and condition would be done using a series of five standard biological indices including biotic index, domimance, diversity, equitability and richness.

Fisheries surveys would be carried out using an electro-shocker and appropriate nets at the five montioring stations. An area large enough to characterize species composition and abundance would be sampled at each station. The number of each species, length and wet weights would be recorded; sex, presence of parsites and general condition of each specimen would be noted. Scale samples would be taken from selected samples for age and growth analyses.

During the fisheries and benthos sampling, special samples of fish and possibly benthic organisms would be collected for trace element analyses. These samples would be analysed for selected trace elements including: As, B, Cd, Cr, Cu, F, Pb, Hg, Ni, Sn, U, V and Zn. The number of samples collected and analysed would be adequate for statistical evaluation and interpretation of the results.

The aquatic biological surveys of habitat, fisheries and benthos in Hat Creek and the Bonaparte River and the trace element analyses would be done annually in the later summer, commencing two years before the start of construction.

Additional monitoring for fish present would be carried out on the Thompson River near and within the process water intake at Ashcroft. During construction, frequent inspections would be made to ensure that adverse effects on the fish are minimised. Approved construction procedures would be followed. During the initial operation, the intake system would be observed for any adverse effects on fish, particularly during the spring downstream migration of young fish. In the first even-numbered year of full operation, intensive monitoring would be carried out in April and May during the seaward migration of pink salmon. These fish are numerous and small in size and thus are the most vulnerable species. Monitoring activities would be coordinated with provincial and federal fisheries authorities.

3.4.5 Acid Precipitation Studies

Gaseous emissions from coal-burning powerplants have been identified as a contributor to acid precipitation. Detailed studies by ERT[3] indicate that the Hat Creek powerplant emissions would not cause significant adverse environmental effects at local or long range due to acid precipitation. These studies predict that only small increases would occur in the acidity of precipitation and in deposition effects. Most water bodies within the area of greatest predicted impact from the project are well buffered and relatively insensitive to acid precipitation. Further, soils found in these areas have moderate to high acid buffering capacities. However, since the processes involved in long-range transport and acid deposition and the possible chronic environmental effects of acid precipitation are not well understood, monitoring would be carried out to document conditions before and during operation of the powerplant. This would include detailed monitoring of possible low pH surges in stream/lake waters as a result of initial snowmelt events.

The monitoring of acid precipitation and its effects is presently being carried out throughout North America but particularly in the eastern half of the continent. Methods for measuring the characteristics of precipitation chemistry, the magnitude and nature of dry deposition and the effects of acidic material on the environment are available. However improvements in monitoring equipment are being made and are expected to show substantial advances in the near future. Suggestions for the monitoring of acid precipitation effects have been made by the British Columbia Fish And Wildlife Branch[7]. Discussions have been held with representatives of the Ontario Ministry of Environment, The Atmospheric Environment Service and Consultants actively engaged in monitoring acid precipitation and its effects. All of these data input and recommendations have been considered in developing the monitoring program detailed below. However as noted above the subject and methods of measuring its effects are developing rapidly. Changes in the proposed program would be made as warrented by any improvements in measurement technology and/or understanding of the subject.

Monitoring Programme

The acid precipitation studies would include the following monitoring programmes: surface water quality; snow pack quality; aquatic biology; meteorology; and precipitation quality. These programmes would commence two years before the operation of the first boiler unit.

The surface water quality and aquatic biology programmes would be conducted on six river systems surrounding the Hat Creek powerplant site (Figure 3-5). These would include: the Adams River which is about 200 km northeast of the site; Hendrix Creek about 150 km to the north; the Tranquille River about 70 km east; Cayoosh Creek which is located about 40 to 70 km southeast, Scottie Creek a tributary of the Bonaparte River which is 20 to 40 km northeast of the powerplant site and Loon Creek which is 35 to 55 km northeast of the plant.

Selection of these six water systems and selection of specific monitoring sites in each system took into consideration the following:

1. Predicted rate of acid deposition from the powerplant based on extensive mathematical modelling[3];

2. Relative sensitivity of the surface waters to acid deposition based on information in other studies[4,5] and available surface water quality data for the region;

3. Importance of recreational and commercial fisheries;

4. Extent and type of drainage area;

5. Accessibility for frequent monitoring.

The predicted average net annual hydrogen ion deposition rates due to Hat Creek powerplant emissions are shown in Figure 3.5. These isopleths were calculated by ERT[3] using extensive computer models. As may be seen from Figure 3.5, the greatest deposition occurs to the northeast of the powerplant. Consequently, the monitoring sites are concentrated in this general direction within 20 to 125 km of the powerplant.

Results from other studies have indicated that the lower the pH and alkalinity of natural waters, the more sensitive are those systems to the effects of acid precipitation. It has been suggested that water bodies with pH's of 7 or less and alkalinities of 25 mg/l (as $CaCO_3$) or less are most likely to be affected[6]. Where possible, systems with these characteristics were selected.

Most of the water systems in the region support important Provincial recreational fisheries and many are important for salmon and steelhead trout spawning and juvenile rearing. The monitoring sites would be located in waters that are important to fish.

Headwater areas are normally less well buffered and more sensitive to acid precipitation than areas further along in a river system. Other studies have found that the effects of acid deposition are most evident in headwaters. Accordingly, monitoring sites were selected in headwater areas wherever possible, and particularly in headwater areas that contained small lakes as well as streams.

Accessibility of the monitoring sites, although not as important as the other criteria, is necessary for an extensive continuous monitoring programme. Year-round access, particularly during critical periods such as during the spring freshet, is required for the collection of complete, contiguous data and for proper calibration and maintenance of monitoring instruments.

The location of the water quality and aquatic biology monitoring sites are shown in Figure 3-5. The characteristics of each site are presented in Table 3-4. Surface waters closer to the powerplant site would be extensively monitored in the surface water quality monitoring programme described in Section 3.4.2 and the aquatic biology programme Section 3.4.4. These sites, which are described in Sections 3.4.2 and 3.4.4, are not identified as sites in the acid precipitation studies, although data from these sites would be used in the evaluation of the effects of acid depositions.

The selection of water quality monitoring sites for the acid precipitation studies has been based on all available data. Water quality data for over 200 water bodies in the project area were reviewed. However, water quality and fisheries data were not available for all of the many small lakes and streams in the area. Before the acid precipitation studies are initiated, field surveys would be carried out to obtain additional surface water quality data to ensure that the most appropriate sites would be selected for the monitoring programmes. The presently identified sites and locations should not be considered final.

TABLE 3 - 4 CHARACTERISTICS OF ACID PRECIPITATION MONITORING SITES

NAME AND LOCATION OF WATER BODY	CHEMICAL CHARACTERISTICS OF WATER				FISHERIES VALUE	PREDICTED HYDROGEN ION DEPOSITION RATE	DISTANCE FROM POWERPLANT SITE - KM	BUFFERING CAPACITY OF LOCAL SOILS	PRIMARY REASON FOR SELECTION **
	pH	Alkalinity MG/L $CaCO_3$	Filterable Residue-MG/L	Conductivity uMHOS/CM					
1. ADAMS RIVER*					High	Low		Low	2,3,4
Tumtum Lake							210		
Below Adams Lake	7.6	22.5	39.3	55.0			140		
2. HENDRIX CREEK					High	Low		Low	2,3,4
Hendrix Lake	6.8		35				150		
Hendrix Creek below Lake	7.2	22.8	60	70.5			140		
3. TRANQUILLE RIVER					High	High		High	1,2
Tranquille Lake							70		
Tranquille River	7.6	40.4	60.0	80.8			60		
4. CAYOOSH CREEK						Low			1,2
Duffey Lake							70		
Near Lillooet	8.1	41.2	64.0		High	Low	40		
5. SCOTTIE CREEK*						High		High	1,5
Brousseau Lake							40		
Scottie Creek							20		
6. LOON CREEK									
Loon Lake	8.9	295	320	505	High	High	50	High	1

* Systems to be more extensively studied
** Numbers refer to text page 3-44, 3-45

The Atmospheric Environment Services (AES) of Canada maintains many meteorological stations throughout B.C. Meteorological parameters and precipitation quality would be monitored at 12 existing AES stations, including: Ashcroft, Kamloops, Lillooet, Lytton, Chase, Blue River, Darfield, Merritt, 100 Mile House, Boss Mountain, Vernon and Dog Creek. An additional station would be established at the water quality monitoring site near Scottie Creek in the region where acid deposition is predicted to be high. The monitoring stations, which are part of the acid precipitation studies, are shown in Figure 3-5. These stations were located to provide data on the changes, if any, on the regional precipitation quality from areas surrounding the Hat Creek site with emphasis in the northeast quadrant, and in areas near surface water quality and aquatic biology monitoring sites.

The surface water quality monitoring would include a specific study for the collection of surface water samples in the early spring during early snowmelt and in the late summer. Standard sampling and analytical procedures would be followed. The following water quality parameters would be documented: pH, alkalinity, conductivity, carbonate, bicarbonate, total phosphorus, nitrate, sulphate, chloride, calcium, magnesium, total dissolved solids, suspended solids. Trace elements would be determined on selected samples.

Snow pack surveys would be conducted twice during the winter in the mountain areas drained by the Adams River and in the Bonaparte River watershed area. In most cases, snow core samples would be collected by helicopter in January and in April. The snow cores would be analysed for the same parameters as the acid precipitation water quality samples including selected trace elements.

More extensive monitoring would be conducted in the Adams River and Scottie Creek areas during the spring snowmelt to better document effects of the snowmelt on surface water quality. The chemical characteristics of accumulated snow pack in these areas would be used to supplement these studies.

The aquatic biology monitoring would include collection of biological samples in the late summer near selected surface water quality monitoring sites. The type and relative abundance of periphyton would be documented in rivers and the types and abundance of phytoplankton would be documented in lakes. Fish populations would be monitored in a qualitative way, especially the young of the year. The latter would indicate spawning-hatching success. The aquatic biology monitoring programme would be conducted every third year commencing two years before the operation of the first boiler unit.

Comprehensive meteorological and air quality data for the region close to the powerplant site would be obtained in the atmospheric resources monitoring programmes described in Section 3.2. These data would be used in the acid precipitation studies.

Meteorological data would be obtained from the station installed in the Scottie Creek area and from the twelve government monitoring stations in the study region, as shown in Figure 3-5. At these stations monthly average precipitation pH would be monitored using special collectors that remain closed except during periods of precipitation to reduce contamination of samples by dust. In addition, samples would also be collected periodically for chemical analyses, and at selected stations samples would be collected on an event basis to more closely assess the pH of precipitation. These samples would be analysed for the same parameters as in the surface water monitoring. Measurements of dry deposition of acidic material would also be made.

3.4.6 References

1. Beak Consultants Limited. April 1979. Hat Creek Project. Detailed Environmental Studies, Water Resources Subgroup, Hydrology, Drainage, Water Quality and Use. Volume 3A, Impact Assessment of the Revised Project. Prepared for B.C. Hydro and Power Authority.

2. Beak Consultants Limited, December 1977. Hat Creek Project. Fisheries and Benthos Study. Prepared for B.C. Hydro and Power Authority.

3. Environmental Research & Technology Inc. June 1979. Air Quality and Climatic Effects of the Proposed Hat Creek Project, Appendix I, Long Range Transport and Implications of Acid Precipitation. Document P-5074-F-I. Prepared for B.C. Hydro and Power Authority.

4. Altshuller A.P., McBean, G.A. 1979. The Long-Range Transport of Air Pollutants in North America, A Preliminary Overview. Prepared by U.S.-Canada Research Consultation Group on the Long-Range Transport of Air Pollutants.

5. Heck, W.W., Krupa, S.V., Linzon, S.N. (Ed) 1978. Handbook of Methodology for the Assessment of Air Pollution Effects on Vegetation. Upper Midwest Section, Air Pollutinn Control Association.

6. Personal Communication with Dr. T. Bridges, Limnology and Toxicity Section, Water Resources Branch, Ontario, Ministry of Environment. (1980.).

7. Newcombe C.P. 1977, Water Quality Near the Proposed Hat Creek Thermal Generating Station: Potential Effects of Acid Precipitation on Streams and Lakes. Fisheries Management Report No. 69, B.C. Fish and Wildlife Branch.

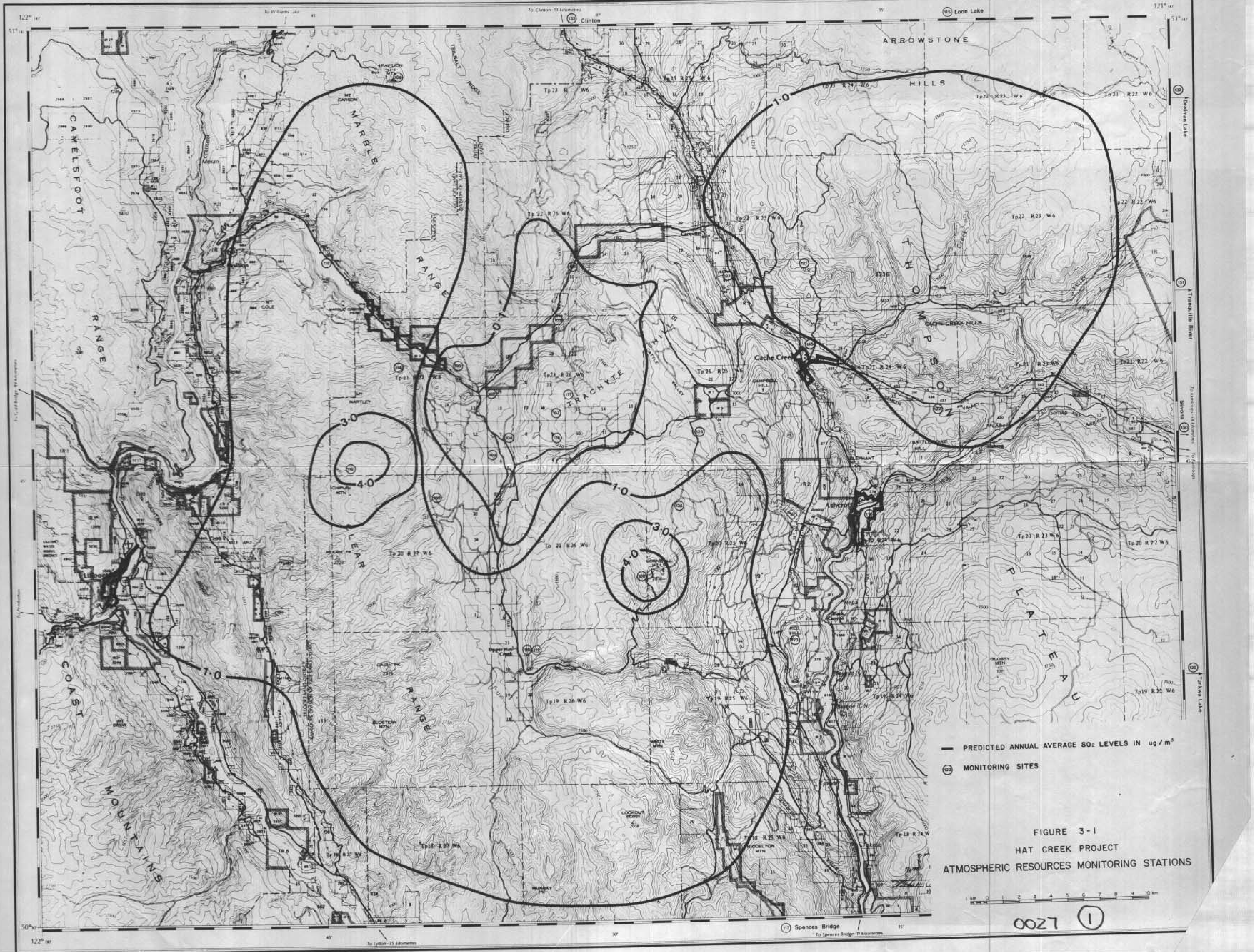
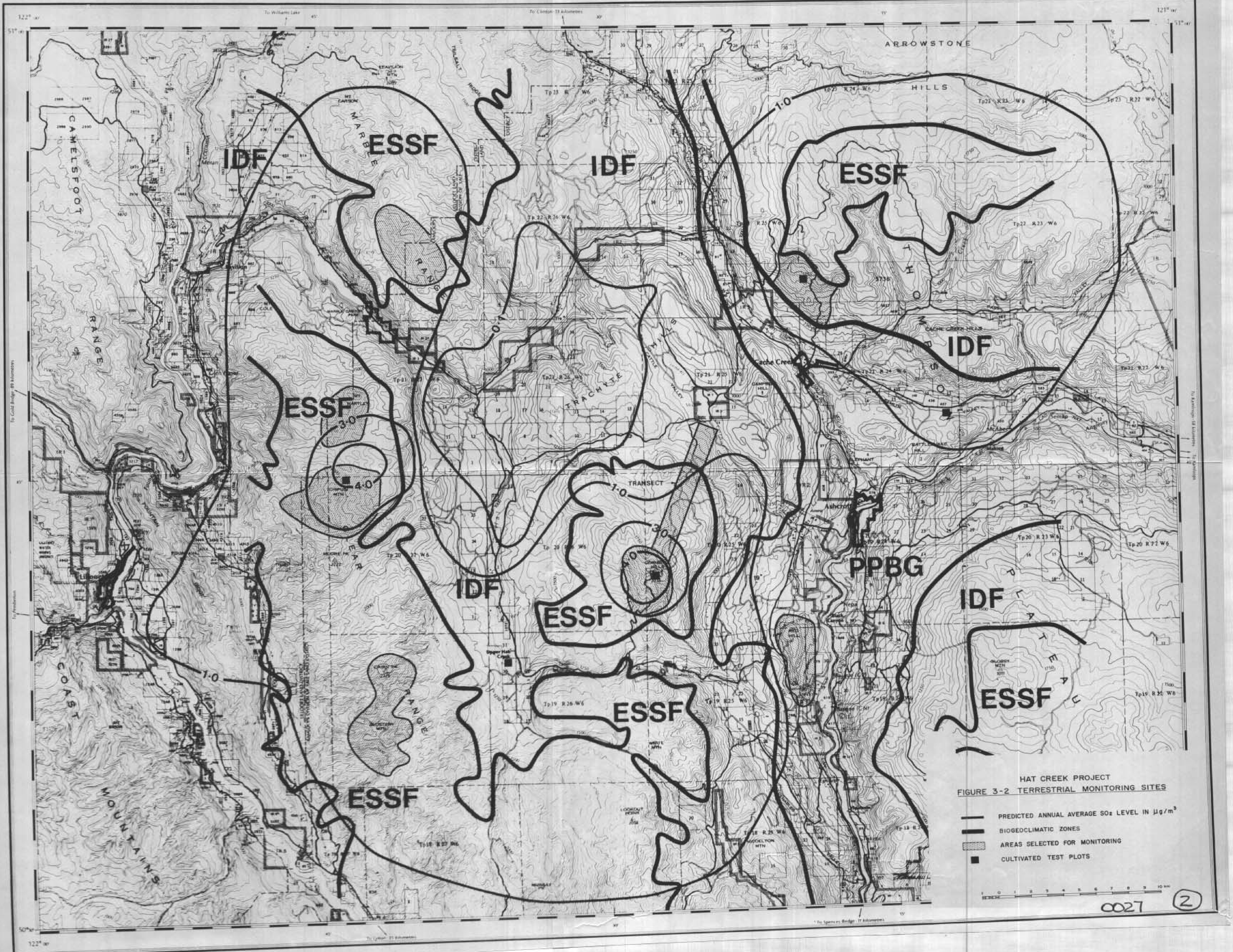


FIGURE 3-1
HAT CREEK PROJECT
ATMOSPHERIC RESOURCES MONITORING STATIONS

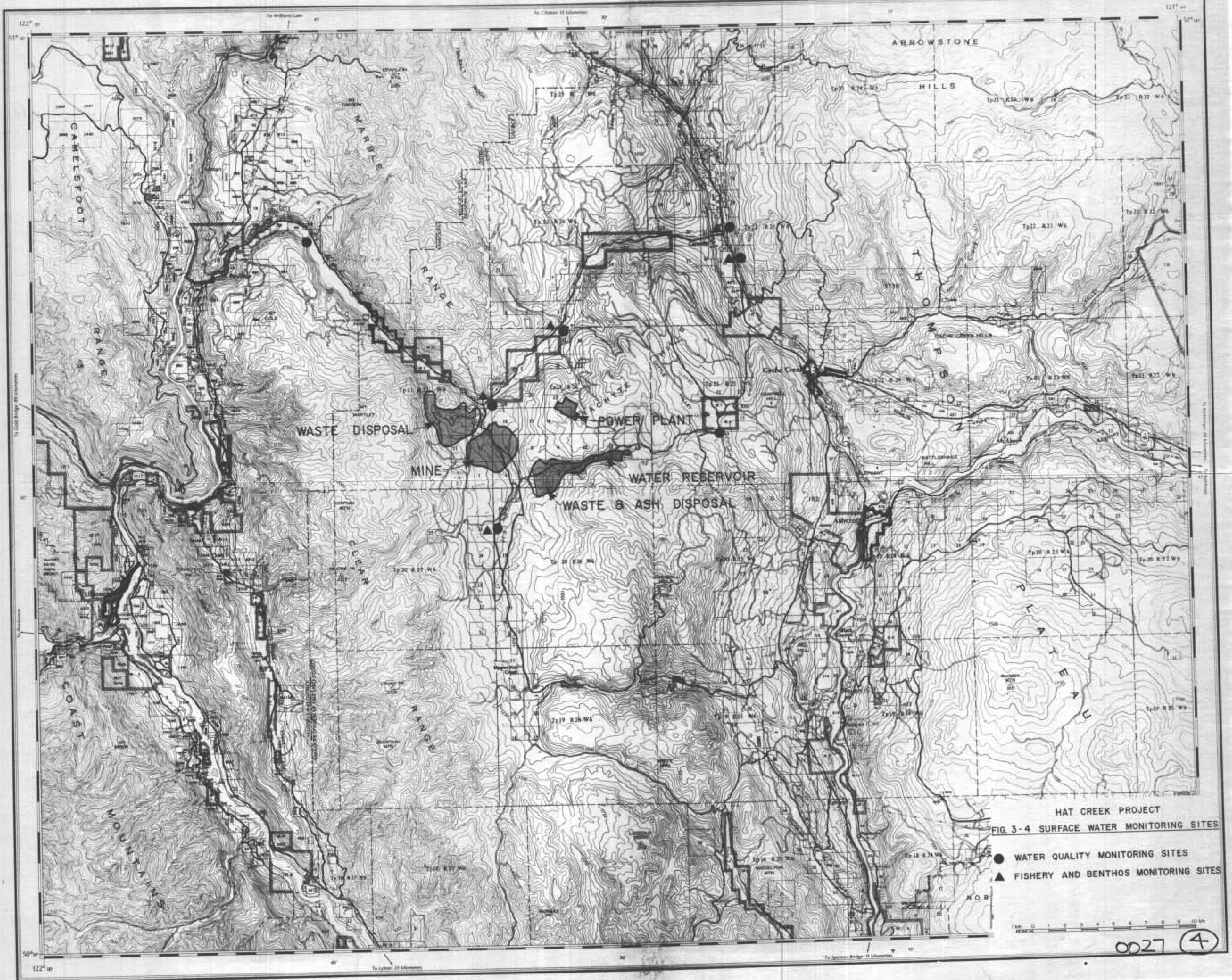
0027 (1)



HAT CREEK PROJECT

FIGURE 3-2 TERRESTRIAL MONITORING SITES


IN MARBLE CANYON AQUIFER
500 kV Line (to Kelly Lake)
500 kV Line (to Nicola)
MARBLE CANYON
Existing 60 kV Line
Indian Reserve IR-1
North Perimeter Diversion Drain
North Valley Sedimentation Lagoons
69 kV Construction Supply
MINE MAINTENANCE COMPLEX
Construction Water Supply Well
Construction Water Reservoir
Leachate Holding Lagoons
COAL BLENDING AREA
HOUTH MEADOWS WASTE DISPOSAL AREA (Final 35 Year Layout)
Spray Evaporation Area
West Perimeter Diversion Drain
Mine Waste Conveyor System
Mine Camp
Hat Creek Diversion Buried Conduit
Dump Pockets & Primary Crushers
Trench B
In-Pit Conveyor System
CLEAR RANGE
Mine Road
Trench A
North Slide Diversion Drain
35 YEAR OPEN PIT MINE
South Slide Diversion Drain
Finney Lake
Upper S.W. Diversion Drain
Lower S.W. Diversion Drain
PIT RIM DAM
Finney Creek Diversion
Existing Airstrip
Finney Creek
Environmental Services Lab
Sedimentation Lagoons
Leachate Holding Lagoon
Potential Nursery
Hat Creek Diversion Canal
Relocated Hat Creek Road
Reservoir Outlet Conduit
Future Waste Conveyor
69 kV Line
Minor Diversion Drain
MEDICINE CREEK MINE WASTE DISPOSAL AREA (Final 35 Year Layout)
Embankment (Elev 1130m)
Minor Diversion Drain
Ambusten Creek Canal Crossing
Diversion Canal
Anderson Creek
HEADWORKS DAM
Fish Hook Lake
Powerplant Construction Camp
69 kV Switchyard
500 kV Switchyard
Turbine Hall
Auxiliary Bay
Boiler House
Precipitators
Stack
POWERPLANT (Elev 1410)
Space Provision for Possible Future Flue Gas Cleaning Equipment
Powerplant Coal Holding System
Coal Storage Area
Cooling Towers
Meteorological Tower
Overland Coal Conveyor & Access Road
Buried Water Line
Harry Lake
Project Access Road
Harry Creek
Powerplant Access Road
Site Drainage Ditch
Possible Access Road From Ashcroft Manor Via Cornwall Creek
Water Supply Pipeline From Thompson River
TRACHYTE HILLS
Pumphouse Access & Conveyor Service Road
North Runoff Canal
Ash Conveyors
69 kV Junction
Site Runoff Holding Pond
Overflow Ditch to Reservoir
Ash Area Drainage Pipe Line (Initial Location)
Water Supply Pipe
WATER SUPPLY RESERVOIR (Normal Max Reservoir Elevation 1230.0m)
Water Supply Pump House
Probable Max Flood Level El. 1242.5
Ash Conveyor (Initial Location)
"DRY" ASH DISPOSAL AREA
Run Off Retention Pond (Initial Location)
Line of Change of Slope (Elev 1221.4m)
South Runoff Canal
Medicine Creek
Existing Diversion Ditch
CORNWALL HILLS
REFERENCE DRAWINGS
PIT DEVELOPMENT YEAR 35 - B.C. HYDRO 1979 MINING REPORT FIG. 5-17
HOUTH MEADOWS WASTE DUMP - B.C. HYDRO 1979 MINING REPORT FIG. 5-19
MEDICINE CREEK WASTE DUMP - B.C. HYDRO 1979 MINING REPORT FIG. 5-20
MINE SERVICE AREA - B.C. HYDRO 1979 MINING REPORT FIG. 10-1
MINE MATERIALS HANDLING SYSTEM - B.C. HYDRO 1979 MINING REPORT FIG. 3.6
MINE DRAINAGE PLAN - COMINCO-MONENCO J.V. REPORT VOL. IX FIG. 3.7
POWERPLANT PLOT PLAN - INTEG-EBASCO No. F-BCH0064-M101
POWERPLANT COAL HANDLING SYSTEM - INTEG-EBASCO No. F-BCH0064-M116
ASH DISPOSAL SYSTEM - INTEG-EBASCO No. F-BCH0064-SK151
COOLING WATER PIPELINE - SANDWELL No. 64191-1
HAT CREEK DIVERSION G.A. - B.C. HYDRO No. 604H-C14-048
FINNEY CREEK DIVERSION G.A. - B.C. HYDRO No. 604H-C14-046
PROJECT ACCESS ROAD - B.C. HYDRO No. 604H-C14-D14
CONSTRUCTION CAMPS - H.A. SIMONS (INTERNATIONAL) LTD. PROJECT 4142 A - PLATE 1 REV. 02
BASIC SURVEY INFORMATION - B.C. HYDRO No. 604H-67-X1(BA-1)
NOTES:
1) PRODUCED FROM DIGITAL TERRAIN MODEL (DTM) UNIVERSAL TRANSVERSE MERCATORS (UTM) PROJECTION
2) THIS DWG. SUPERSEDES DWG. 604H-Z31-X02000I
WASTE WATER DISCHARGES
GROUND WATER WELLS
Scale in Metres
0027
3
BRITISH COLUMBIA HYDRO & POWER AUTHORITY
HAT CREEK PROJECT
FIG 3-3 WATER QUALITY MONITORING SITES
SCALE 1:10,000



HAT CREEK PROJECT

FIG. 3-4 SURFACE WATER MONITORING SITES

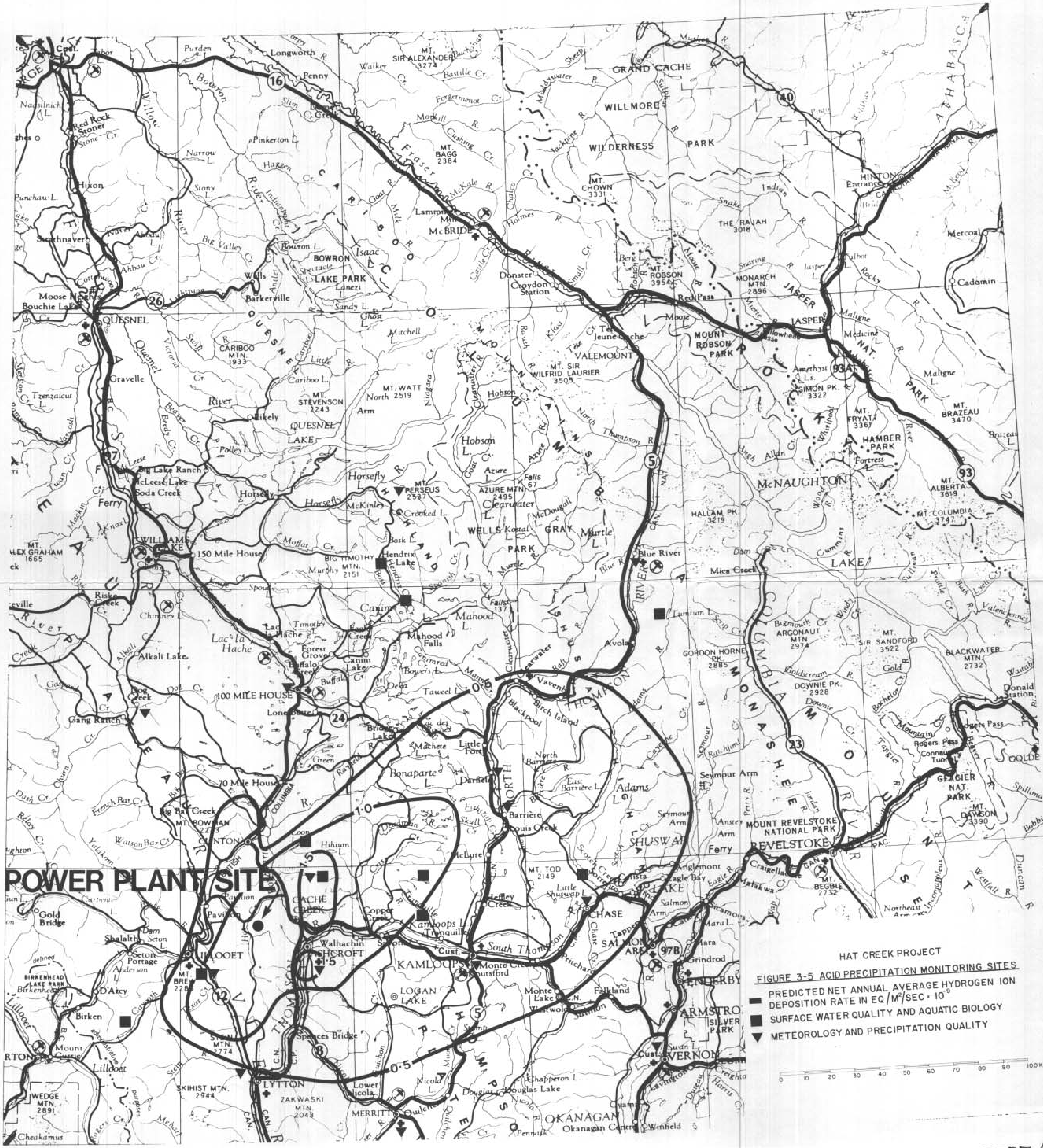


FIGURE 3-5 ACID PRECIPITATION MONITORING SITES

0027 (5)

4.0 RECLAMATION

4.1 Introduction

A major activity of the site environmental group would be the reclamation of land areas disturbed by the project. Reclamation work has already been carried out at the site following exploration drilling, excavation of a bulk coal sample and construction of roadways. Land reclamation would continue through the construction, operation and decommissioning of the powerplant development. The ultimate objective of the programme is to rehabilitate disturbed lands to equivalent or higher land use status upon completion of the project. Initial objectives are to revegetate the land to reduce erosion and to enhance aesthetics of the area.

Extensive studies have been carried out to determine the suitability of waste materials and various vegetation species for reclamation at Hat Creek. Many of these studies are being continued to evaluate long term considerations.

This section presents a description of the reclamation activities and studies completed and outlines the reclamation programmes to be carried out by the site environmental group.

4.2 On-Site Reclamation Studies

Both laboratory and on-site testing has been undertaken to determine the properties of the waste materials as growth media and to evaluate a variety of grass and legume species for revegetation at Hat Creek. Initial laboratory (greenhouse) studies were followed by detailed on-site reclamation testing, making use of materials generated during the 1977 Bulk Sample Program, (Acres,1977). These latter tests have demonstrated most effectively that the revegetation of waste materials is feasible at Hat Creek consistent with B.C. Hydro proposed goals for reclamation, which are as follows:

Short-term goals	-	Control of wind and waterborne erosion,
	-	Aesthetics,
	-	Stabilization of waste;
Long-term goals	-	Self-sustaining vegetation,
	-	Suitable end use - mixed agriculture and wildlife.

The on-site tests comprised two major programmes, one to examine the revegetation potential of slopes at different angles of repose, and the other to examine the different materials and determine their characteristics as growth media. All waste dumps associated with the 1977 Bulk Sample Program were also reseeded and provided facilities for further testing. Detailed descriptions of the land reclamation studies and the results obtained to date are contained in the following reports: Acres (1977), Cominco Monenco (1978), Integ Ebasco (1978), B.C. Hydro (1979), B.C. Hydro (1980) and Monenco (1980).

Slope Plots

Sloped revegetation test areas were constructed at Houth Meadows and Medicine Creek to examine the revegetation potential on typical embankment material, gravel at Houth Meadows and till at Medicine Creek, at slopes of 22 degrees, 26 degrees, and 30 degrees. Half of each plot at Houth Meadows was covered with a thin layer of top soil. Aspect and altitude were selected to simulate as closely as possible climatic conditions to be encountered at the Medicine Creek and Houth Meadows waste disposal embankments. Both areas were hydro-seeded with a single seed mix in the Fall of 1977 and subsequently fertilised in the Spring of 1979.

Growth assessments were made during the latter part of the 1978, 1979 and 1980 growing season and the plots examined for signs of waterborne erosion. Results of these examinations have shown that there is essentially no difference in the success of vegetation establishment on the materials without topsoil at the three slope angles; in all cases growth was satisfactory with a good mix of grass and legume. Soil erosion due to runoff was not apparent even though several thunderstorms were experienced during this period. On the topsoil treated plots at Houth Meadows, growth of seeded species was severely inhibited by the abundance and vigorous growth of weeds, the seeds of which were transported to the site in the topsoil.

From the results of these studies it is concluded that embankment slopes at Houth Meadows and at Medicine Creek could be constructed to stable and reclaimable slopes at least up to 30o.

Waste Material Plots

Seven waste materials were identified during the excavations of the 1977 Bulk Sample Program. Samples of these materials and of fly-ash from the Battle River Combustion Tests were set out in 15 m x 15 m x 1 m plots near Aleece Lake. Half of each plot was covered with a thin cover of topsoil and seeded in the Fall of 1977 with three different seed mixes of four species each. The soil characteristics of the mine waste materials suggest that they fall into essentially three categories, namely surficial materials such as colluvium (till), gravel, and baked clay; non-seam waste, gritstone (sandstone/claystone), and bentonitic clay; seam waste such as carbonaceous shale and waste coal. Each plot was fertilised during the Spring of both 1978 and 1979, based on recommendations from the B.C. Ministry of Agriculture following soils testing.

Detailed vegetation monitoring was carried out after one growing season to determine the success of revegetation based on seedling emergence and biomass production. A less comprehensive evaluation was conducted during 1979 and 1980 (B.C. Hydro (1980) and Monenco (1980)) to further monitor the progress of these test plots. The results of these studies may be summarised as follows:

(1) Revegetation of surficial materials such as colluvium (till), gravel, and baked clay can be readily achieved. Further, these soils are suitable for reclamation purposes without the addition of topsoil. This result is noteworthy: in the case of colluvium, both biomass production and seedling emergence were lower on the topsoil-treated part of the plot. Plants were healthy and showed few signs of ambient deficiencies. These results indicate that the materials selected for stripping, stockpiling and/or use as surface growth media may comprise any of these surface materials, gravel, colluvium (till), baked clay and topsoil, either separately or in combination. The implication here is clearly that the separate stripping of topsoil has been shown to be unjustified in the presence of suitable quantities of other surficial materials;

(2) Revegetation of non-seam mine waste, gritstone (claystone/sandstone), and bentonitic clay proved to be more difficult to achieve in the short term. In addition to low emergence success, the biomass production of vegetation was poor; most plants exhibited signs of nutrient deficiency. The physical and chemical properties of these soils contribute to poor soil structure under extreme conditions of moisture and nutrient imbalances.

The addition of topsoil proved beneficial although plants remained somewhat stunted. Subsequent 1979 and 1980 observation showed some species of vegetation progressing well on the untreated gritstone. Nevertheless, it is considered that a surface capping of surficial material would be required to satisfactorily revegetate these waste materials;

(3) Seam waste was the most difficult of all materials tested to vegetate. However, the chemical characteristics of these materials appear to be less of a deterrent than do their

physical properties, particularly their dark colour resulting in excessive surface temperatures and the hydrophobic nature of the carbonaceous shale. A capping of surficial material would be required for satisfactory reclamation.

Tests on the fly ash showed that a surface capping of surficial material would be necessary forsatisfactory revegetation.

Waste Dumps

Waste material stockpiles from Trenches A and B were seeded in late 1977. Piles at Trench C and unsatisfactory portions of the piles at Trench A were seeded in the Fall of 1978. Topsoil (15 cm) was applied to half of the uppermost dump at Trench A and to half of the dumps at Trench C. In addition, water retention furrows were constructed across the dump fall line in an attempt to improve moisture retention on the dump surface.

The results on these dumps confirm the results at Aleece Lake and the slope plots. Gravels and baked clay are readily revegetated, while bentonitic clay and gritstone show less success. Germination in topsoil was substantially less successful than germination in baked clay. Further, the dramatic growth in the water retention furrows constructed in bare carbonaceous shale and bentonitic clay clearly identifies the lake of moisture as a most important factor in revegetation at Hat Creek. where the annual average precipitation totals only 317 mm.

Vegetation Species

In total 16 different species of grass and legume have been tested in these revegetation trials. The species were selected on the basis of their known characteristics and adaptation to the soils and climatic conditions at Hat Creek. To ensure that the species were both viable and available, only agronomic species were considered. Seed mixes of four and five species were devised, and, in some instances, species were used individually.

Results of these field tests have identified several species would could be used for reclamation purposes at Hat Creek. Among the grass species the following perennial grasses show excellent potential: Crested Wheatgrass (Nordan), Streambank Wheatgrass (Sodar), Slender Wheatgrass, Tall Wheatgrass (Altar), and Smooth Bromegrass (Manchar). Fall ryegrass proved to be an excellent species for short-term (1 year) revegetation. However it is an annual, and because it is particularly tall-growing and vigorous, it is suspected of inhibiting the growth of other perennial species with which it was seeded. As a result, its use would be restricted to those occasions where short-term revegetation for example, for dust control is required.

Several legumes have been tested. Of these Alfalfa (Drylander) and Sainfoin (Melrose) have proved most successful. Double-cut red clover and white clover, a biannual, showed lesser success, but may be useful as minor species in seed mixes. All legumes performed better when competition from other plants was absent.

The selection of species for revegetation of waste dumps and related areas at Hat Creek would be largely based on those identified above. Mixes of approximately five species, of which three would be grasses would be selected and seeded, mostly by harrow-seeding methods. Only in areas too steep for harrow-seeding would hydro-seeding be used. Due to the low precipitation, seeding would be carried out in late Fall (September-November) or early Spring (April-May), the former period being favoured in order that maximum use could be made of moisture accumulating over the Winter months. Legumes may benefit from early Spring seeding to reduce losses by Winter kill.

In addition to these agronomic species, native shrubs and forbs considered essential in the reclamation of wildlife habitats would need to be transplanted and/or propagated in a nursery which would be established near the Pit Rim Reservoir.

4.3 Reclamation During Construction, Operation and Decommissioning

Waste Dumps and Embankments

Rapid revegetation of embankments and waste dumps would stabilise exposed surfaces against erosion. Temporary reclamation would be carried out on all areas of dump surfaces left inactive for a number of years. Retaining embankments would be constructed in lifts which allow for long-term reclamation concurrently with construction. Waste dump surfaces would be reclaimed as soon as the final surface elevation is reached.

Waste dumps would be concurrently revegetated to an end use comparable with adjacent lands at similar elevation. Topography and diversity of native species similar to pre-mining conditions cannot be duplicated, but reclamation of waste dumps would be designed to provide a revegetated, self-sustaining, stable surface composed of materials similar to, or better than those of adjacent lands. Presently, land in the area is used for mixed wildlife and agricultural (mostly ranching) purposes. It is proposed to revegetate waste dump surfaces to a similar land use as now exists.

As a result of on-site testing as described in 4.2, it is proposed to strip and to stockpile surface soils only from those areas where the depth of the soil allows for economic extraction methods. Allowance has been made to cover all waste dumps comprised of seam or non-seam material and powerplant waste (ash/scrubber sludge) with approximately 1 m of surficial material, though the precise depth required would be established through further on-site testing. Those areas exposed by stripping, and stockpiles of surficial material, would be temporarily revegetated to prevent erosion and dusting.

Material Storage Areas After Abandonment

The coal stockpile and blending area would be levelled and sloped to harmonise with the surrounding topography. The contoured surfaces would then be covered with a buffering medium of non-sodic overburden, and seeded.

The surficial soil stockpiles would decrease progressively as the soil is spread over disturbed lands throughout the mine site. The remains would be levelled, sloped to blend in with the surrounding topography, and seeded.

Transportation Corridors

These take up about 4% of the disturbed land within the mine area. Before construction, suitable surface soils would be removed and stockpiled. Inactive sections would be seeded as soon as possible after construction, to minimise dusting and erosion. Cut and fill slopes would be graded and seeded. Trees and brush would be removed from rights-of-way to reduce any fire hazard.

During the years immediately following shutdown of the mine, conveyors, transmission lines, and culverts would be dismantled and removed. Wherever possible, corridors would be resloped to blend in with the surrounding topography. All roads (except main access roads) would be ripped to relieve compaction, and seeded. Water bars would be constructed on slopes with a potential for rill erosion.

Support Facilities

The present site has a poor quality rating in terms of land use, and the reclamation measures would be designed to enhance the value of the disturbed land.

During construction, the buildings would be screened from the main access roads by a belt of trees, not merely to improve the appearance, but to prevent dusting. No significant reclamation would take place until after the mine closes.

During the years following closure, buildings not retained for alternative uses would be dismantled, sold, and levelled to their foundations. Any areas littered would be cleared during the mine clean-up operation. Most of the Mine Services Area would then be ripped to relieve compaction, covered with 15 to 30 cm of soil, and seeded. Where practical, slopes would be regraded to blend in with the surrounding topography. Where surface materials are unsuitable for plant growth, a suitable depth of over burden would be placed before soil coverage and seeding.

The Open Pit After Abandonment

Considerable planning has gone into measures designed to minimise the potential hazard to human life, livestock and wildlife, of a large void constructed of weak material. A proposal to flood the pit and convert it into a lake was explored but rejected on the grounds of poor stability of the surrounding ground, the anticipated poor quality of the pit water, and the costly and possible irrevocable nature of a decision that would make it virtually impossible to re-open the pit at some future time in order to extract the substantial coal reserves which would remain.

The plan adopted provides for resloping the top three benches (about 115 ha) from 45° to 26° to provide a safer perimeter and lessen the visual impact. No resloping would be done below this level. After resloping, fertiliser and seed would be aerially broadcast on all pit benches. Germination is expected to take place readily on those portions which consist of non-sodic glacio-fluvial and glacial till overburden, less readily on those composed of saline slide deposits. Sodic siltstones, claystones and coal. In time, revegetated overburden and slide areas may be expected to creep and to slump into the pit.

A protective fence to restrict access would surround the pit perimeter and those areas to the South-West which may be susceptible to failure. Trees would be planted at selected points on the perimeter to screen the pit.

4.4 Expected Results of Reclamation Programmes

A maximum of 2,506 ha would, at one time or another, have been disturbed by Year 35. By Year 45, however all but 906 ha would have been restored. This represented less than 1.5 percent of the Hat Creek Watershed. Of this, 396 ha include transportation corridors, airstrip, reservoirs, lagoons, and remaining facilities for long-term environmental monitoring. The remaining area represents the lower portions of the pit itself which would remain as is so as not to preclude the further economic extraction of the coal resource. Table 4.1 shows the details of areas disturbed and those reclaimed by Year 45. The areas to be reclaimed by Year 45 are also shown in Figure 4.1.

The only resources likely to be buried or otherwise alienated by the mine are aggregate (sand and gravel), and some limestone in areas immediately adjacent. And much of the aggregate excavated during construction would be stockpiled for future use.

TABLE 4.1 - AREAS RECLAIMED BY YEAR 45

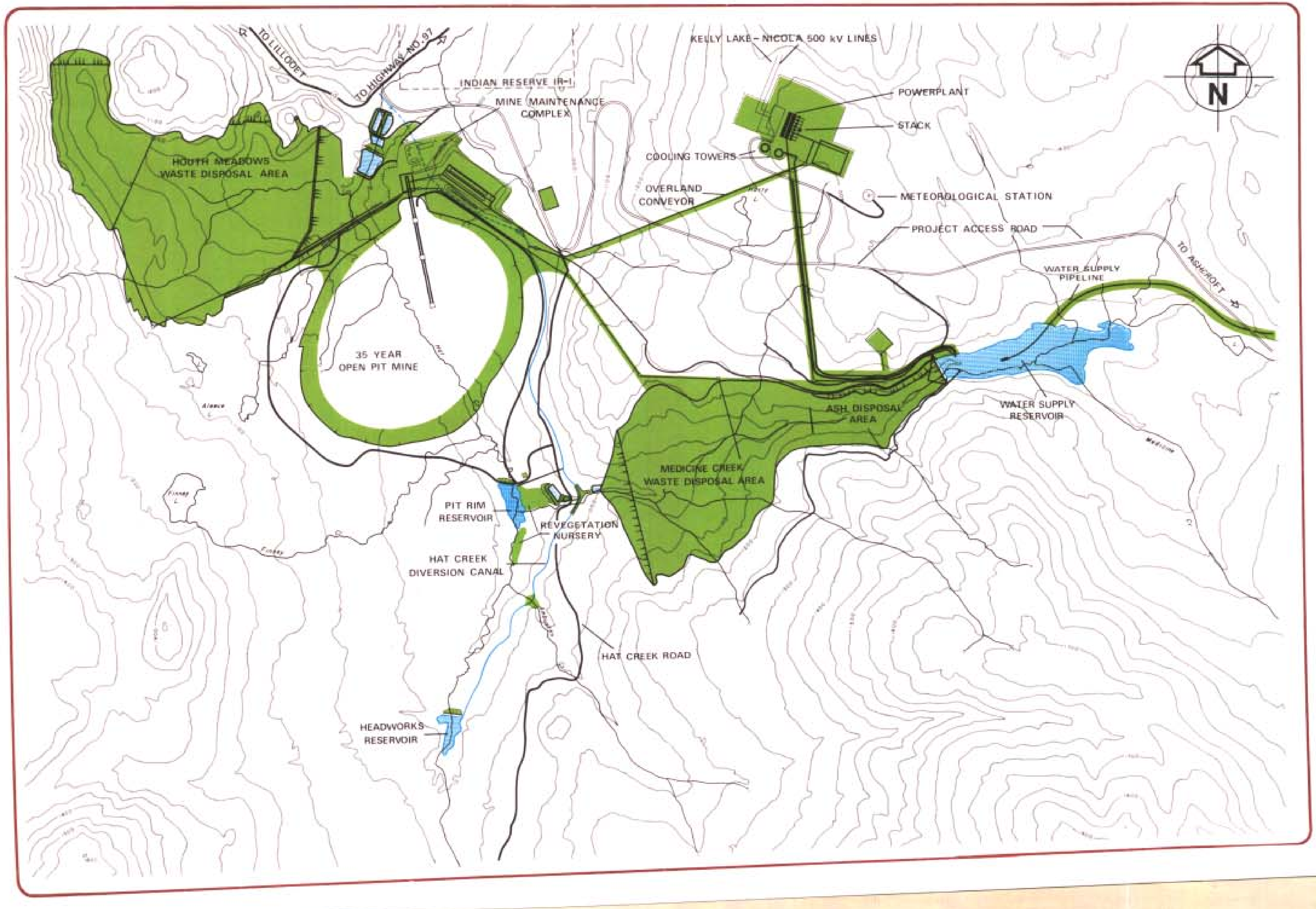
POWER PLANT	ha
Fenced Power Plant Site	99
60 kv Transmission lines Mine to Plant Substation	7
P.P. Construction Camp, Housing & Parking	11
P.P. Construction Camp, Water Supply Pipeline	2
Ash Transport Conveyor, 6C kv lines, Access and Conveyor Load Water Supply Pipe i.e. Common Corridor (to ash works?)	8
Ash Transport Conveyor	4
60 kv lines	8
Water supply pipe	7
Ash runoff Pond Water pipeline	1
OFFSITES	
Potential Nursery	10
Env. Services Lab.	-
Site runoff Holding Pond	2
- overflow to Reservoir	1
- Site Drainage Ditch	2
Make-up Water Pipeline from Thompson River	35
Offloading Area	3
60 kv Transmission Line to Booster St. 1	21
60 kv Transmission Line to Booster St. 2	9
60 kv Substations	1
SUBTOTAL -	231
MINE	
Construction Camp, Housing and Parking	5
Construction Camp Water Supply & Pipeline	-
Medicine Creek Waste Dump (including Powerplant Waste)	427
Houth Meadows	601

TABLE 4.1 (continued)

Coal Blending Area		42
Maintenance Buildings		25
Minewaste Conveyors		22
Coal Conveyor		7
60 kv lines, waste & mine		42
Mine Road		37
Drains	Lower SW	3
	SE	1
	Upper SW	2
	N. Perimeter	2
	W. Perimeter	7
	S. Run-off	14
	N. Run-off	8
	Mine Diversion	5
	N. Slide Diversion	3
	S. Slide Diversion	1
Mine Pit - Upper 3 berms		115
	SUB TOTAL - MINE	1369
	POWER PLANT & OFFSITES	231
	TOTAL RECLAIMED -	1600

TABLE 4.1 (continued)

AREAS NOT RECLAIMED:	ha
Plant Site Access and Conveyor Service Road	6
Make up Reservoir	94
Main Access Road	117
Power Plant Site Access Road	10
Rattlesnake Substation	3
Pit Rim Reservoir & Dam	11
Pipeline - P.R. Res. to Canal	-
Pipeline Res. to Canal	12
Relocated Hat Creek Road	7
Meteorological Tower	2
Finney Lake Diversion Canal	8
Hat Creek Diversion Canal	41
Headworks Dam	6
Airstrip	45
Airstrip Access Road	6
Pump House/Conveyor Road	4
Mine Construction Access	1
Leachate Storage & Sedimentation Lagoons	23
Mine Pit	470
Low Grade Stock Pile	40
TOTAL NOT RECLAIMED :	906
TOTAL DISTURBED:	2506
PERCENTAGE RECLAIMED:	64%



LEGEND

RECLAIMED AREA (MAJOR RECLAMATION)

SCALE — 1:40,000

1 km 0 km 1 km 2 km

CONTOUR INTERVAL — 50 METRES

HAT CREEK PROJECT

FIGURE 4.1

RECLAMATION — YEAR 45

SOURCE: British Columbia Hydro and Power Authority (43)

0027

(6)

4.5 References

1. Acres Consulting Services Limited, 1977. "Hat Creek Project, Environmental Studies, Bulk Sample Program". Report P4636.00 prepared for B.C. Hydro, December 1977.

2. Cominco-Monenco Joint Venture, 1978. "Hat Creek Project Mining Feasibility Report - Volume V - Mine Reclamation and Environmental Protection".

3. Integ Ebasco, 1978. "Hat Creek Project, Alternative "B" Ash Disposal Study".

4. B.C. Hydro and Power Authority, 1979. "1978 Environmental Field Programs". Vancouver, B.C.

5. B.C. Hydro and Power Authority, 1981. "1979 Environmental Field Programs". Vancouver, B.C.

6. Monenco Consultants Pacific Ltd., 1980. "Hat Creek Project, Revegetation Potential of Waste Materials". Report prepared for Acres Consulting Services Ltd. and B.C. Hydro. December 1980.

5.0 MANPOWER AND ORGANISATION

5.1 Introduction

The environmental protection, environmental monitoring and land reclamation programmes would commence early in the mine and power-plant project development and continue to after the plant is decommissioned. These programmes would be carried out by an on-site environmental group throughout all phases of the project.

The environmental protection programme commences with site construction activities five years before the in-service date. During the construction phase this programme involves monitoring and control of construction activities to minimise local environmental degradation and during operation it involves control of drainage, control of dust and noise emissions, control of atmospheric emissions from the powerplant and overall supervision of the environmental monitoring and land reclamation programmes.

The environmental monitoring programme commences two years before site construction work. It includes monitoring of atmospheric, terrestrial and water resources to quantify and document the actual effects of construction and operation of the mine, powerplant and offsite facilities on the environment.

The reclamation programme commences when construction starts and continues after decommissiong. It involves effective revegetation of disturbed land areas.

The organisation and estimated manpower to carry out these programmes are outlined in this section.

5.2 MANPOWER ACTIVITIES AND RESPONSIBILITIES

The major activities associated with the environmental protection, monitoring and land reclamation programmes are summarised in the following table commencing in the year minus seven, seven years before the operation of the first 500 MW powerplant unit and two years before any site construction work. This summary of activities is used in this report as a basis for the manpower estimates. The personnel to be hired by B.C. Hydro for the Hat Creek project environmental protection programmes and work to be carried out by outside consultants are also listed in Table 5.1.

TABLE 5.1 MAJOR ACTIVITIES AND PERSONNEL HIRED

YEAR	MAJOR ACTIVITIES	BY
-7	1 - Ground Water Quality Monitoring	Consultant
	2 - Surface Water Quality Monitoring	"
	3 - Aquatic Biological Survey	"
	4 - Air Quality Monitoring	"
	5 - Meteorological Monitoring	"
	Personnel Hired:	
	1 - Pollution Control Officer - Site	
-6	1 to 5 - as in year -7	
	6 - Noise Monitoring	BCH
-5	1 to 6 - as in year -6	
	7 - Vegetation Monitoring 5-year programme	Consultant
	Personnel Hired:	
	2 - Supt. Environment - Site	

YEAR	MAJOR ACTIVITIES			BY
-4	1 to 6	-	as in year -5	
	7	-	Nil	
	8	-	Dust and drainage control	BCH
-3	1 to 8	-	As in year -4	
	9	-	MCS programme and computer facilities	BCH & Consultant
	10	-	Start operation of environmental protection complex and laboratories	BCH
	11	-	Set-up Vegetation Monitoring programme	BCH & Consultant
	12	-	Fisheries observations during construction of water intake	
	Personnel Hired:			
	3	-	Air Quality Engineer	Site
	4 & 5	-	Monitoring Technicians (2)	Site
	6	-	Data Reduction Technician	Site
	7	-	Sr. Reclamation Officer	Site
	8	-	Reclamation Technician	Site
	9	-	Chemist	Site
	10 to 12	-	Monitoring & Laboratory Technicians (3)	Site
	13 & 14	-	Secretary (2)	Site
-2	1	-	Ground Water Quality Monitoring	BCH
	2	-	Surface Water Quality Monitoring	BCH
	3	-	Aquatic Biological Survey	Consultant
	5	-	Meteorological Monitoring	BCH
	6	-	Noise Monitoring	BCH
	7	-	Nil	
	8	-	Dust and Drainage Control	BCH
	9	-	MCS Programmes	BCH
	10	-	Operation of Environmental Protection Complex	BCH

YEAR	MAJOR ACTIVITIES			BY
-2 (cont)	11	-	Vegetation Monitoring	BCH
	12	-	Fisheries Observations at Intake	Consultant
	13	-	Wildlife Monitoring	BCH
	14	-	Reclamation	BCH
	15	-	Acid Precipitation Studies - Aquatic	BCH & Consultant
	Personnel Hired:			
	15	-	Monitoring Technician	Site
	16	-	Botanist/Terrestrial Ecologist	Site
	17	-	Reclamation Technician	Site
-1	1 to 15	-	as in year -2	
+1	1 to 6	-	as in year -2	
	7	-	Vegetation Monitoring - 5 year programme	BCH & Consultant
	8	-	as in year -2	
	9	-	MCS programme - stack monitoring	Consultant
	10 to 15	-	as in year -2	Consultant
+2	1 to 8	-	as in year -2	
	9	-	MCS programme - stack monitoring (2 stacks)	Consultant
	10 to 14	-	as in year -2	
	15	-	Acid Precipitation studies	
+3	1 to 8	-	as in year -2	
	9	-	MCS programme - stack monitoring (3 stacks)	Consultant
	10 to 14	-	as in year -2	
	15	-	Acid Precipitation studies	

YEAR	MAJOR ACTIVITIES	BY
+4	1 to 8 - as in year -2	
	9 - MCS programme - stack monitoring (4 stacks)	Consultant
	10 to 15 - as in year -2	
+5	1 to 8 - as in year -2	
	9 - MCS programme - stack monitoring (4 stacks)	Consultant
	10 to 14 - as in year -2	
	15 - Acid Precipitation Studies	
+6	1 to 6 - as in year +3	
	7 - Vegetation Monitoring 5-year programme	Consultant
	8 - as in year -2	
	9 - MCS programme - stack monitoring (4 stacks)	Consultant
	10 to 14 - as in year -2	
	15 - Acid Precipitation Studies	
+7	Major evaluation of all environmental monitoring programmes after two years of full mine and powerplant operation and revision of monitoring programmes based on assessment of all data collected.	

The general responsibilities of BCH personnel concerned with environmental protection, monitoring and land reclamation at Hat Creek are given in Table 5.2. In the early years the major portion of the monitoring programmes would be carried out by consultants with input from BCH Vancouver project management personnel. In year minus 3 the environmental protection complex would be completed on-site and monitoring and laboratory facilities would be available. Personnel would be hired in year minus 3 and minus 2 and commencing in year minus 3 most of the environmental protection, monitoring and reclamation work including laboratory analyses would be carried out on-site by BCH personnel. Only specialised work, for which the scope of work does not require full time technical personnel, would be carried out by consultants. Such programmes include the aquatic biology surveys; fisheries monitoring at the water intakes; five-year vegetation monitoring; and annual stack emission surveys.

TABLE 5.2 - RESPONSIBILITIES OF BCH PERSONNEL

YEAR	NO. OF BCH PERSONNEL	PERSONNEL AND RESPONSIBILITIES
-7	1	Pollution Control Officer - Site Oversee field work for monitoring programmes. Carry out special studies and coordinate with regulatory authorities and other BCH personnel.
-5	2	Supt. Environment - Site In charge of Hat Creek environmental protection, monitoring and reclamation programmes. Manage site activities and hire staff.
-3	14	Personnel to establish and operate Monitoring Programs including: 3 Air Quality Engineer - Site 4,5 Monitoring Tech - Site (2) 6 Data Reduction Tech - Site 7 Senior Reclamation Officer - Site In charge of land reclamation activities including planning, conducting and monitoring 8 Reclamation and Monitoring Tech - Site Carry out and monitor land reclamation programmes 9 Chemist - Site In charge of analytical laboratory 10-12 Monitoring & Laboratory Tech - Site (3) Carry out air, water and land monitoring and laboratory analyses 13, 14 Secretary - Site (2)
-2	17	15 Maintenance Tech - Site (2) 16 Botanist/Terrestrial Ecologist - Site Reclamation and vegetation monitoring programmes 17 Reclamation Tech - Site

5.3 MANPOWER ORGANISATION

An organisation chart of Hat Creek site personnel is shown in Figure 5.1. The on-site personnel are grouped into three major categories, air, water and land, which are descriptive of the overall functions and responsibilities of each group. However, these three groups overlap extensively and in practice the functions and responsibilities would be extensively integrated. For example, technicians, although shown in specific categories in the organisation chart, would carry out work in all three categories depending upon special work requirements and individual capabilities.

FIGURE 5-1 - OVERALL ORGANISATION CHART

ENVIRONMENTAL PROTECTION, MONITORING AND RECLAMATION

SUPT. ENVIRONMENT

AIR

PERSONNEL

Air Quality Engineer
Maintenance Tech (3)
Data Reduction Technician

MAJOR RESPONSIBILITIES

- Operate & maintain Air Quality Monitoring Network
- Operate & maintain other Air Quality & Meteorological Monitoring Systems
- Dust Control Monitoring
- Coordinates Stack Monitoring
- Coordinates Noise Monitoring
- Precipitation Monitoring for Acid Rain Studies
- Data Reduction and Analyses
- Prepare reports

WATER

PERSONNEL

Pollution Control Engineer
Chemist
Monitoring & Laboratory Tech (3)
Secretary

MAJOR RESPONSIBILITIES

- Groundwater Quality Monitoring
- Surface Water Quality Monitoring
- Monitor Wastewater discharges
- Coordinates Aquatic Biology Surveys
- Coordinates Fisheries Monitoring
- Acid Precipitation Studies
- Operate On-site Analytical Laboratory
- Seepage and Sediment Control
- Data Reduction and Analyses
- Prepare reports

LAND

PERSONNEL

Senior Reclamation Officer
Botanist
Reclamation & Monitoring Tech (2)
Secretary

MAJOR RESPONSIBILITIES

- Vegetation & Soils Monitoring Programs
- Land Reclamation
- Wildlife monitoring
- Data Reduction and Analyses
- Prepare reports