Report No. UKH/96/01

SITE CHARACTERIZATION

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1. Introduction

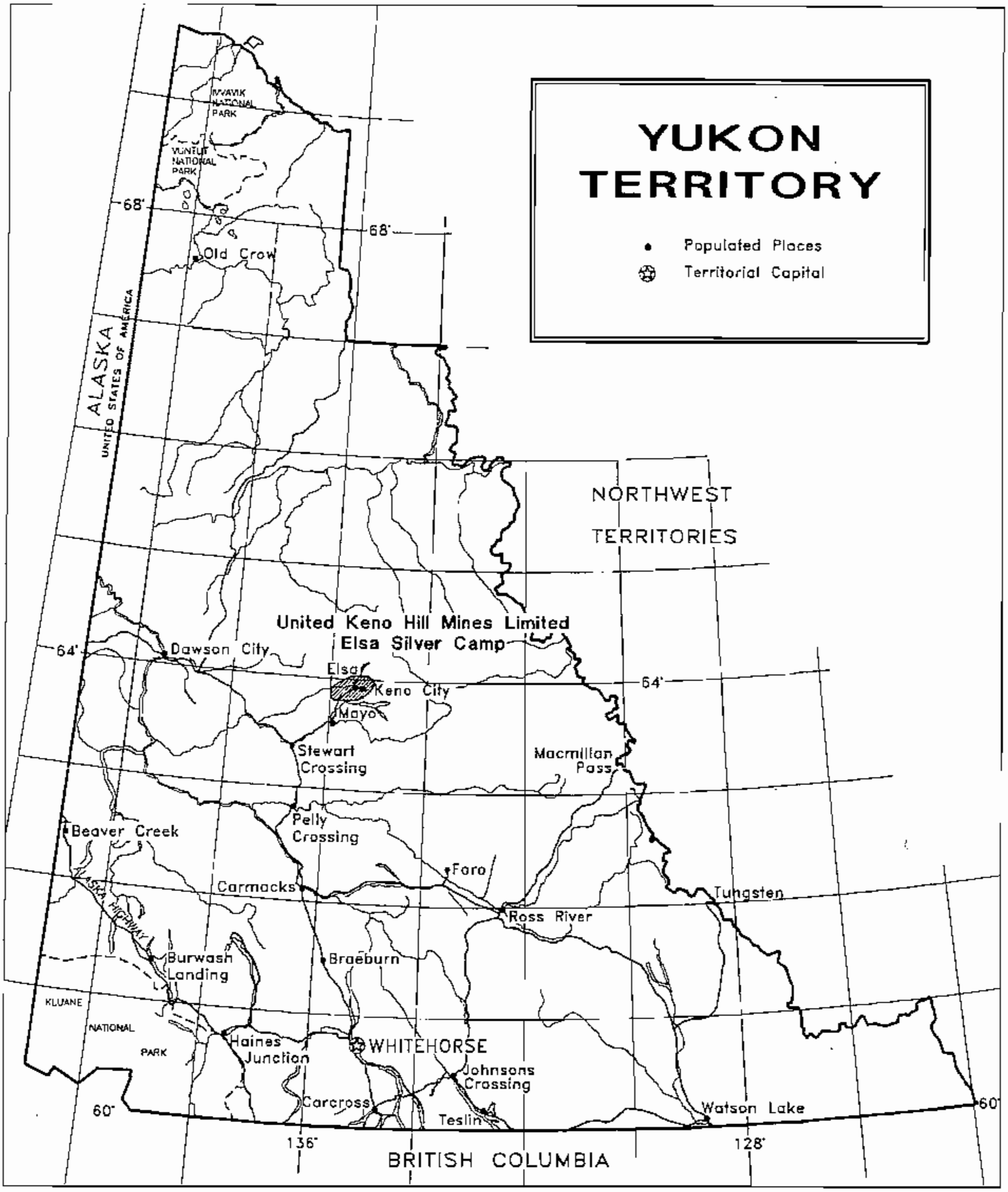
1.1 Property Location and General Description

The Keno Hill, Galena Hill, and Sourdough Hill area properties are located in the central Yukon Territory, 354 km (220 miles) due north of Whitehorse in the vicinity of the villages of Elsa and Keno City. A general location map is provided in Figure 1-1.

Access to the property is by a two-lane paved road from Whitehorse to Mayo and an all weather gravel road running 45 km (28 miles) northeast from Mayo; a total distance of 452 km (281 miles). Whitehorse, the capital of the Yukon Territory is connected to southern Canada by the Alaska Highway. The tidewater ports of Skagway and Haines, Alaska are both accessible by road from Whitehorse. There is daily air service between Whitehorse and Vancouver. Scheduled air service also operates between Whitehorse and Mayo.

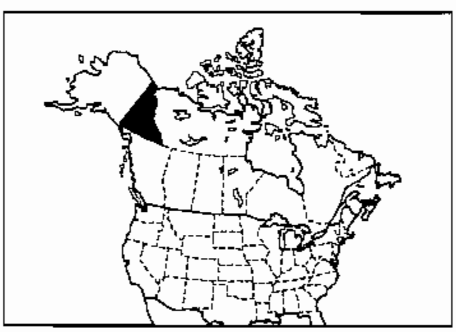
The UKHM property consists of two Crown Grants, 674 mining leases and 289 mineral claims, as well as ownership interest in 3 mining leases, 36 mineral claims and a leasehold interest in 1 mineral claim. The property covered by claims and leases is approximately 15,000 ha. (37,000 acres) in a roughly east-west belt about 29 km (18 miles) long and up to 8 km (5 miles wide). A claim map of the property is shown in Figure 1-2. Fifteen surface leases, and several parcels of freehold property cover parts of the mineral rights.

The property lies along the broad McQuesten River valley and three prominent hills to the south of the valley. The elevation of the valley is about 700 m (2,300 feet) above sea level. Galena Hill, Keno Hill and Sourdough Hill rise to elevations of about 1,400 m (4,600 feet), 1,825 m (6,000 feet) and 1,370 m (4,500 feet), respectively. The hills, although locally steep, are generally moderately sloped, unlike Mount Haldane which rises out of the McQuesten River valley to the west of the UKHM property with an elevation of over 1,825 m (6,000 feet) but with steep slopes and a cirque at the peak.

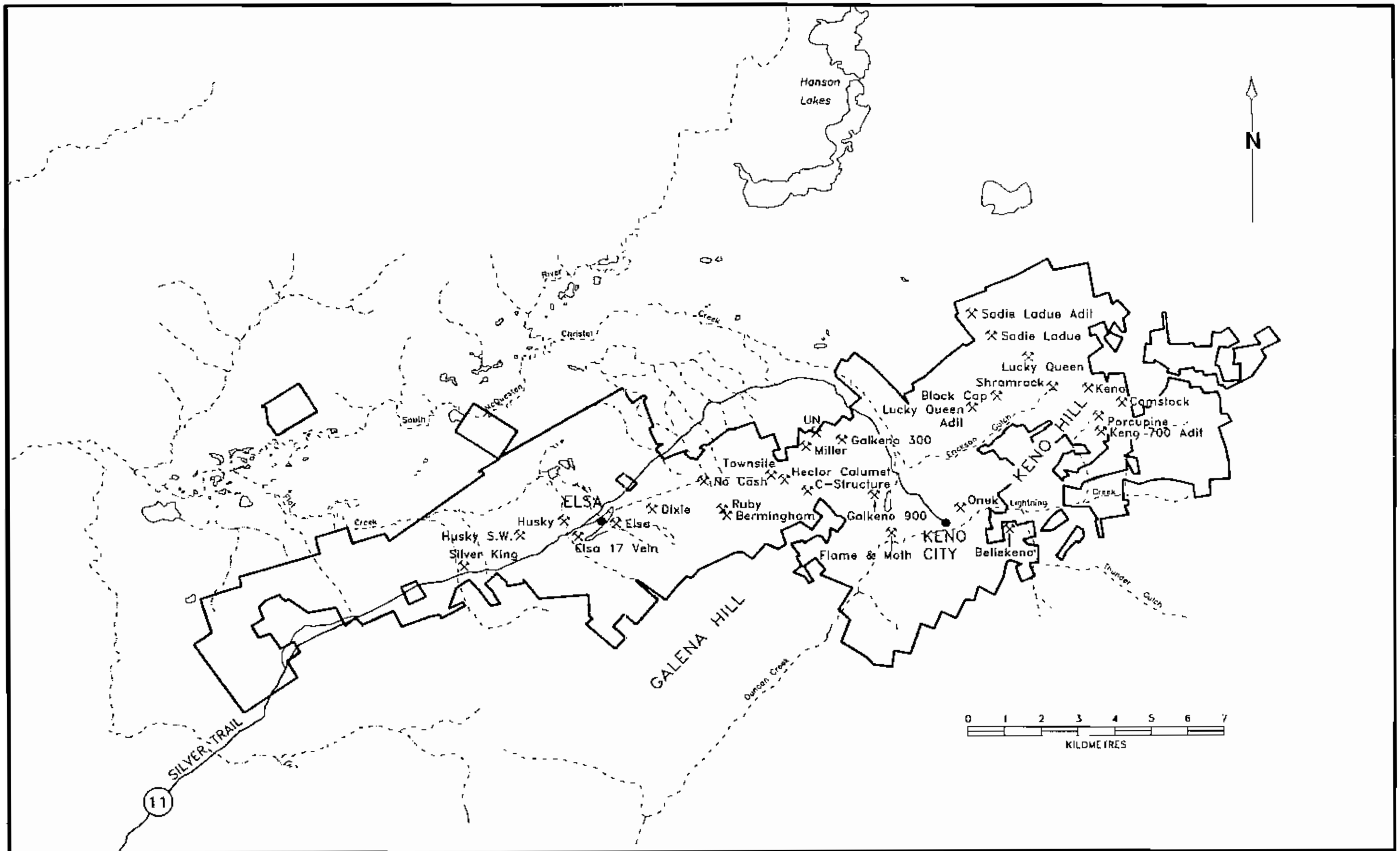


0 100 200 300
KILOMETRES

Lambert Conformal Conic Projection
with Standard Parallels at 49°N and 77°N



UNITED KENO HILL MINES LIMITED		
ELSA SILVER CAMP General Location Map		
ACCESS MINING CONSULTANTS LTD.		
SCALE: 1 : 6 000 000	FILE: 224-6	DATE: 31/05/96
DRAWN:	DWG:	FIGURE: 1-1



LEGEND

CREEK, STREAM, RIVER
TERRITORIAL HIGHWAY
PAST PRODUCER, MINE WORKINGS
UNITED KENO HILL MINES LIMITED
PROPERTY BOUNDARY (APPROXIMATE)

UNITED KENO HILL MINES LIMITED

PROPERTY LOCATION MAP

ACCESS MINING CONSULTANTS LTD.

SCALE: 1 : 150 000	FILE: 2248-1.DWG	DATE: 30/05/96
DRAWN:	DWG: 95UK26	FIGURE: 1-2

Each of the three prominent hills in the area of the property is incised by local linear valleys, commonly fault-controlled, with fast-flowing streams. The effects of soil creep due to frost action are evident on the hill slopes.

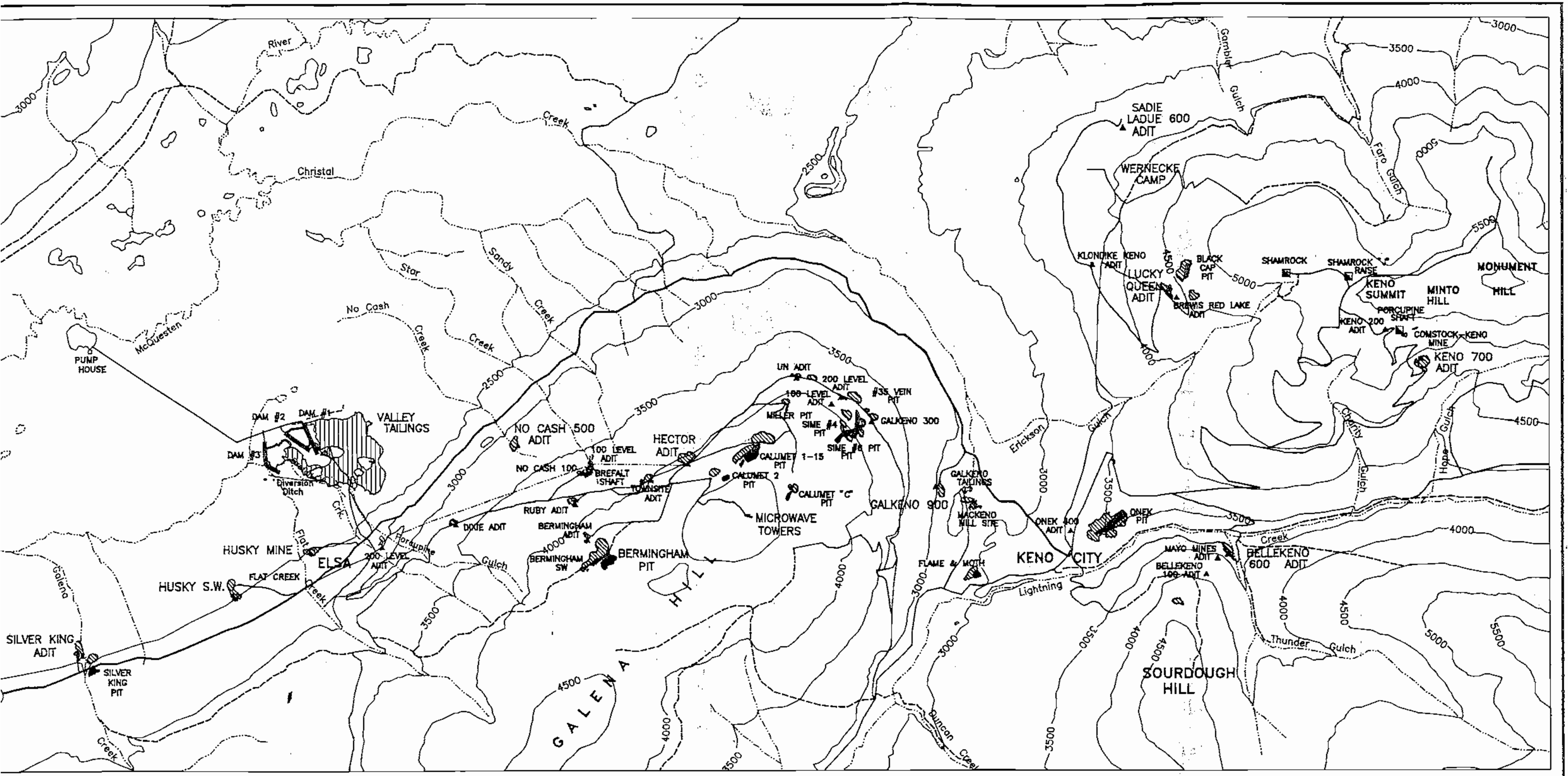
The climate of the area is rigorous. The mean annual temperature at Mayo is -3°C. Winter temperatures have been recorded to -55°C and summer temperatures to 32°C. There is no true daylight in December and, in June, there is no true darkness because of the latitude of about 64°N. The average annual precipitation is 285 mm (11.2 inches). The area of the property is underlain by permafrost so run-off is almost complete.

Vegetation is dominantly low bush and mountain alder (willow), with black spruce in the McQuesten valley seldom exceeding a height of four metres, and scattered spruce and black birch on the hillsides. The tree line is at an elevation of about 1,370 m (4,500 feet).

The Elsa townsite, owned by UKHM, is situated on the property. It has been on “care and maintenance” since the cessation of production in 1989. All the silver deposits are located within a 12 mile radius of Elsa. Facilities available in Elsa include houses, bunkhouses, mine dry, offices, warehouse, transport shop, machine shop, carpentry shop and assay laboratory. A 544 tonne per day (600 ton per day) concentrator, and small silver refinery are also located in Elsa. The general layout of the property is shown in Figure 1-3.

Power is supplied from a Yukon Energy Corporation 5 megawatt hydro dam located near Mayo. UKHM owns a 10.4 megawatt steam plant utilizing diesel and electric power and a 1.2 megawatt diesel standby powerhouse in Elsa for emergency use.

Local labour and some supplies are available in the village of Keno City and the nearby town of Mayo.



LEGEND

	Creek, river, waterbody
(11)	Territorial Highway
	Secondary road
	Trail
▲	Adit
	Shaft
	Open pit
	Waste rock dump
	Tailings

0 1000 2000 3000

METRES

Elevation contour interval – 500 feet

UTM GRID NORTH

UNITED KENO HILL MINES LIMITED

SUMMARY OF SITE DEVELOPMENT

ACCESS MINING CONSULTANTS LTD.

SCALE: 1 : 50 000	FILE: LCTN_MAP.DWG	DATE: 28/05/96
DRAWN: LCP CONSULT	DWG: 95UK26B	FIGURE: 1-3

1.2 Current Status

UKHM operations remain on a care and maintenance basis. In 1994, a new exploration programme was carried out on several targets including Silver King and Bellekeno. Considerable effort has been directed forward re-evaluating existing geological plans and sections, resulting in several more interesting targets. Underground drilling at Bellekeno and Silver King has led to increased reserves and indications of additional potential requiring further definition. A second phase of underground exploration is currently in the planning stages. Preliminary feasibility studies of mine and mill reopening are also currently underway.

UKHM's water licence expired in 1990. A water licence is the main operating licence in Yukon and is required in order to use water and to deposit waste in or near water. Re-opening the mine and mill will require a water licence. UKHM currently has a "B" type water licence to allow its underground exploration programmes to proceed; however, production can not resume until a "A" type water licence is obtained. Previous environmental assessments of the property outlined the need for a comprehensive abandonment plan and this plan was required by the previous operating water licence. UKHM submitted an abandonment plan in 1990; however, this was judged to be deficient in several respects by government regulatory agencies.

1.3 Scope of this Document

UKHM has been advised that it will be necessary to submit a satisfactory closure plan before any new water licence that authorizes mine operation can be granted. UKHM currently has an application for a Type "A" licence outstanding. The "A" type licence is required by water storage volumes. The application was submitted in September, 1994 and is intended only to cover the current status quo - explicitly prohibiting commercial production until the required closure plan is submitted.

This document provides the baseline description of the mines of the Elsa Silver Camp; the regional setting, local environment including terrestrial and aquatic resources and land use. The mine development by UKHM and others on the Galena, Keno and Sourdough Hills is documented with extensive drawing and figures. There is also a detailed description of the site water chemistry and geochemistry, and an assessment of the environmental impacts of past and current conditions. This document therefore provides the basis for the identification of priorities for closure and the development of a closure plan for the UKHM Elsa property. It will also provide the basis for evaluating environmental aspects of mine reopening.

2. History of Development and Ownership

2.1 History of Elsa Silver Camp

Prospecting for placer gold began in the Elsa area in 1885. The first discovery of silver was in July, 1903, when the Silver King Vein was found on Galena Creek. Silver vein discoveries on Galena Hill in 1919 led to a staking rush in the area. The Treadwell Yukon Company Limited initiated development on Keno Hill in September 1914, and in 1925 constructed a 110 tonne per day (125 ton per day) mill at Wernecke Camp. Most of the favourable ground had been staked by 1929 and was actively being explored. The Wernecke mill was shut down in 1931, and in 1936 a 136 tonne per day (150 ton per day) mill commenced operations in Elsa, supplied with ore by mines operating on Galena Hill. Most mining activity had ceased by 1942 due to declining silver prices.

In 1943, Thayer Lindsley of Ventures Limited expressed his interest in the area to developers Karl J. Springer and F.M. Connell, noting geological similarities between the Keno Hill area and the Coeur d'Alene district of Idaho.

Several studies were prepared in the next few years regarding the economic potential of the Keno Hill area by a number of geologists and engineers; these resulted in negative conclusions. One geologist, Frank Buckle, however, was enthused by the potential of the camp. Buckle concluded in his study that previous exploration had been "sloppy" and little use had been made of diamond drilling. He recommended that the Hector Mine be purchased and that underground exploration, involving diamond drilling, be carried out. Buckle believed that this would lead to the discovery of significant additional reserves at depth. The Treadwell Yukon workings were relatively shallow as it was believed that silver values decreased with increasing zinc values at depth.

Conwest Exploration Co. Limited and Frobisher Exploration Co. Limited formed Keno Hill Mining Company Limited in 1945 and acquired all former Treadwell Yukon Company Limited's interests. Frank Buckle was put in charge to follow up on his recommendations. This company was reorganized as United Keno Hill Mines Limited (UKHM) in 1948.

The first UKHM production came from the Hector-Calumet vein system and from the Elsa mine in 1947. In 1949, the mill in Elsa was destroyed by fire and was replaced by a 225 tonne per day (250 ton per day) facility. The mill was expanded to 450 tonnes per day (500 tons per day) in 1951 and a decision was made to sink a 150 m (500 foot) winze at the Hector-Calumet. The Hector-Calumet and Elsa Mines were the main producers in the 1950's. UKHM controlled most of the ground in the Keno Hill-Galena Hill area by 1958 with production coming from both Keno and Galena Hill.

The Keno Mine was brought into production in 1962 as reserves at the Hector-Calumet and Elsa Mines declined in the early 1960's. This mine did not sustain the same reserve base as the Hector-Calumet, in part because it had not been properly explored.

Falconbridge Nickel Mines Limited, which had acquired control of UKHM in 1962, decided to launch an aggressive exploration program because of the drop in reserves. An exploration team, including an assistant manager reporting directly to Toronto, was sent to the site.

The new exploration team carried out an extensive exploration program between 1963 and 1965 consisting of surface and underground diamond drilling, drifting, geophysics and overburden drilling. Management reassessed the exploration effort, particularly underground exploration, due to the limited success of the exploration progress and operating losses. All underground diamond drilling ceased in 1966.

Overburden (percussion) drilling, which was a relatively inexpensive method of testing bedrock, achieved some success and became the dominant exploration tool. Eventually diamond drilling was almost completely abandoned. No exploration for deeper ore was carried out because the depth penetration of the percussion drill was limited to 60 m (200 feet).

The Hector-Calumet Mine, by far the largest producer in the camp, was abandoned in 1972. The newly discovered Husky Mine then became the major producer in the camp.

The first of the open pits delineated by shallow percussion drilling was brought into production in 1977. The replacement of higher grade underground ore (1,370 g//t Ag or

40 oz/ton Ag) with lower grade pit ore (580 g/t Ag or 17 oz/ton Ag), led to a drop in annual silver production from about 93,300 kg (3 million ounces) to 62,200 kg (2 million ounces). The pit ores also incurred higher indirect costs due to dispersal of mining operations over a wide area. The combined effect of these factors and work stoppage resulting from a labour dispute forced UKHM to suspend operations in June 1982 when the silver prices declined.

Operations resumed in March, 1983. A major exploration effort, partly funded by flow-through shares was initiated to increase reserves in 1984. The programme consisted largely of surface exploration, in particular rotary percussion drilling to depths of less than 60 m (200 feet). This was followed up by the developing of adits at poorly defined targets. Little use was made of diamond drilling and almost no exploration was carried out underground adjacent to existing workings.

Additional silver reserves were discovered, but the cost per ounce discovered was extremely high due to the lack of focus in the exploration effort.

Significant reserves were identified in the Bellekeno, Husky Southwest, and Silver King mines. A number of exploration targets were delineated, but only partially explored.

UKHM suspended commercial production due to falling silver prices, high production costs, and an inability to achieve production targets on January 9, 1989. The high production costs and inability to achieve production targets can be attributed in part to high townsite costs, high labour costs, high labour turnover and costly mining practices. Control of UKHM was acquired from Falconbridge by the current management in July, 1990.

2.2 History of Production

Mining in the Keno Hill-Galena Hill area from 1914 to January 9, 1989, produced 5.342 million tons of ore grading about 1,370 g/t (40 oz/ton) Ag, 6.6% Pb and 4.1% Zn from 34 different deposits for a total of about 6.6 million kg (214 million ounces) of silver.

This ore was obtained from both open pit and underground operations. Underground production, including documented small hand cobbing operations, totals 4.420 million tonnes (4.873 million tons) grading about 1,440 g/t (42 oz/ton) Ag, 7.0% Pb and 4.4%

Zn. Well over half of this production has come from the Hector-Calumet and Elsa mines, which are also two of the deepest mines in the camp. An examination of plans and sections reveals that these are also the only two mines in which systematic underground diamond drilling was utilized to guide exploration and mining.

Most of the underground mines have been accessed by adits due to topographic relief. Only the Husky and Husky Southwest mines have surface shaft access, although several mines have internal shafts, notably the Hector-Calumet and Elsa mines. The lower levels of the Silver King and Bellekeno mines are accessed by internal trackless ramps driven in recent years.

Ground stabilization requirements in the mines can be described as heavy due to fracturing and faulting within the vein systems, and the incompetent schistose host rocks. The mines were conventional tracked drift operations. Drifting was carried out on the veins at 30 m (100 ft) to 46 m (150 ft) vertical intervals. Overhand stoping was practised with support generally provided by square set timbering, as dictated by ground conditions. Stopes were backfilled with waste rock, tailings or piped pneumatic backfill.

Mechanized mining using small trackless diesel Load-Haul-Dump (LHD) equipment was introduced in some of the mines in the late 1980’s.

Open pit production, which commenced in 1977 with mining from the Porcupine Pit, has totalled 425,600 tonnes (469,200 tons) grading about 580 g/t (17 oz/ton) Ag, 3.0% Pb and 0.4% Zn from 14 different deposits.

3. Regional Setting

This chapter provides a description of the regional setting for the Galena Hill - Keno Hill area; bedrock geology, soils, wildlife, vegetation, climate, hydrology, and aquatic resources. The regional setting descriptions are not intended to provide baseline environmental conditions for the area prior to mining. The area had nearly a century of mining activities. The collection of data to describe baseline environmental conditions was not even a consideration during early mining development; as such, very little baseline data has been documented.

It should also be recognized that over the course of time the local ecosystem has changed, and in some areas adjusted or even adapted to reflect the current mining activities in the area. This has complicated the establishment of “baseline” conditions necessary to measure and assess the impacts that have occurred. The regional setting for the area is therefore based on the present environmental conditions.

3.1 General Description of Area

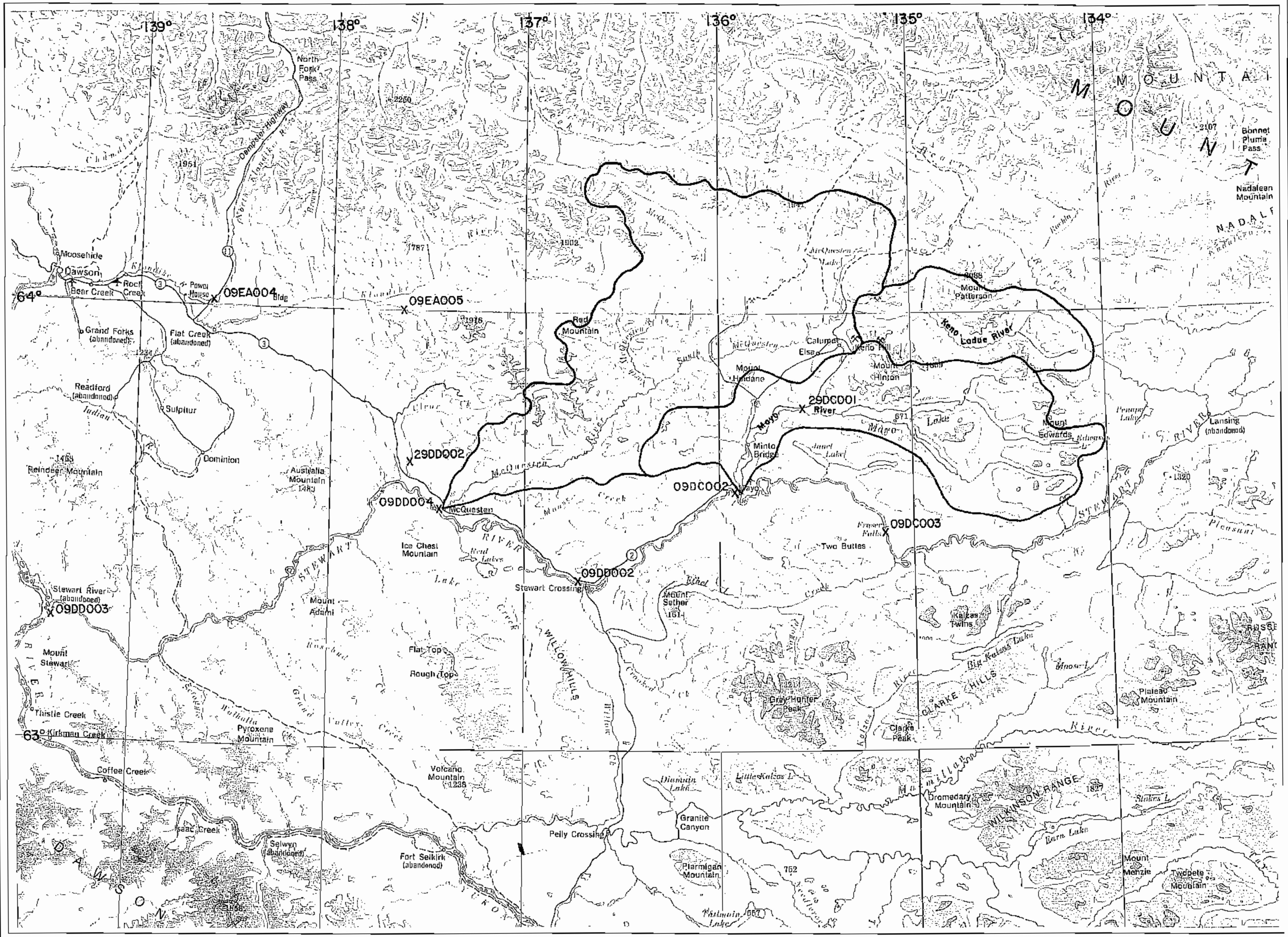
The UKHM mine site lies within the Yukon Plateau, just south of the rugged Wernecke Mountains. The terrain consists of concordant, rolling, upland areas separated by wide valleys. Alpine mountain peaks extend above the uplands locally. Valley bottoms and slopes are have dense boreal forest cover but the upland commonly extends above tree line and is tundra covered.

Geologically, the area is part of the Selwyn Basin and is characterized by late pre-Cambrian through Mississippian marine clastic meta-sedimentary rocks intruded by mid-Cretaceous granitic plutons. The meta-sediments are complexly deformed and thrust imbricated. Silver bearing veins are found along late brittle faults that cut the deformed package. The camp is at the western extent of the Cordilleran ice sheet thus a complex assemblage of glacial and peri-glacial landforms and deposits are present. Valley bottoms are broad and overburden covered, commonly boggy and contain thick peat deposits. Permafrost is widespread though discontinuous, and is always a consideration for development.

The mine site is wholly contained within the catchment of the Stewart River. Figure 3-1 shows the location of the mine site in relation to this river and to other major rivers and lakes in the region. As can be seen, the area occupied by the mine development is somewhat unique in terms of drainage patterns. Drainage from the UKHM mine site enters the Stewart River at not one, but three different points. This is because the site straddles the drainage divides of three different tributaries of the Stewart River. Listed in the downstream order in which they enter three Stewart River, these tributaries are the Keno Ladue River, the Mayo River, and the McQuesten River.

The location in the interior of Yukon, south of the Wernecke mountains, results in the area being semi-arid but subject to occasional heavy rainstorms. Snow cover is light and blankets the area from October to May. Temperature extremes are characteristic of the area. Winters are long, cold and dark. Summers are mild to cool, often rainy and grey but occasionally interrupted by hot, dry, clear spells. Stream flows generally peak in May with the spring snow melt but heavy flows also occur in summer and fall during thunderstorms. Long daylight hours in summer are conducive to lush plant growth but the short growing season limits the overall growth rate and size of most vegetation.

The area has experienced a long history of occupation and development thus it's original wilderness character has changed considerably. Road access and consequent hunting pressure has diminished wildlife populations but the habitat remains generally healthy and productive. Hardrock mining has caused an influx of population but in itself has not caused a great deal of habitat destruction. Placer mining has profoundly changed some valley bottoms causing significant changes to stream beds and creating new and commonly productive wildlife habitat. Logging, partly to support mining operations, has been carried out on a small scale in many valleys but large scale mechanized logging has not occurred and re-growth is progressing well. Fish populations have declined due to a combination of off shore harvest and local habitat degradation, both chemical and physical, from hardrock and placer mining respectively as well as other undertakings. The effects of local activities on habitat do not appear to be either irreversible or necessarily long term since, based on water quality and benthic invertebrate studies as well as observations of extensive re-vegetation, there has been considerable self healing in the time frame of the area developments.



LEGEND

x 09DC003 Regional Hydrometric Gauging Station

Catchment Boundary

N

0 10 20 30 40

KILOMETRES

UNITED KENO HILL MINES LIMITED

REGIONAL LOCATION MAP

Access Mining Consultants Ltd.

SCALE: 1:1,000,000	FILE: 224_7.DWG	DATE: 31/05/96
DRAWN: ODS	DWG: 95UK26	FIGURE 3-1

The following sections provide further detail on the bedrock and surficial geology, physiography, soils, vegetation, wildlife, climate, hydrology and aquatic resources of the area. Land use patterns are discussed in Chapter 5 and an extensive discussion of water quality is included in Chapter 6. Because of the importance of potential chemical impacts on water quality and resultant impacts on the aquatic environment and fishery, these subjects are most extensively covered.

3.2 Bedrock Geology

The Keno Hill - Galena Hill area is underlain by mid-Paleozoic meta-sedimentary rocks overthrust by late pre-Cambrian meta-sedimentary rocks. The rocks of the district, for many years, have been divided into a three formations, the “lower schist”, the “central quartzite” and the “upper schist”. Most of the ore deposits occur in the “central quartzite”. These three formations were considered to represent a conformable sequence of meta-sedimentary strata. This subdivision remains a useful one; it corresponds to UKHM’s usage and will be used in this document. It should be noted, however, that more detailed work since the 1960’s has shown the situation to be much more complicated. Recent mapping in the area (Figure 3-2) has continued a long standing tradition of re-interpretation of the stratigraphy and structure of the district as summarized in Roots and Murphy (1992).

The “lower schist” is now correlated by Roots and Murphy (1992) with the Devonian and Mississippian Earn Group and includes carbonaceous phyllite, siliceous carbonaceous meta-siltstone and rare calcareous greywacke. Intercalated with the meta-sedimentary rocks are waxy green, locally quartz and feldspar porphyritic, felsic, meta-volcanic phyllite, particularly abundant in the top 100 m. The “central quartzite” is now referred to by Roots and Murphy (1992) as the Keno Hill Quartzite. It is thought to be of Mississippian age and consists of finely to coarsely foliated, lineated, light to dark grey, vitreous quartzite; interlayered are carbonaceous phyllite, chloritic phyllite and rare limestone. Intrusive into both these units are foliation concordant meta-diorite bodies (actinolite-chlorite-plagioclase bearing, fine to coarse grained greenstone) thought to be of mid-Triassic age. The “upper schist” is now thought to be an imbricated and/or isoclinally folded zone comprising intercalated rocks of late pre-Cambrian Hyland Group and Keno Hill Quartzite (Roots and Murphy, 1992). The structurally overlying Hyland

Figure 3-2 Regional Geology of Elsa - Keno Hill

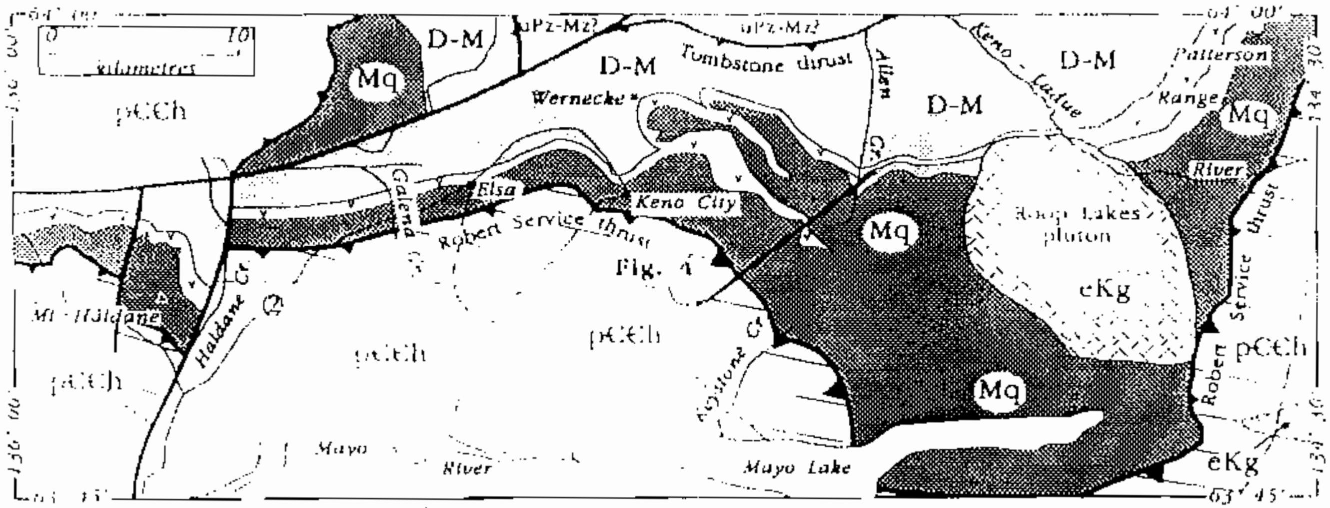


Figure 2. Simplified geological map of the Keno Hill region. Unit designation symbols as in Figure 1. "v" pattern indicates felsic metavolcanic unit below the "Keno Hill quartzite"; metavolcanic strata also occur within the "Keno Hill quartzite" but the contact relations are poorly understood. Ruled area is approximate area underlain by Green's (1971) Unit 1 (see text for discussion)

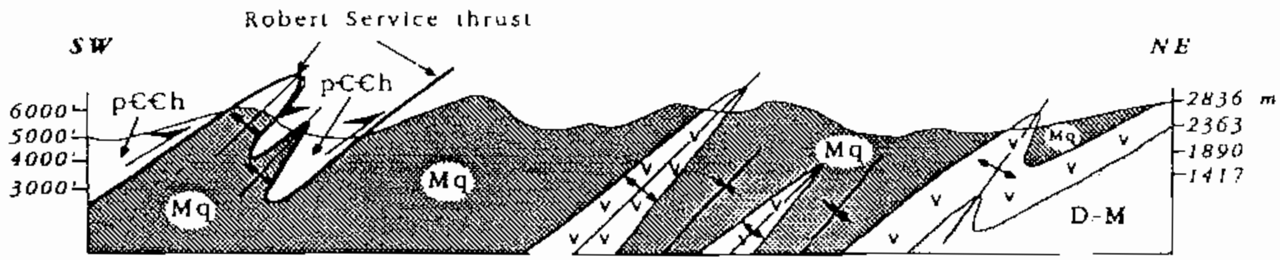


Figure 4. Simplified northeast-trending cross-section illustrating the geometry of D_{p+1} folds of the "Keno Hill quartzite". Location shown in Figure 2

Group (grit unit) is thrust over the above Paleozoic sequence on the Robert Service Thrust. The Hyland Group is a meta-sedimentary sequence consisting of medium brown, foliated and lineated phyllite and psammite (a sandstone); quartz and feldspar pebble psammite; with lesser calc-phyllite, marble and carbonaceous phyllite. The meta-sedimentary rocks are intruded by dykes and sills of fine grained, locally porphyritic, locally altered, aplite and granite. These dykes and sills are neither common nor large. They are most abundant in the north flank of Keno Hill.

Irrespective of stratigraphic formations or regional map units only a few major rock types are commonly encountered in the area of the old mine workings. These are:

- schists and phyllites with variable carbon content;
- chloritic phyllites or schists;
- quartzites and phyllitic quartzites;
- sericite-quartz phyllites; and,
- greenstones.

Boyle (1962) produced a classic study of the geology and geochemistry of the Keno Hill - Galena Hill district. Boyle's description of the major rock types of the district remains one of the best published and is quoted below to provide details on each of the major lithologies as well as their chemistry.

> **Argillites, Phyllites, Slates, and Schists**
> Of this group of rocks, schists are the most abundant, followed by phyllites and argillites; slates have a limited local occurrence.
>
> The argillites occur in beds ranging in thickness from a few inches to 10 feet or more and are generally interbedded with the various types of schists, phyllites and quartzites. All varieties of argillite exhibit a poorly developed cleavage approximately parallel with the bedding. In many occurrences they are crumpled, fractured, or crushed and contain numerous carbonate and quartz stringers.
>
> In hand specimens most argillites are grey, but some are dense black and contain much carbonaceous matter and pyrite.
>
> In thin sections the grey argillites are seen to contain white mica (sericite) and/or brown mica (biotite), microcrystalline quartz and leucoxene, chlorite, isotropic colloidal material, and pyrite. Some contain a little carbonate. Accessory minerals are tourmaline, zircon, and rutile. The texture is commonly banded, with layers containing essentially sericite, leucoxene,

and a little quartz alternating with layers containing quartz, carbonate, and subordinate sericite and/or biotite. In most sections the small irregular masses of pyrite are strung out along particular bands.

The black argillites are composed mainly of layers of carbonaceous material containing much fine-grained pyrite and minor amounts of carbonate minerals, quartz, and sericite. These generally alternate with layers containing quartz, sericite, carbonate minerals, some carbonaceous material, and a little pyrite.

Mineralogically, the phyllites are essentially the same as the argillites. They are, however, a little coarser grained and exhibit a silky sheen on cleavage surfaces. Most are greyish or buff; some are black and contain much carbonaceous material and pyrite. In the field many of the phyllites are warped, dragged, or crushed, and such rocks generally contain numerous stringers of quartz and carbonate. Boudins of quartz may also occur in these rocks but are rarely as abundant as in the schists.

The slates generally occur in highly disturbed zones, particularly on the noses of small folds. In most occurrences the slaty cleavage is not well developed. Mineralogically, the slates are similar to the argillites and phyllites.

There is little evidence of residual clastic grains in any of the argillites, slates, and phyllites. Most of these rocks are also remarkably devoid of original sedimentary features such as grain gradation, crossbedding, concretions, etc. Some argillites and phyllites, however, exhibit a fine bedding lamination.

The varieties of schist found in the area include graphitic schists, quartz-sericite schist, and chlorite schist. All are highly foliated and locally exhibit wrinkle lineations, many small drag folds, and innumerable crenulations. Most contain an abundance of stringers irregular masses, and bulbous lenses (boudins) of white quartz in small fractures, between schist layers, in dragged and crenulated zones, and along bedding planes.

The graphitic schists weather easily to a crumbly mass of small black schistose fragments and hence only rarely form good outcrops. In drill-cores and underground exposures they occur in beds ranging from a fraction of an inch to a few feet in thickness and are everywhere intercalated with phyllites, slates, or thin- and thick-bedded quartzites. In hand specimens they are black or greyish black, and exhibit well-developed schist planes that possess a dull to bright sheen when wet.

Under the microscope the principal mineral constituents are dense opaque carbonaceous matter (graphite), quartz, sericite, carbonate minerals, feldspar, chlorite, isotropic colloidal material, and numerous metacrysts of pyrite. The accessory minerals, where identifiable, are tourmaline, rutile, and zircon. The texture is schistose with interlaced laminae, strands, and wisps of graphite and sericite enclosing elongated micro-lenses or in the wavy and crumpled zones of the graphite laminae. In some sections microcrystalline pyrite is strung out along the graphitic laminae. Micro-boudins of quartz, many containing a cube of pyrite, are common in nearly all sections.

The quartz-sericite schists also weather easily and form few prominent outcrops. All occurrences exhibit a marked schistosity and where dragged, crenulated, or crushed contain numerous stringers, masses, and boudins of white quartz. In hand specimens they are greenish or mottled greenish yellow, and have a silvery lustre when wet.

In thin sections the quartz-sericite schists are seen to consist essentially of quartz and sericite with subordinate amounts of carbonate minerals and leucoxene. The leucoxene consists of a felted aggregate of rutile needles and is invariably concentrated in swirling masses in the laminae of sericite. The main accessories are apatite, zircon, and tourmaline, and a few pyrite metacrysts are also present in most sections. The texture is schistose with laminae, shreds, and wisps of sericite and leucoxene enclosing irregular elongated lenses and bands composed principally of quartz with some shreds of sericite and a few cubes of pyrite.

Quartzites

Quartzites occur throughout the sedimentary sequence, but tend to be concentrated in well-defined bands in the various formations. Both thick- and thin-bedded varieties are present. The thick-bedded variety comprises beds ranging from 3 to 25 feet in thickness; thin-bedded varieties occur in beds from an inch to a foot or more thick. Both varieties are interbedded with assemblages of schist, argillite, and phyllite. All thick-bedded quartzites are well jointed and yield large blocks during weathering and frost action. The thin-bedded varieties are generally contorted, warped, and locally drag-folded. Stringers, irregular veinlets, and small lenses of quartz are abundant in both varieties.

In hand specimens the fresh quartzites are white to grey to black, and have a gneissoid to schistose appearance. Some are very fine grained and resemble recrystallized cherts. On weathered surfaces most of the quartzites are buff, but others are grey or white.

Thin sections show that the quartzites consist essentially of quartz, with minor amounts of white mica (sericite) and, locally, carbonate minerals. Calcareous varieties contain up to 30 percent carbonate minerals. The black quartzites contain much carbonaceous material. Accessory minerals in all varieties include irregular patches and specks of leucoxene, tourmaline, zircon, apatite, and pyrite. The pyrite occurs mainly as cubes, distorted cubes, and crystal groups.

Most of the quartzites are fine grained, the cherty variety being very fine grained. Typical specimens have a gneissoid to schistose mosaic texture with the quartz grains showing a pronounced elongation. Most of the sericite flakes and wisps and the carbonaceous material occur at the boarder of the quartz grains, and both exhibit parallelism. Some varieties of white quartzite are banded, with relatively pure quartz laminae alternating with laminae of quartz and sericite or quartz, sericite, and carbonate minerals.

Some of the quartzites exhibit crossbedding, bedding laminations, and other original depositional features, and a few show faint overgrowths of silica on the quartz grains. These were undoubtedly originally fine-grained orthoquartzites. Other quartzites, especially the nearly pure white cherty varieties as well as some fine grained grey varieties, exhibit no observable original clastic features but have a banding similar to certain recrystallized cherts.

Greenstones

The greenstones are schistose, greyish green to dark green rocks that occur in conformable elongated lenses and sills, principally in the schistose formations and to a lesser extend in the quartzite formations. The greenstones weather differentially compared with the schists and quartzites and form prominent precipices and knobs. In most occurrences they are jointed and present a slabby appearance. In some bodies narrow shear zones, joints, and irregular fractures contain small lenses and masses of quartz, epidote, and calcite.

In thin sections the greenstones present considerable variety both in mineral composition and texture. All are highly altered, and it is rare to find bodies with any original minerals. Remnants of original textures are, however, preserved in most bodies.

The principal minerals now present in the greenstones are hornblende, actinolite, saussurite (zoisite, epidote, albite, sericite, carbonate), plagioclase (oligoclase to andesine), chlorite, stilpnomelane, biotite, white mica (sericite), leucoxene, and carbonate minerals. Quartz, potash feldspar, illuminate, magnetite, limonite, and apatite are common minor constituents, and pyrite is present in some bodies. All these minerals are not necessarily found in any one greenstone mass.

The texture of most of the larger greenstone bodies is diabasic with amphibole in various degrees of alteration as large lath-like crystals. In a few sections pyroxene (augite?) is present. Most of the feldspars are so highly saussuritized that their precise original composition is impossible to decipher. Originally magnetite and ilmenite crystals are rimmed or pervaded by leucoxene and limonite. Apatite occurs in small euhedral crystals. Chlorite is generally present, commonly in considerable amounts, and biotite, sericite, quartz, and carbonate minerals are found in some bodies. Some of the quartz may be primary, but most appears to have originated from alteration processes.

Smaller greenstone bodies and the borders of the large lenses have a schistose texture. In these the amphibole, saussurite, carbonates, and other minerals are fine grained , highly intergrown, and drawn out into bands, streaks, and elongated lenses and trains.

A few greenstones bodies have pseudo-porphyritic texture due to the presence of large, irregular, commonly somewhat angular, masses of leucoxene and/or saussurite set in a fine-grained, felted groundmass of amphibole, feldspar, chlorite, carbonates, and saussurite.

Geochemistry

Boyle (1965) provides some whole rock major and trace element analyses for composite samples of various rocks of the district. These are summarized in Table 3-1 (major elements) and Table 3-2 (minor and trace elements).

The phyllites and schists show a fairly uniform composition throughout the district. The composition is consistent with siliceous marine shales. Sulphur, carbon and CO_2 are all fairly high compared to the other rock types as would be expected from rock descriptions. These constituents are also high compared to average shales or schists. CaO, FeO, Fe_2O_3, K_2O, Na_2O, and MgO are lower than average shales. The phyllites and schists contain elevated concentrations of several metals such as Pb, Zn, Cu, As Sb, Mo and Ba. Gleeson and Boyle (1980) also note Ni, Sn, F and U are enriched in the phyllites compared to other lithologics. Table 3-3 summarizes their findings. Barium enrichment is not unusual for Devonian-Mississippian marine shales of central Yukon nor is the elevated metal carbon and sulphur content. These rocks are an important feature influencing background metal and sulphate contents of stream waters.

The analytical data for quartz-sericite schist are ambiguous. These rocks are thought to be felsic metavolcanics however the available major element whole rock analysis provide little support for this hypothesis. Trace elements show slight enrichments in Zn, Cu, Ba and Mo. The limited trace element data of Kwong et al. (1992), Table 3-4, particularly high Ti, Ni, Co and Cu, imply an affinity to greenstone rather than felsic rocks. The quartz-sericite schists are low in carbon and contain fairly low sulphur.

Table 3-1 (After Boyle 1965)
Major Elements in Rocks of Keno Hill - Galena District

Sample from (Hill)	Sourdough	Keno	Galena	Galena	Keno	Galena	Keno-Galena	Keno-Galena	Keno-Galena	Galena	Sourdough	Galena
Sample Number	A-464	A-619	A-697	A-692	A-621	A-691	A-698	A-622	A-620	A-694	A-463	A-695
Constituent	%	%	%	%	%	%	%	%	%	%	%	%
SiO_2	66.9	65.7	63.6	80.8	49.7	46.3	88.9	88.2	66.9	97.4	75.8	81.5
Al_2O_3	16.7	12.2	15.5	7.5	15.3	13.8	1.5	2.1	8.4	0.6	1.9	1.1
Fe_2O_3	2.1	1.4	1.7	0.8	2.6	0.8	0.2	0.3	0.8	0.0	0.4	0.2
FeO	1.79[1]	1.93[1]	2.44[1]	2.33	8.07	10.12	1.05	1.10	1.72	0.34	0.46	0.74
CaO	1.3	2.3	2.4	1.4	9.3	12.9	3.2	1.5	7.7	0.9	10.3	7.4
MgO	1.7	1.1	1.5	1.2	6.3	4.5	0.0	1.1	0.8	0.0	0.9	0.3
Na_2O	0.2	1.1	0.7	0.3	2.2	1.7	0.2	0.4	1.1	0.1	0.1	0.0
K_2O	2.7	2.3	2.7	1.3	0.2	0.2	0.2	0.3	1.6	0.1	0.3	0.2
H_2O (total)	2.7	3.49	2.8	1.91	2.9	4.05	0.71	0.56	0.9	0.15	0.44	0.32
TiO_2	0.9	0.7	0.8	0.4	1.7	1.7	0.2	0.2	0.5	0.1	0.2	0.1
P_2O_5	0.2	0.4	0.4	0	0.2	0.2	0.1	0.1	0.2	0.0	0.2	0.1
MnO	0.3	0.2	0.0	0	0	0.1	0.1	0.10	0.1	0	0	0
CO_2	2.25	4.66	2.1	0.51	0.31	2.56	2.94	2.94	7.97	0	8.42	7.24
S	0.72	0.56	1.2	0.21	0.03	0.14	0.1	0.17	0.52	0.0	0.25	0
C	1.37	1	1.3	-	-	-	-	0.09	0.29	-	-	-
Total	101.8	99	99.1	98.7	98.8	99.1	99.4	98.7	99.5	99.7	99.7	99.2
Less O=S	0.3	0.2	0.5	0.1	0	0.1	0	0.1	0.2	0	0.1	0
Total	101.5	98.8	98.6	98.6	98.8	99	99.4	98.6	99.3	99.7	99.6	99.2
Powder Density	2.755	2.736	2.8	2.717	3.03	2.975	2.668	2.690	2.726	2.684	2.701	2.670

[1] Values uncertain because of the presence of large amounts of carbon

A-464 Graphitic schist and phyllite - composite sample.
A-619 Graphitic schist, phyllite, argillite, and slate - composite sample
A-697 Graphitic schist, argillite, phyllite, and slate - composite sample
A-692 Quartz-Sericite schist - composite sample
A-621 Composite sample greenstone lenses
A-691 composite sample greenstone lenses
A-698 Composite of all samples and thick- and thin-bedded quartzite
A-622 Composite of medium- and thick-bedded grey quartzite
A-620 Composite of thin-bedded quartzite and phyllite
A-694 Composite of white cherty quartzite
A-463 Composite of calcareous quartzite
A-695 Composite of calcareous quartzite

Table 3-2 (After Boyle, 1965)
Minor and Trace Elements in Rocks of Keno Hill-Galena Hill District

All values in parts per million

No. of Composite Samples: Constituent	Greenstones		Graphitic argillites schists, and phyllites		Quartz-sericite schist		Thick- and thin-bedded grey quartz		Siliceous White quartzites		Calcareous quartzites	
	6		29		8		27		9		3	
	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average
Pb	2-10	5	5-38	15	5-25	7	2-20	7	2-15	6	5-8	5
Zn	30-140	73	25-120	62	65-160	90.5	5-85	30	5.3	10	15-50	27
Cd		<2	0-2	<2		<2		<2		<2		<2
Ag	0.10-1.50	0.32	0.17-1.60	0.50	0.12-1.1	0.44	0.13-1.30	0.31	0.17-0.37	25	0.24-0.54	0.36
Cu	30-200	132	10-180	31	10-90	46	2-60	12	5-33	14	5-8	7
Ga	2-50	20	5.54	18.3	5.2-35	16	0-17	4	5-14	5	<5	<5
In	<0.5	<0.5	<0.5	<0.5	<0.5-0.8	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Mo	<5	<5	5-52	8	5-22	10	0-25	<5	<5	<5	<5-11	<5
Sn	2-10	3	2-15	4	5-6.3	5	<5	<5	<5	<5	<5	<5
W	<4	<4	<4-14	<4	<4	<4	<4	<4	<4	<4	<4	<4
Bi	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ba	100-3000	475	100-15000	2240	1000-15000	3200	100	310	100-500	200	100-1000	400
Sr	50-500	130	100-2000	195	100-1000	<100	1000	<100	<100	<100	<100	<100
C_1	50-600	164	50-900	235	100-500	<100	<100	<100	<100	<100	<100	<100
Ti	10000-15000	12000	4000-5500	4800	2000-3000	2500	100-900	1300	400-800	600	600-1200	900
Mn	500-1000	775	620-2300	1500	500-1500	1000	600-3000	775	200-400	300	100-300	200
As	2-25	6	2.75	18.5	2-15	6	2-35	7.6	1-15	5	3-10	7
Sb	<1.0-1.0	<1	1.0-7.0	3.1	1-1.5	1	1.0-6.0	1.5	<1-1	<1	<1.0-1.0	<1
S	300-1400	850	5600-11800	8200		2100	1000-5200	2635		200	100-2500	1200

Table 3-3 (After Gleeson and Boyle ,1980)
Range and Median Values of Trace Elements
in Rocks of the Keno Hill District

	Rock Type	Quartzite	Phyllite	Greenstone	Limestone
	No. of Samples	95	76	44	14
Cu	R[1]	2 - 400	2 - 180	2 - 2600	2 -400
	M[2]	2	4	60	20
Pb	R	2.5 - 1350	2.5 - 1800	2.5 - 65	2.5 - 35
	M	2.5	2.5	2.5	2.5
Zn	R	5 - >800	5 - 360	5 - 460	5 - 230
	M	20	60	110	10
Ni	R	2.5 - 130	2.5 - 95	2.5 - 145	2.5 - 55
	M	2.5	20	70	2.5
Co	R	2.5 - 20	2.5 - 55	2.5 - 60	2.5 - 15
	M	2.5	2.5	10	2.5
As	R	1 - 60	1 - 70	1 - 44	1 - 6
	M	1	1	1	1
Sb	R	0.5 - 30	0.5 - 20	0.5 - 3.0	0.5 - 3.0
	M	0.5	0.5	0.5	0.5
Mo	R	0.5 - 9	0.5 - 20	0.5 - 3	0.5 - 6
	M	0.5	0.5	0.5	0.5
W	R	2	2	2	2
	M	2	2	2	2
U	R	0.1 - 6.7	0.8 - 13.5	0.4 - 4.6	0.3 - 4.2
	M	1.5	2.5	2	1
Sn	R	ND - 10	ND - 24	ND - 11	ND - 5
	M	4	5	ND	ND
Ag	R	ND - 7.6	ND - 1.2	ND - 1.2	ND - 0.3
	M	ND	ND	ND	ND
F	R	ND - 1825	ND - 1500	70 - 1110	115 - 1135
	M	180	550	320	300
Ba	R	80 - 9461	277 - 14345	82 - 9674	32 - 1383
	M	350	1200	400	70

Notes:
1 - R = Range of values (ppm)
2 - M = Median values (ppm)
3 - ND = detectable for: Sn < 1ppm
Ag < 0.1 ppm
F < 20 ppm

Table 3-4 (After Kwong et al., 1992)

Major and trace element composition of major rock units in the Keno Hill mining district and net neutralization potential of selected samples

Field #	SiO_2	Al_20_3	Fe_2O_1	CaO	MgO	K_2O	Na_2O	Ti_2O	MnO	P_2O_5	LOI	Total%	Cu	Zn	Cd	A_5	Pb	Ag	Ni	Co	Bi	Mo	%C	NNP*
	%												ppm											
Hyland Group																								
JK-1	88.7	5.67	2.54	0.09	0.66	0.8	0.38	0.22	0.032	0.06	1.5	100.65	33	37	3	1	1	0.2	12	2	2	1	0.3	2
Keno Hill Quartzite																								
DB-5	94.6	0.28	1.36	1.47	0.40	0.1	0.04	0.14	0.012	0.02	1.9	100.32	2	2	1	1	2	0.1	6	1	31	1	0.56	-
JK-2	4.5	0.27	0.40	54.67	0.41	0.2	0.01	0.04	0.007	0.01	40	100.91	2	3	1	1	3	0.1	1	1	2	2	12.6	934
JK-7	88.6	4.88	0.66	0.01	0.26	1.6	0.06	0.24	0.001	0.03	4	100.34	4	14	1	1	31	0.3	7	1	2	9	2.86	-
JK-11	99.7	0.01	0.69	0.01	0.01	0.1	0.02	0.16	0.001	0.01	0.1	100.81	1	2	1	3	1	0.1	4	1	2	1	0.02	-3
Earn Group metavolcanics																								
JK-3	71.8	13.37	6.09	0.28	2.13	3.1	0.71	0.59	0.121	0.12	2.4	100.71	30	86	1	1	2	0.1	35	14	2	1	0.08	6
JK-21	44.7	13.55	12.22	10.49	5.15	0.1	2.83	1.65	0.176	0.10	9.5	100.46	230	76	3	#	13	0.3	30	24	2	1	nd	162
Earn Group metasediments																								
JK-6	74.2	6.36	3.02	8.80	2.26	1.7	0.14	0.39	0.084	0.38	1.2	98.53	9	87	1	#	6	0.1	13	5	2	1	2.85	182
JK-8	74.4	7.72	2.47	7.20	2.05	1.8	0.18	0.53	0.075	0.30	3.4	100.12	9	66	1	#	21	0.3	15	4	2	2	2.41	-
JK-10	62.6	11.70	4.01	5.15	2.51	3.0	0.84	0.66	0.056	0.24	8.3	99.06	16	52	1	6	9	0.1	21	8	2	3	2.31	105
Triassic metadiorite																								
DB-11	47.7	14.19	12.38	11.69	7.66	0.4	2.10	1.54	0.178	0.15	2.1	100.08	154	52	1	1	1	0.1	36	15	2	1	0.03	-
JK-4	48.3	16.20	10.91	11.92	7.45	0.3	2.11	1.26	0.153	0.10	2.2	100.9	75	26	1	1	1	0.1	40	13	2	1	0.11	-
JK-5	48.2	15.15	11.31	12.38	7.83	0.1	2.49	1.39	0.169	0.07	2.3	101.38	137	93	1	6	1	0.1	31	14	2	1	0.16	18

* Net neutralization potential in kg $CaCO_3$/tonne

The quartzites are, as expected, rich in SiO_2, low in Al_2O_3 and most of the metals relative to the phyllites and schists. Analytical data for variants of the quartzites such as thin-bedded or phyllite quartzite and calcareous quartzite show elevated Al_2O_3 and Ca0 respectively as would be expected. Trace elements in the quartzites are generally low although elevated Pb and Zn are noted near the veins.

Greenstones show compositions not inconsistent with altered mafic igneous rocks. This mafic affirmity is particularly displayed in elevated levels of Ti, Ni, Co and Cu.

3.2.1 Structure

All rocks of the district are very complexly deformed; their outcrops are dominated by a low angle (dipping 15^o to 35^o) foliation related to strong isoclinal folding and thrust faulting. The region includes three thrust sheets of regional significance. The "central quartzite" and "lower schist" are part of the middle thrust sheet. As noted above, the "upper schist" may be an imbricated zone at the base of the upper sheet. The foliation is generally parallel to lithologic contacts and thrust boundaries. Country rock units in the district trend east-west and dip 20 to 30 degrees south. The meta-sedimentary sequence forms the south flank of the northeast trending, open, McQuesten anticline which gently warps the entire deformed and thrust imbricated sequence.

Approximately parallel to the axis of the McQuesten anticline are a series of faults striking northeast and dipping steeply southeast, these faults show left-lateral apparent offset and have displacements of up to 150 m. This fault system is the locus of most mineralization in the district and its members are referred to locally as the "vein faults" (Watson, 1985). The vein faults are offset by two additional fault sets which are less mineralized or un-mineralized. The first of these is known as the "cross faults" and strike northwest, dipping 40 to 60 degrees southwest; these faults are typically normal and exhibit right lateral apparent displacements of 1 m. to 600 m. The second set are referred to as the "bedding plane faults" which are foliation parallel faults, apparently showing thrust displacement on the order of 1 to 30 m.

Both the cross faults and bedding plane faults appear to show post ore movement and several ore zones are displaced by them. Vein faults also show limited evidence of post-ore movement. Faults, especially the three sets of late faults, are of great importance to ore formation and groundwater flow thus also oxidation of the lodes and contaminant migration. As discussed below, of the major underground workings, several are hydraulically connected via the fault zones.

3.2.2 Ore Deposits

The ore in the Keno Hill - Galena Hill camp occurs in irregular shoots within vein systems developed along the vein faults. Vein development is related to the competence of the country rock thus the best veins are found where at least one wall is in brittle rocks like quartzite or greenstone. Where the fault passes into soft phyllites or schists it is poorly mineralized or may not be visible at all. The veins are commonly less than a metre wide but in some areas may be up to several tens of metres wide. Mineralogy in the veins of the district is complex and varied, oxidation and supergene enrichment adds further complexity. A summary of the minerals of the district compiled by the staff of UKHM is provided in Technical Appendix I. The following quotation from Watson (1986) provides a good overview on vein morphology and mineralogy.

> In excess of 65 ore deposits and prospects have been identified within the district. These deposits are contained within vein faults with a combined total strike length in excess of 160 kilometres (100 miles). All the economically mineable silver lodes located to date have been contained within an area 26 kilometres (16 miles) long by 1.6 to 6.4 kilometres (1 to 4 miles) wide.
>
> The principal lode deposits occur within the Central Quartzite in areas where brittle failure of the competent quartzite has allowed open areas conductive to ore deposition. Where the vein faults pass into schistose units they generally become narrow and normally contain little or no ore. Ore zones are also known to occur in the Lower Schist where a competent unit, such as a greenstone lens, forms one or both of the walls of the vein fault. Most ore zones (ore shoots) in this area have had their shape and size boundaries defined on a greater than 515 g/t Ag (15 oz/ton Ag) basis.
>
> Principal ore minerals are argentiferous galena, freibergite (argentiferous tetrahedrite - “grey copper”), and pyrargyrite (“ruby silver”). Polybasite, stephanite, argentite and native silver occur locally in minor amounts. The principal gangue mineral is siderite.
>
> Vein faults can take the form of ‘simple’ veins, breccia zones and sheeted zones.
>
> ‘Simple’ veins consist of a gangue of siderite, often with some quartz. Mineralization consists of discontinuous bands and lenses of silver-bearing

sulphides. Some brecciation is always present with fragments of country rock included in the vein.

Breccia zones consist of generally angular rock fragments (quartzite, phyllite, greenstone) in a matrix of siderite, often with some quartz. In some areas the breccia fragments have been rounded or ground into a clay or sandy gouge. Breccia fragments normally account for 20 to 50 percent o the vein but may exceed 90 percent in places.

Sheeted zones consist of rectilinear slabs of quartzite or greenstone separated by narrow (1-10 cm; 0.5-4 inch) breccia or gouge filled fractures. The breccia fragments and rectilinear slabs are cemented by siderite, sulphides and some quartz within the ore shoots. The fractures are barren or contain only a few carbonate minerals outside of ore shoots. Vein faults may grade from breccia to sheeted zones.

Several vein fault systems consist of two or more distinct, parallel to sub-parallel, vein faults. The inter-vein material between these vein faults in some locations consists of country rock shot with narrow mineralized fractures. In areas where the density of the mineralized fractures is sufficient this inter-vein material may produce ore.

Vein faults are often made up of a series of slips or fault planes. Slickensides are common on wall rock, siderite and sphalerite along these fault planes.

The transition from an ore shoot to a barren section of vein fault often exhibits no changes in vein appearance other than a decrease in silver-bearing minerals.

Ore shoots range from 0.3 to 30 meters (1 to 100 feet) in thickness. Strike length and dip extension of individual ore shoots range from 30 to 355 meters (100 to 1,110 feet). Several ore shoots commonly occur in a single vein fault.

Ten deposits in the Keno Hill - Galena Hill area have had documented silver production in excess of 31.1 million grams (1,000,000 ounces), 8 more deposits have produced from 3.1 to 31.1 million grams (100,000 to 1,000,000 ounces) and a further 7 have produced in excess of 311,000 grams (10,000 ounces).

The largest single producer is the Hector-Calumet Mine which has produced 2,383,543 tonnes (2,627,406 tons) or ore with an average grade of 1,237 g/t Ag (36.09 oz/ton Ag).

Two stages of vein mineralization are distinguished in the area. The first stage deposited quartz, pyrite, some arsenopyrite, trace gold and some sulphosalts in the vein faults. Following movement on the vein faults, a second stage of mineralization deposited siderite, galena, sphalerite, pyrite, freibergite, and pyrargyrite. Most of the economically mineable ore deposits to date have been stage two types. Supergene enrichment has occurred but is not believed to have been an important ore forming process. The oxidation zone extends from a few meters to 150 meters (10 - 500 feet) below surface. Within this zone, minerals such as limonite, pyrolusite, cerussite, and anglesite are common. Native silver, argentite and jarosite may occur locally.

Ore zones, within vein faults in the Central Quartzite, appear to be spatially associated with some or all of the following features: a) adjacent to and in the footwall of cross faults; b) the junction of two or more veins; c) cymoid loops; d) areas where the vein fault changes dip; e) directly beneath the contact with the Upper Schist. The ore deposits are believed to be of hydrothermal origin and the listed features have produced areas of lower pressure and temperature within the vein faults, conducive to ore deposition.

The origins of the Keno Hill - Galena Hill mineralized vein faults are still a subject of much debate. K-Ar dating has returned an age of 90 Ma for the mineralized vein faults (Sinclair et al, 1980). Granitic intrusions occur to the north and south district and are of similar age to the vein mineralization. It is assumed that these granitic intrusions, or a buried intrusion below the district, acted as a heat pump for the hydrothermal systems. The temperature of formation of the deposits has not been clearly determined.

All deposits known to date have been located in a near surface environment. This may be due in part to exploration techniques which have been directed towards shallow lying deposits. One current theory is that deeper, buried deposits may be present but have yet to be found.

Most deposits mined to date have been mined to a depth of 90 to 150 meters (300 to 500 feet) below surface. A notable exception has been the Hector-Calumet Mine which was mined to a depth of 366 meters (1,200 feet) below surface. Part of the apparent depth limitation is man-made, with contributing factors such as the topographic location of adits and the pre-determined depth of shafts. Several mines appear to have ore zones continuing below the lowermost level of the mine.

Metal zonation has been difficult to establish. There appears to be a trend towards a regional lateral zonation of silver and gold. Silver is predominant within the central lode deposits of the district. Gold has never been an important economic constituent within these lodes. Outside the central core are several gold and gold-silver lodes such as those on Mt. Hinton and in the Dublin Gulch area. Most of these are hosted by quartz rich veins. Even within the central core, elevated gold values have been noted at the extremities, in the Husky S.W. and Silver King vein systems, the Moth vein and some of the Keno Hill vein systems. The significance of this zonation, if any, has yet to be determined.

Vertical zonation within individual deposits is also a matter of some debate. An overriding theory in this area, developed in the 1920's, maintains that all deposits bottom out in zinc. This has been a self fulfilling theory in some mines with decisions made to bottom a mine based on elevated zinc values

> rather than on a lack of silver values. The depth of oxidation, when compared to the depth of the workings in many mines, may be significant. Zinc depletion within this oxidation zone may be a contributing factor to the apparent zonation which indicates a significant increase in zinc with depth.
>
> There does not appear to be any well defined trace element zonation within or around individual ore shoots. A workable exploration technique utilizing trace elements has yet to be developed.
>
> Alteration haloes surrounding vein faults are usually not distinct. Alteration with the sedimentary sequences may take the form of a minor pyritization, some small chemical changes and irregular carbonate leaching. The leached zone may extend up to 4.6 meters (15 feet) away from the vein zone. Other alteration rarely extends more than 15 meters (50 feet) from the vein fault.
>
> A fracture zone, consisting of small stringers of siderite with sulphides, is common in all types of country rock, for distances up to 7.6 meters (25 feet) away from the main vein fault.
>
> Alteration haloes are distinct but narrow where the vein faults cut greenstone. The alteration zone commonly extends only a few centimetres (inches) away from the vein fault. It consists of a carbonate + sericite zone adjacent to the vein fault grading to a carbonate + chlorite zone grading to unaltered greenstone.

Lynch (1986) has investigated the zoning of vein mineralogy in the district and noted potentially important regularities in the distribution of phases such as calcite, siderite, pyrrhotite and arsenopyrite that may have environmental significance. The following excerpt from Lynch provide a good overview of zoning within the district.

> The principal hypogene minerals in the deposits are siderite quartz, pyrite, galena, and sphalerite with lesser to minor freibergite, pyrargyrite (ruby silver), arsenopyrite, chalcopyrite, pyrrhotite, jamesonite, boulangerite, polybasite, stephanite, calcite, and barite among others. The dominant minerals are generally medium to coarse grained and massive. Some veins are variably banded (Boyle, 1965), or can change in mineralogy along strike from quartz-rich to carbonate and/or sulphide rich fractions. Mineralized faults are sharp planar veins up to 50 cm wide or may be extensive stockwork, sheeted vein, and breccia zones greater than 15 metres in width. Systems such as the Hector-Calumet and the Sadie-Ladue veins are each continuous along strike for over two kilometres.
>
> On a detained scale paragenetic and textural relationships can be complicated and variable, showing considerable overlap and repetition. Such complications are possibly due to advancing and retreating hydrothermal fronts, as well as by continued movement and brecciation along the faults during mineralization. However, on a broader scale zoning

patterns defined by specific vein minerals become clear. Three veining stages are often recognized. The earliest is principally a quartz veinlet stockwork and lesser pyrite and arsenopyrite and occasional feldspar. Minor boulangerite, some galena and sphalerite are reported by Boyle (1965). Boyle stresses that arsenopyrite is a typical mineral of this stage of Keno Hill but is absent or present in only small amounts of the veins of Galena Hill. The second stage consists of carbonate-sulphide-sulphosalt veins crosscutting the early quartz stockworks; this includes the bulk of the ore material. A third stage of veining and vug encrustations consists of quartz and pyrite and has a sparse distribution.

Alteration of host rocks is generally weak, however, pyrite disseminated through the wallrock along the veins is common and is accompanied by silicification/recrystallization. Bleaching of the dark graphitic host to lighter colours is also seen, especially in sections of the quartz-pyrite rich Husky S.W. deposit. The greenstones in contact with the veins are variably sericitized and chloritized.

The deposits at the western end of the district, such as the Husky, Husky S.W., Elsa, and Silver King Mines, as well as the Lucky Queen Mine in the east, are distinguished by the presence of pyrargyrite. It occurs as fine grained stringers in association with typical hypogene minerals such quartz, siderite, and pyrite. It was not firmly established in the past whether pyrargyrite is of a supergene or hypogene origin, however the occurrence of pyrargyrite in deep exposures of the Husky Mine apparently untouched by surface processes, such as rust staining, indicates a likely hypogene nature.

Along the eastern flank of Galena Hill, deep vein exposures at low altitudes contain pyrrhotite. It is typically fine grained and a minor component; however, in the Flame and Moth as well as the Duncan Creek veins it is present in considerable quantity. Arsenopyrite within these carbonate-quartz-pyrrhotite veins is another indicator for this zone. Chalcopyrite and sphalerite appear to be more abundant here as well.

Calcite is in the deep veins of the valley between Galena and Keno Hills but also extends east onto Keno Hill and beyond. Along the eastern side of Galena Hill, calcite, siderite, arsenopyrite and pyrrhotite bearing veins reach up to 900 metres in altitude, whereas siderite veining without calcite, arsenopyrite or pyrrhotite, extends upwards above 1300 metres altitude. The trio calcite, arsenopyrite and pyrrhotite appear to be markers for relatively deeper vein exposures.

At the eastern end of the district, the Keno, Homestake, and Mt. Hinton deposits are characterized by jamesonite-boulangerite. They are associated with abundant quartz, arsenopyrite, pyrite, and light reddish-brown sphalerite. Carbonate is typically absent from these portions of the veins, though they appear to extend laterally into siderite and/or calcite rich fractions. Jamesonite is characteristic of splay faults extending off of the principal vein faults in the Keno deposit (Boyle, 1965).

Wall rock alteration, as noted, is not strongly developed in the country rocks around the vein systems. Boyle (1965) notes a definite base metal enrichment in the wall rocks of some veins and Lynch (1986), in the above quotation, describes a weak pyritization of the wall rocks of several vein systems. This limited dispersion of metal and sulphur from the veins is of environmental significance since underground development has tended to be within, or close to, the vein faults thus adit dumps tend to be dominated by more sulphide rich lithologies. Open pit dumps, on the other hand, include rocks further from the vein and would be expected to contain material with a lower sulphide and base metal content, more akin to the regional rock units.

The amount, form and distribution of pyrite in the veins is of importance in understanding the acid generation potential. Available evidence suggests that pyrite is widespread but does not amount to more than a few percent of most veins. Pyrite grain size is variable but much is described as medium to coarse grained. Most of the pyrite has already been destroyed in the oxidized portion of the veins. These relationships suggest that the potential for acid generation exists but is limited. Widespread distribution of carbonate and its abundance relative to pyrite further limits potential for acid generation since pH is not likely to reach levels that will be conducive to bacteriological catalysis of the oxidation reactions. Hydrolysis of ferric iron from weathering of siderite will create some acidity but this is limited. Further consideration of acid generation potential is provided in Chapter 7 along with test data collected during this study.

3.2.3 Physiography and Surficial Geology

The district lies within the northeastern part of the Yukon Plateau (Bostock, 1948), and the terrain is mountainous with elevations ranging from 1,848 metres (Summit of Keno Hill) to 610 metres (McQuesten River valley). The area has been profoundly influenced by the latest glaciation but shows more subtle evidence of an earlier event as well.

The lower slopes of Galena Hill show clear evidence of ice marginal deposits such as kame terraces related to the glacial lobes occupying the major valley. Ice moved south down the McQuesten Valley and a lobe extending up Christal Creek to a terminus near Keno City. This lobe diverted Lightning Creek into Duncan Creek from its original course in to Christal Creek. The terminus of the south McQuesten lobe is north of Mt. Haldane. There were local alpine glaciers in the higher eastern part of the area, in addition to the large ice sheet in the major valleys, but they appear not to have coalesced with the larger sheets. The retreat of the Cordilleran ice sheet has had a major impact on the south McQuesten valley. Till blankets much of the valley and glacio-fluvial deposits are widespread. Glacio-lacustrine deposits formed in ice marginal lakes occur in the deeper part of the valley. Large meltwater streams have left huge meander scars which divert those of the underfit present day south McQuesten River. Boyle (1965) provides the following additional description of the physiography and glacial deposits in the area.

> Galena Hill trends northeast between Duncan Creek and the McQuesten River valley. It has an elevation of 4,740 feet, a moderately steep southwestern slope, and steeper north, northwestern, and southeastern slopes. The terrain above 4,300 feet is relatively flat and rolling, and marked by several level grassy meadows. The north, northwestern, and southeastern slopes of the hill are crossed by several streams that have cut steep gulches into the rock strata. The principal streams responsible for these gulches are Galena, Flat, Brefalt, and Sandy Creeks and Porcupine Gulch on the northwestern slope and Hinton and Fisher Creeks on the eastern and southeastern slopes.
>
> Keno Hill and Sourdough Hill are adjacent hills separated by Lightning Creek. Keno Hill trends northeast and lies between the Keno Ladue-McQuesten River valley and Allen, Faith, Lightning, and Christal Creeks. The hill has relatively gentle southern and southeastern slopes and a precipitous northern slope, marked by two cirques, Faro Gulch and Silver Basin Gulch. The terrain above 4,500 feet is relatively flat and rolling with five prominent rocky knolls known as Keno, Minto, Monument (the highest point on Keno Hill, elevation 6,065 feet), Caribou, and Beauvette. On the slopes of the hill several streams follow steep gulches in the rock strata, the principal ones being Gambler, Faro, McKay, and Silver Basin on the northern slope, Faith, Hope, and Charity on the northeastern and southern slopes, and Erickson on the western slope.
>
> Sourdough Hill (Pl. VI) lies southwest of Keno Hill and trends north between Thunder, Lightning, and Duncan Creeks. The part of the hill described in this report is on the northern and northwestern slopes, which are gentle up to 4,200 feet and from there rise abruptly to a steep rocky hogsback that trends southwest for some 6,000 feet.
>
> Extensive rock outcrops are uncommon on Galena, Keno, and Sourdough Hills, and with the exception of the gulches and cirques where relatively good geological sections are present, detailed mapping can only be done by observing float. Below an elevation of 4,400 feet rock outcrops are sparse, and the slopes are covered with till, soil, rock debris, much, and muskeg, in which conifers, birch, aspen, Arctic black-birch, and other vegetation grow abundantly. Above this elevation the soil is thin, outcrops are more numerous, the ground is covered with local rock float, the terrain

is treeless, and the vegetation is limited to alpine species and grassy meadows.

The lower slopes of the hills were severely glaciated during Pleistocene time by ice-sheets that spread, from the east, over the entire area. Glacial till, gravel, and other debris lie in a series of benches on the slopes of the hills and floor the valleys. The deposits are generally 5 to 20 feet thick, but in some areas as on the southern slope of Keno Hill facing Lightning Creek and north of Christal Lake, they are 30 to 50 feet thick or more.

The Keno Hill-Galena Hill area is in the region of permanently frozen ground. Wernecke (1932) has given an interesting account of the permafrost conditions, and the present investigation has added further data. The permafrost is irregularly distributed and its occurrence is dependent upon the elevation, hillside exposure, depth of overburden, amount of vegetative cover, and presence of flowing underground and surface water. At high elevations and on slopes with a northern exposure it is generally present. Thus, on Keno Hill, the mine workings on the top of the hill and on the northern slope encountered permafrost some 400 feet below the surface. On the northern slopes of Sourdough Hill and Galena Hill a similar situation prevails, and frost and ice lenses have been encountered at depths of 250 feet or more in the mine workings. On the lower southern slope of Keno Hill, however, the workings of the Onek and Mount Keno mines show little evidence of permafrost. In places where surface and underground water are flowing the permafrost has been thawed out and frostfree windows and strips are present. These provide access and egress for waters that are oxidizing the lodes.

The effects of frost action, soil creep, and slope wash are marked on the hills, particularly at the higher elevations. Frost action is responsible for features such as stone rings and stripes, and produces a general ‘boiling action’ that brings rock float, mineralized float, and soil from deeper layers to the surface, thus facilitating the mapping of both the underlying bedrock and the tracing of vein faults. On steep slopes, however, frost action and land creep have transported float downhill places, 100 feet or more, making the accurate mapping of contacts and vein faults difficult.

Glacial Deposits

The glacial deposits of the area were laid down during the advance and retreat of at least two ice-sheets that spread over the area from the east. The evidence for the first glaciation is rather meagre and is restricted to the presence of erratics above an elevation of 4,000 feet on Keno and Galena Hills and to an old till in the upper part of Dublin Gulch. The most distinctive deposits are those of the last glaciation.

These deposits floor the principal valleys and form benches on the lower slopes of the hills. They vary in thickness from a few feet to 50 feet or more and are composed mainly of till, glacio-fluvial deposits, glacio-lacustrine gravel, sand and silt, and layers of peat.

> The tills, rarely more than a few feet thick, are absent in places. They are grey or greenish buff and consist of a heterogeneous mixture of fine sand, clay, small particles of schist, quartzite, and greenstone, and variously sized stones and boulders. Carbonate, mostly in the cementing materials, is present in some tills.
>
> The clay and sand fractions are composed principally or irregular grains and broken fragments of quartz, feldspar, mica minerals, and hornblende. Heavy mineral accessories as determined by X-ray are magnetite, ilmenite, rutile, sphene, leucoxene, zircon, staurolite, garnet, monazite, epidote, tourmaline, pyrite, and red and black jasper pebbles. The till minerals are generally angular and abraded, and look fresh with little visible evidence of chemical decomposition. Most tills give a neutral or slightly alkaline reaction (pH 7-7.5).
>
> Most of the rock pebbles and fragments and the heavy minerals in the tills are probably derived locally. Some minerals such as garnet and staurolite and the jasper pebbles may, however, have travelled considerable distances, because these minerals are not plentiful in the rocks underlying Keno and Galena Hills.
>
> Lenses of gravel and sand are common in some tills, and thin peat layers are present locally. The gravel and sand lenses generally contain the same mineral assemblage as the tills. The peat layers are composed essentially of brownish and brownish black decomposed plant remains and much brownish material (humus). A small amount of mineral matter, consisting of quartz, feldspar, mica flakes, and a suite of heavy accessory minerals similar to that in the tills, is present throughout the peat.
>
> The glacio-fluvial deposits are as much as 50 feet or more thick and include poorly sorted gravels and sand deposits which occur in kames, eskers, and glacial benches. Most of the pebbles and stones are relatively well rounded to subangular and consists of quartzite, schist, greenstone, diorite, and granite, all mainly derived locally. the fine sandy fractions contain the same mineral assemblage as the tills.
>
> The glacio-lacustrine deposits range from a few feet to tens of feet in thickness. In places they are stratified, in others they consist of unsorted, washed gravels containing sand lenses. The gravels contain well-rounded pebbles, stones, and subangular schist fragments of local derivation. The mineral constitution of the sand lenses and fine fractions of the gravels is similar to that of the other glacial deposits described above.

3.3 Soils

Soils were not studied as part of this work programme, however, the following description of soil is excerpted from Boyle's (1965) work:

> Soil development has been affected by four principal factors: the variability of parent materials, the marked relief of the country, the climatic and

vegetative forces under which the soil developed, and the presence of permafrost.

In the Keno Hill-Galena Hill area both bedrocks and glacial materials have served as parents for soil. The marked relief has had the effect of producing deeper soils in the valleys and on the lower slopes of the hills. The difference in the exposure of the hillsides has been responsible for the occurrence of greatly different soils within short distances. South-facing slopes are generally less densely wooded and freer from permafrost than north-facing slopes. On the former the soils are somewhat better developed; the latter are covered in most places by deposits of muck, peat, and half-bog soils.

Except for a few localized areas, the soils are not strongly weathered or deeply leached. They also exhibit a poor profile development, particularly those underlain by permafrost.

The soils in the area can be conveniently classified into two general types: (1) residual, and (2) muck peat, and half-bog.

The residual soils were formed principally from the weathering of the various types of bedrocks, or as is evident in some places, particularly in the vicinity of Dublin Gulch, from the decomposition of a till that predates the last glaciation.

The thickness of the residual soils varies, depending on the slope of the hills. On the tops of the hills they are rarely more than 3 feet thick and in places are entirely absent; lower down on the slopes the soils, thickened by slope wash and land creep, may exceed 10 feet. In most areas they are highly disturbed by solifluction and frost-boiling, and their profile development is either immature or non-existent. In places the following generalized profile is present from the surface downward:

HORIZON	DESCRIPTION
Surface A_{00}	Trees, Shrubs, grass, moss, loose leaves, etc.
A_0	Undecomposed, partly matter organic layer consisting of roots, moss, woody fragments, humus, etc. - 3 to 6 inches thick - unfrozen during summer.
A_1	Organic layer consisting of decomposed roots, moss, woody fragments, humus, clay, sand, etc. - 3 to 6 inches thick - generally unfrozen during summer. This layer is thin or absent in places.
B + C	Residual soil - 1 foot to 10 feet thick. Frozen except locally.
	The soil overlying quartzite and greenstone is light reddish and yellow brown and contains much fine sand, clay, and small amounts of humus. Because of frost action angular blocks of quartzite and greenstone are generally admixed with the soil in all areas. The principal mineral constituents are quartz, feldspar, micas, clay minerals, hornblende, and limonite. The common heavy minerals are zircon, rutile, sphene, ilmenite, magnetite, epidote, monazite, tourmaline, and garnet. The soils overlying greenstones carry much sphene and leucoxene and small amounts of chromite. In the vicinity of the siderite-galena-sphalerite and pyrite-arsenopyrite lodes cerussite, beudantite, scorodite, native gold, oxidized galena cubes, goethite and limonite particles, and oxidized pyrite nodules appear in the heavy fractions. Over parts of the Dublin Gulch granodiorite mass and in the vicinity of some skarn zones the soils are weathered residuum carry scheelite.
	The soil overlying schists is grey or black, depending upon the type of schist. Over graphitic schists the soil is black and contains much graphitic material. Small fragments and plates of schist are universally present. The principal mineral constituents are quartz, feldspar, micas, clay minerals, graphite, and limonite. The common heavy minerals are similar to those overlying quartzite. Near the cassiterite veins north of Dublin Gulch the soils overlying schists and quartzites carry small amounts of cassiterite and tourmaline.
Bedrock D	Quartzite, phyllite, greenstone, and schist.

Most residual soils are moderately well drained on the lower slopes of the hills, but poorly drained on the tops of the hills, where the upper layers of the soil are water-saturated all summer. The pH of most residual soils varies from 5.2 to 6.5.

The muck, peat, and half-bog soils are largely developed on the north slopes of the hills and on low-lying poorly drained ground. In most occurrences the profiles show the following sequence from the surface downwards:

HORIZON	DESCRIPTION
Surface A_{00}	Trees, grasses, low shrubs, mosses, loose leaves, etc.
A_0	Slightly compressed undecomposed organic matter consisting of woody fragments, roots, mosses, leaves, and minor amounts of mineral matter; 3 to 6 inches thick; unfrozen during summer.
A_1	Muck composed of dark brown to black decomposed organic matter and humus with a slight admixture of clay, sand, etc.; 6 to 10 inches thick; generally permanently frozen below top few inches.
B + C (Residual Soils)	Residual soil or till, gravel, and sand; generally frozen; thickness varies.
D (Glacial Materials)	Thickness varies
Bedrock D	Quartzite, phyllite, greenstone, and schist.

The muck, peat, and half bog soils are very poorly drained and are water-saturated all summer. Their pH varies from 6.0 to 7.0.

3.4 Vegetation

The Elsa-Keno Hill area is located within the Mayo Lake-Ross River Ecoregion (Oswald and Senyk, 1977). The region is characterized by discontinuous widespread permafrost, with much of the area poorly drained and underlain by perennially frozen ground. Many valleys include peatlands, palsas, fens and meadows of sedge tussocks. Upper slopes may be covered with scree material, with treeline occurring at 1350 to 1500 meters.

The predominant tree cover in the area consists of white spruce (*Picea glauca*), black spruce (*Picea mariana*) and willows (*Salix spp*.). Less commonly occurring trees are trembling aspen (*Populus tremuloides*), balsam poplar (*Populus balsamifera*), white birch (*Betula papyrifera*). Alpine fir (*Abies lasiocarpa*) is common at higher elevations and alder (*Alnus crispa*) occurs along creek banks and in disturbed areas. Isolated pockets of lodgepole pine (*Pinus contorta*) can also be found.

Most south-facing slopes are covered with white spruce along with aspen, balsam poplar and willows, while north-facing slopes are underlain by permafrost and covered with stunted black spruce. Much of the drier south-facing slopes has been burned at some point during the past century (Green, 1971).

The shrub layer on the north facing slopes and peatbog areas consists of dwarf birch (*Betula glandulosa*), willows (*Salix spp*.), shrubby cinquefoil (*Potentilla fruticosa*), crowberrry (*Empetrum nigrum*), cloudberry (*Rubus chamaemorous*) and dwarf raspberry (*Rubus acaulis*), as well as ericaceous shrubs such as Labrador tea (*Ledum decumbens*), bearberry (*Arctostaphylos rubra*), blueberry (*Vaccinium uliginosum*), cranberry (*Vaccinium vitis-idaea*) and bog cranberry (*Oxycoccus microcarpus*). The drier south-facing slopes have a shrub layer which includes rose (*Rosa acicularis*), twinflower (*Linnaea borealis*), and gooseberry (*Ribes oxyacanthoides*).

Alpine areas support a variety of a plant communities. The low ground vegetation mainly consists of mat forming plants such as moss campion (*Silene acaulis*) and ericaceous shrubs such as heather (*Cassiope spp*.). A variety of alpine flowering forb species are also found. Dry areas, particularly well-drained rocky alpine sites, have extensive lichen development.

Wetland species are mostly graminoids, including sedges such as Carex aquatilus and Carex lugens, cotton-grass sedges (*Eriophorum augustifolium, Eriophorum russeolum and Eriophorum vaginatum*), and grasses such as reed-bentgrass (*Calamagrostis canadensis*). Forb species such as Sudeten lousewort (*Pedicularis sudetica*), wintergreen (*Pyrola spp*.) and coltsfoot (*Petasites spp*.) are also scattered throughout wetland areas.

Aquatic plants commonly found in the area include water-milfoil (*Myriophyllum exalbescens*), pondweed (*Potamogeton richardsonii*), mare's-tail (*Hippuris vulgaris*) and bur-reed (*Sparganium spp*.).

Common horsetail (*Equisetum arvense*) is the predominant species of vegetation occurring on the unsubmerged portion of the Elsa tailings impoundment. Squirrel-tail grass (*Hordeum jubatum*) is found in large patches in the higher, drier areas. Hairgrass (*Deschampsia caespitosa*) and willows (*Salix spp*.) are scattered throughout. Sedge (*Carex aquatilus*) is the predominant plant in the wetter tailings and shallow water, along with occasional occurrences of willow, water horsetail (*Euisetum arvense*) and sloughgrass (*Beckmannia syzigachne*).

Metal levels in local wetland plant species were investigated as part of the Galkeno 900 pilot wetlands testwork. Samples for metal analyses were collected from wetland plant tissue and sediments to determine the extent of metal uptake by plants. Test results indicate that sediments contain considerable quantities of metals, while plant tissue metal levels remain near reported values for non-enriched sites. A complete discussion of metals uptake by plants is found in Appendix II, Table 3.

3.5 Wildlife

The Elsa-Keno Hill area supports a variety of wildlife including ungulates, fur-bearers, small mammals, upland game birds and waterfowl.

This area is included in the range of the Mayo woodland caribou herd, although only anecdotal information on the herd is available. Little is known about the caribou population in the area, as no recent inventories have been carried out. Caribou are occasionally harvested in the area.

Aerial moose surveys in the Mayo area in 1988 and 1993 included the area between the Mayo-Elsa-Keno highway and the South McQuesten River. The estimated density in 1993 was 119 moose/1000 km^2 compared to a density of 104 moose/1000 km^2 in 1988. The estimated average density for the entire Yukon is 127 moose/1000 km^2 (Ward, 1993). The resident non-native harvest in the survey area (game management zones 2-

58, 4-01, and 4-04) averages about 11 moose per year. The area is not currently hunted by non-residents. No accurate record for the native harvest of moose is available.

The Elsa-Keno area no longer supports thin-horn sheep. A small population had existed on Keno Hill, but was hunted out during the 1920's (Carey, 1992). There has been some discussion regarding the re-introduction of sheep to Keno Hill, but some believe that the habitat has been too much altered by mining development and access roads to make sheep re-establishment viable.

The South McQuesten River area is known as good quality fur-bearer habitat, although fur harvest records for traplines in the area are not currently available. The most commonly harvested fur-bearers are marten, wolverine and lynx. A total of 5 registered traplines occur wholly or partly in the Galena - Keno Hill area.

Other small mammals common to the area include muskrat, beaver, ground squirrel, red squirrel, varying hare, fox, mink, weasel, vole and shrew. Less common are porcupine, river otter and chipmunk. Alpine areas have local populations of hoary marmot and pika. Large carnivores include black bear, grizzly bear and timber wolf.

Information on waterfowl populations is restricted to casual observations. No systematic surveys have been carried out. There are reports of Canada geese nesting on wetlands in the area, and large numbers of Canada, snow and white-fronted geese have been seen to use the area during spring and fall migrations. Loons, grebes and diving ducks have been seen on larger water bodies such as McQuesten Lake and dabbling ducks have been observed in the wetlands.

Game birds common to the area include spruce grouse and ptarmigan. Less common are ruffed grouse, blue grouse and sharp-tailed grouse.

The health of the local wildlife populations near the Galena - Keno Hills area has not been studied. Within the last two years local people have expressed concern over the health of local wildlife which are routinely consumed. Government programs have attempted to address this issue by collecting wildlife muscle, kidney, and liver tissue; particularly for caribou and moose, and analyzing these tissues for metal and organo chlorine levels. To date, a limited number of moose (2 samples) and caribou samples have been specifically collected from the South McQuesten River area. Although a detailed comparison is not possible, metal levels from the moose tissue were not atypical of other animal results in the territory. A detailed summary of all wildlife test results by local communities is being compiled (M. Palmer, M. Gamberg, 1996) Y.T.G. Renewable Resources routinely accepts wildlife tissue samples for metal analyses. It is expected that a database of metal levels in local wildlife species will develop as additional data is compiled.

3.6 Climate

3.6.1 General

This section presents an assessment of two climatic variables which were required to develop an overall water balance for the UKHM mine site (as described in Section 8.2). The two variables are average precipitation and average evaporation. These two variables were considered the key parameters in developing the water balance for the UKHM site.

3.6.2 Available Data

The climate records from a total of eleven climate stations were assembled to assist in characterizing the climate of the UKHM mine site. Details of these stations are presented in Table 3-5. The table also identifies the type of climatic information each station provided for the study.

Table 3-5 Details of Regional Climate Stations

Station Name[3]	Latitude		Longitude		Elevation (m.a.s.l.)	Period of Record	Mean Annual Precipitation (mm)	Information Applicable To This Study
	Deg.	Min.	Deg.	Min.				
AES[1]								
Boundary/ Mile 34 Boundary Rd	64	14	140	21	1036	1967 - 1978	576	Precipitation
Clinton Creek	64	28	140	44	576	1964 - 1978	370	Precipitation
Dawson	64	3	139	26	320	1897 - 1979	306	Precipitation/ Humidity/ Temperature
Dawson Airport	64	3	139	8	369	1976 - 1995	340	Precipitation/ Humidity/ Temperature
Elsa	63	55	135	29	814	1948 - 1965, 1974 - 1989	413	Precipitation
Pelly Ranch/ Fort Selkirk	62	49	137	22	454	1954 - 1995	286	Precipitation/ Bright Sunshine
Keno Hill	63	56	135	12	1472	1974 - 1982	590	Precipitation
Klondike/ Dempster	64	27	138	13	960	1966 - 1995	469	Precipitation
Mayo Airport/ Mayo/ Mayo Landin	63	37	135	52	504	1924 - 1995	306	Precipitation/ Humidity/ Temperature
Snag Airport	62	22	140	24	587	1943 - 1966	339	Humidity/ Temperature
DIAND[2]								
Flat Creek	63	55	135	30	730 (approx.)	1992 - 1994 (summers only)	Not available	Humidity/ Temperature

Notes: 1. Environment Canada, Atmospheric Environment Service

2. Department of Indian Affairs and Northern Development, Fire Management Program

3. For some stations, more than one name is presented. Where this happens, the first name given is the current official designation of the station. Other names represent past designations of the station. Name changes appear to have most often been triggered by the slight relocation of the station.

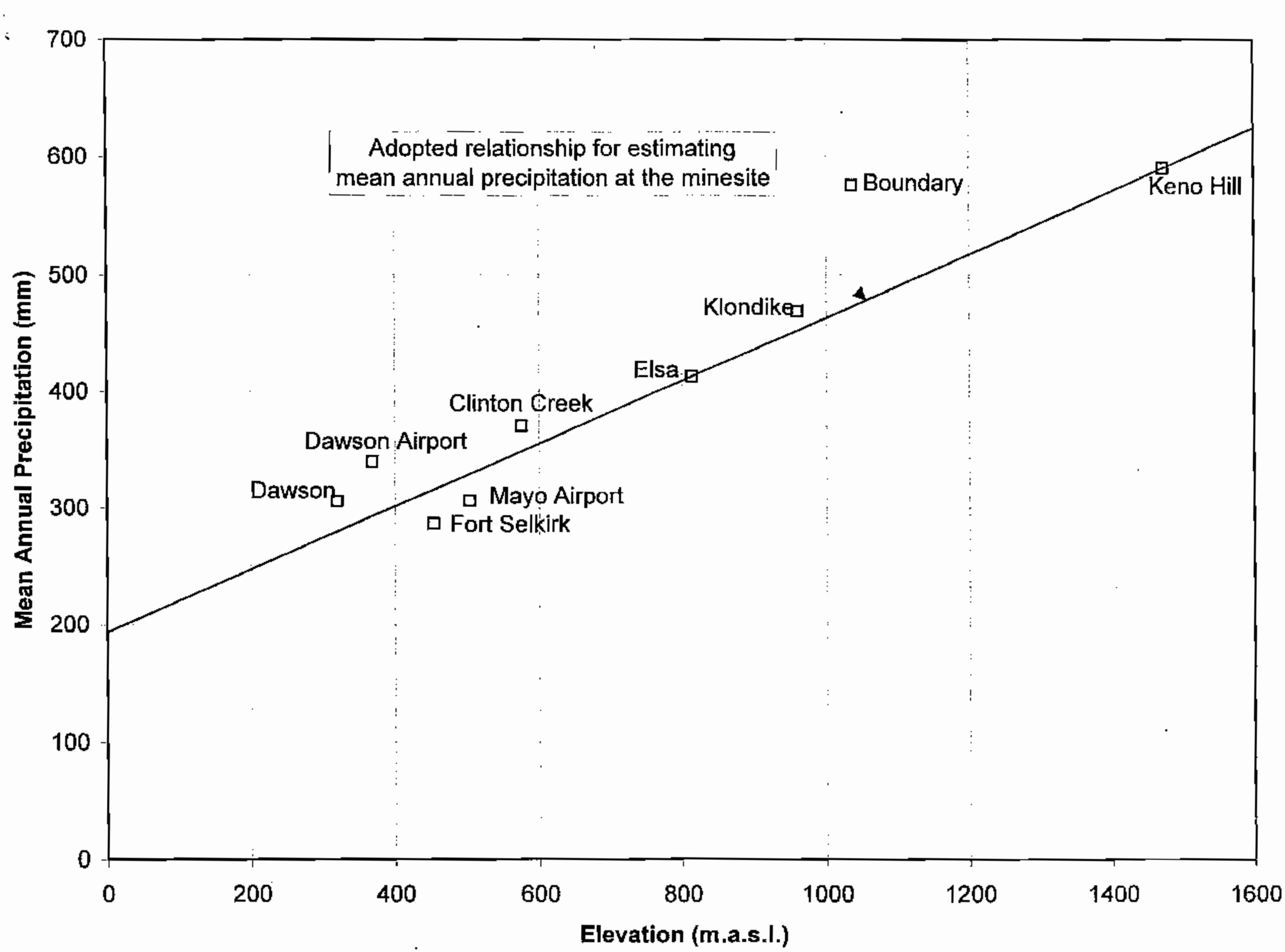
The region around the UKHM mine site is well served by a reasonably dense network of climate monitoring stations, a most unusual situation for a mine site located in the sparsely populated regions of northern Canada. Of particular noteworthiness is the fact that at least three climate stations have been operated within the boundaries of the mine site. Two of these stations were maintained by the Atmospheric Environment Service (AES) and were located at the Elsa townsite and on the southern flank of Keno Hill. The third station was operated on a seasonal basis by DIAND at a site in the Flat Creek catchment near the Elsa townsite. In addition to these mine site stations, the AES operate a principal climatological station at the Mayo Airport, located some 40 km southwest of Elsa. The data from the Mayo Airport can be combined with that of two discontinued stations in the near vicinity of the airport (i.e. Mayo Landing and Mayo) to construct a long-term climate record spanning 72 years.

Another source of information, but not included in Table 3-5, is climate data collected at the Dublin Gulch property, a proposed heap-leach gold operation located approximately 21 km northwest of Elsa. These data have not been used in the present study but may be incorporated into future analyses related to the water licence application.

3.6.3 Precipitation

Mean annual precipitation (MAP) within a mountainous region typically increases with increasing elevation. The region around the UKHM mine site is no exception to this rule as illustrated by the graph of MAP versus elevation shown on Figure 3-3. The data points on this graph were obtained from the information assembled in Table 3-5 for the regional AES climate stations.

Figure 3-3 Mean Annual Precipitation as a Function of Elevation



The UKHM mine site is in an area of significant relief. Accordingly, MAP can be expected to vary considerably within the boundaries of the mine site. In order to quantify this variation, an empirical relationship was derived between MAP and elevation using the data from the two AES stations which were operated on the mine property, namely the Elsa and Keno Hill stations. These are suitable stations for deriving the relationship since their elevations are widely separated (i.e. 814 m versus 1472 m). Assuming a linear relationship between MAP and elevation, a line was fitted to the data of these two mine site stations (see Figure 3-3). The slope of this line indicates that MAP increases by an average of 27 mm for every 100 m of ascent, a value not too dissimilar from that observed in other regions of the Yukon interior.

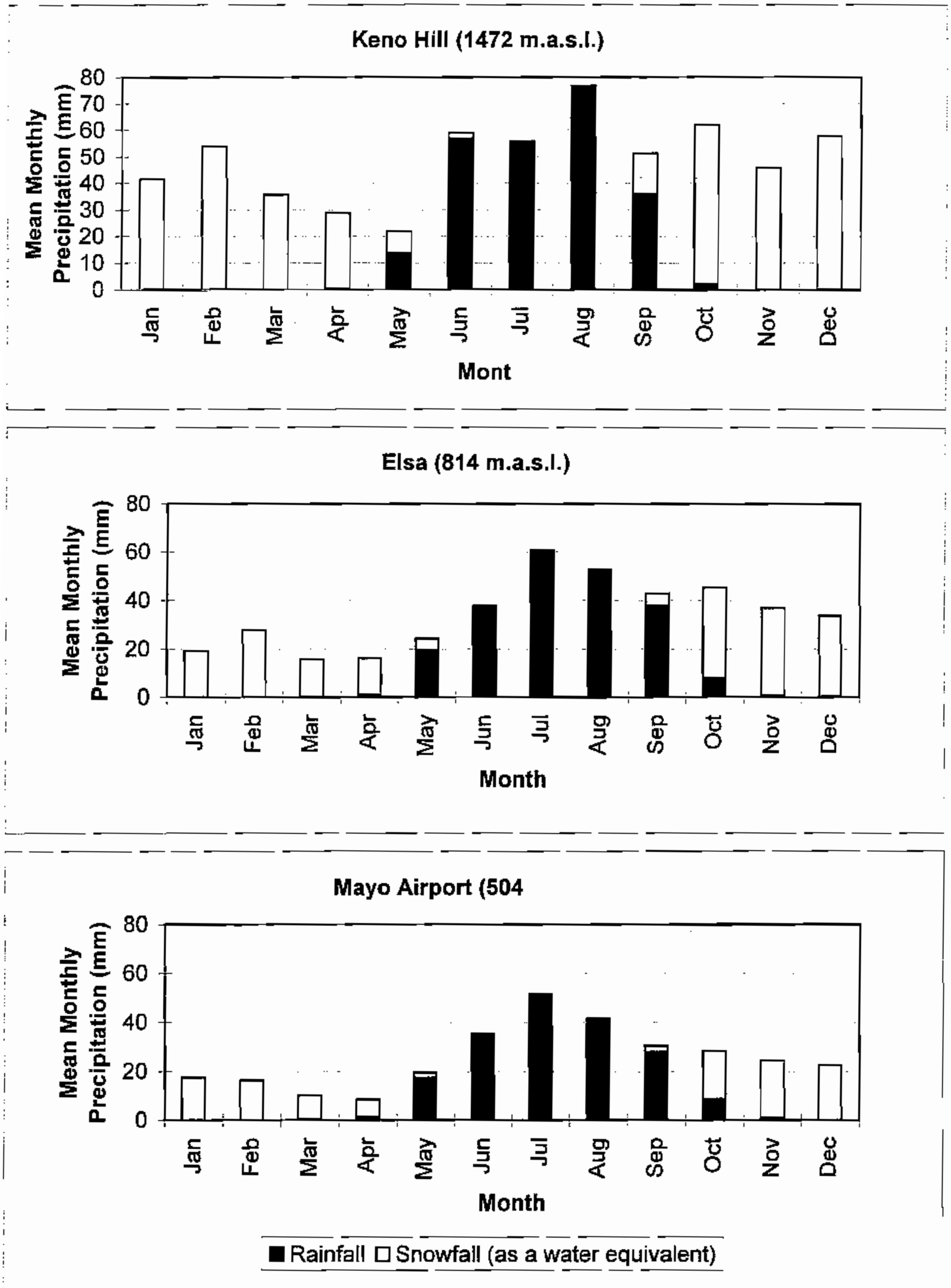
The curve fitted exclusively to the Elsa and Keno Hill data seems to also explain much of the variation in MAP observed at the other regional AES climate stations. The scatter about the line drawn on Figure 3-3 can largely be attributed to a mild drying trend as one moves from the northwest to the southeast across the region. This drying trend is made apparent by noting where the individual climate stations are located in relation to the mine site. All stations plotting above the line are located north and west of the UKHM site. In contrast, the two stations plotting below the line are found south of the mine site.

The adopted empirical relationship shown on Figure 3-3 should be viewed as providing only approximate estimates of MAP for ungauged points within the mine site. Although elevation is the principal control, precipitation also varies according to other variables such as slope and aspect which are not explicitly accounted for in the empirical relationship.

Figure 3-4 was prepared to illustrate the seasonal distribution of precipitation at the mine site. As with MAP, the seasonal distribution is influenced by elevation. To demonstrate this influence, the seasonal distributions for Mayo Airport (504 m), Elsa (814 m), and Keno Hill (1472 m) have been plotted on Figure 3-4. The following observations can be drawn from examining these distributions:

- precipitation is common throughout the year;
- the wettest period is normally the summer months of July and August;

FIGURE 3-4 Mean Monthly Precipitation



- the driest month of the year is typically April;
- the proportion of total precipitation which falls as rain decreases as elevation increases (60% of total precipitation at Mayo Airport, 53% at Elsa, and 41% at Keno Hill); and,
- the precipitation gradient during winter is steeper than that during summer (which suggests orographic effects are more pronounced during snowfall than during rainfall).

Evaporation

Two rates of evaporation are of interest, namely lake evaporation and evapotranspiration. The former refers to evaporation from a free-water surface while the latter refers to evaporation from a land surface including transpiration from plants. Both rates were estimated from meteorological data using a computer program known as WREVAP which was developed by Environment Canada's National Hydrology Research Institute (Morton, 1985).

The meteorological inputs to the WREVAP model comprise humidity, temperature, and sunshine duration. In order to obtain valid estimates of evaporation, the model must be provided with accurate measurements of the first two climatic variables. Model results are less sensitive to the accuracy of the third input requirement, i.e., sunshine duration. Thus, the use of sunshine duration records from another nearby climate station provides adequate accuracy. With this in mind, a search was made for climate stations which met the following two criteria:

- the station experiences a comparable climate to the mine site; and,
- as a minimum, the station monitors both humidity and air temperature.

Using these criteria, a total of four climate stations were selected for the evaporation modelling, one located at the mine site itself (Flat Creek) and three located in the general region (Dawson, Dawson Airport, and Mayo Airport). At none of these locations was sunshine duration monitored. To obtain this additional information, reference was made to the closest climate station equipped to measure sunshine duration (viz, Pelly Ranch or, as it was formerly known, Fort Selkirk).

Figure 3-5 displays the results of applying the WREVAP model to the meteorological conditions at each of the four climate stations. The top graph shows estimates of mean monthly evapotranspiration while the bottom graph shows the monthly distribution of lake evaporation. As can be observed, all four stations experience similar rates of both lake evaporation and actual evapotranspiration. Based on this similarity, the average of the evaporation rates at the four stations was selected to represent the conditions at the mine site. The average annual lake evaporation is about 460 mm while the estimated actual evapotranspiration is about 200 mm per annum, or 43% of lake evaporation.

3.7 Hydrology

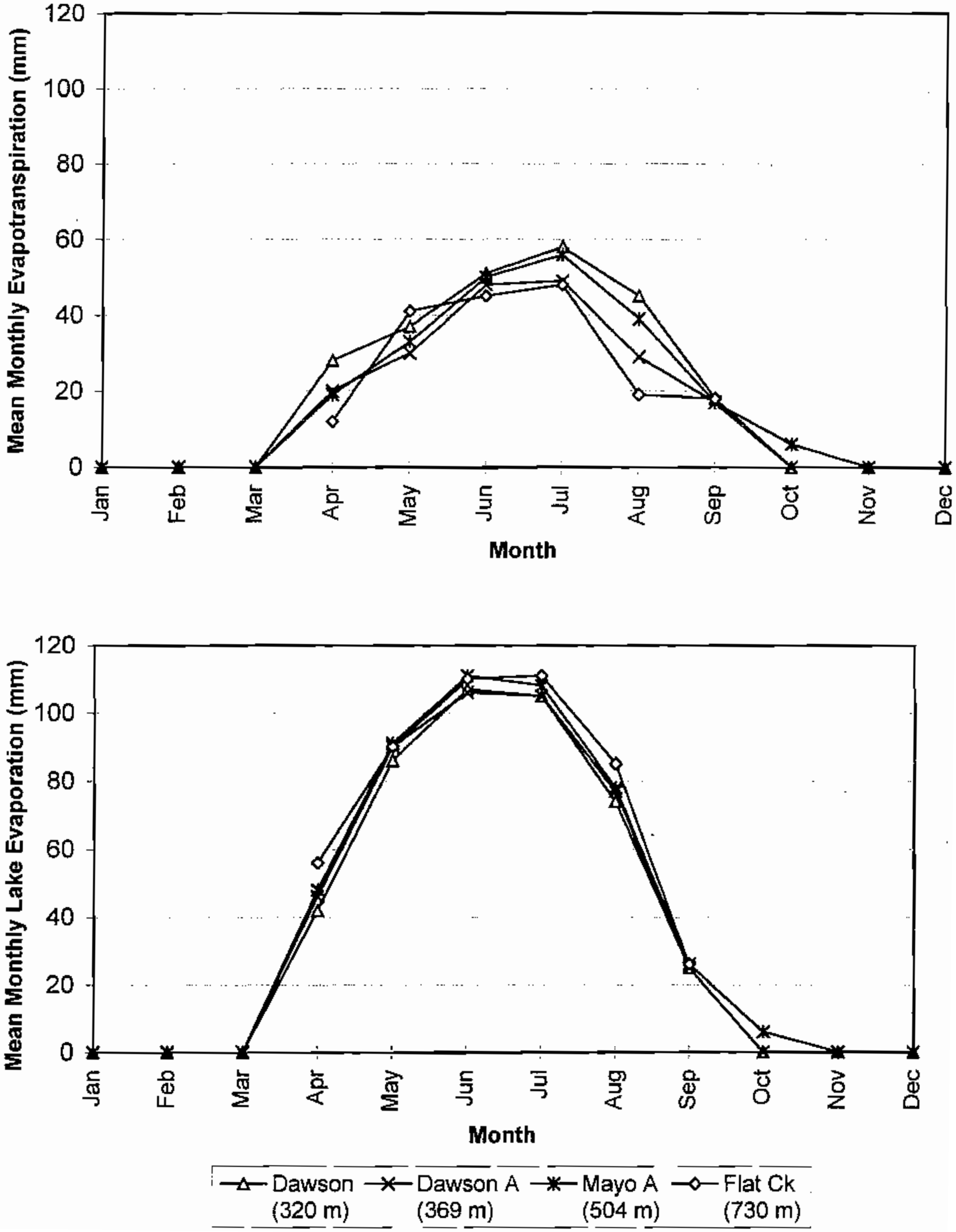
3.7.1 General

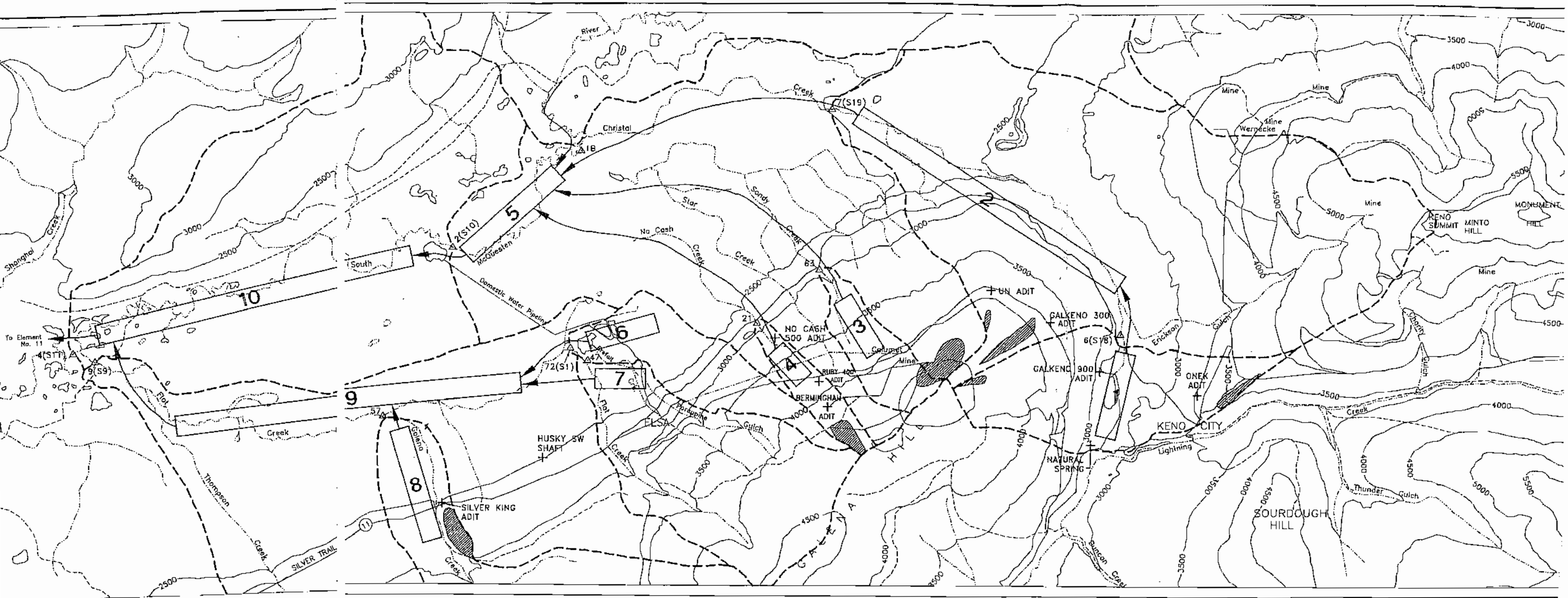
This section describes an analysis undertaken to estimate the average flows at key locations on the mine site streams. This information was required to construct an overall site water balance and chemical load balances for the UKHM mine site.

3.7.2 Available Data

The hydrology of the mine site streams was characterized using a mix of both site-specific and regional data. The site-specific data can be categorized into two groups. The first group encompasses a series of spot flow measurements made at the mine site water quality stations by UKHM personnel, government agencies, and consultants. The second group is data collected at five streamflow gauging stations established on mine site streams during 1994 and 1995 by Laberge Environmental Services. One of these stations is automatically monitored using a pressure transducer and data logger. The other four stations are equipped with staff gauges and must be manually read. The data collected to date at the five gauging stations are presented in Technical Appendix III. Maps showing the gauge locations and the catchment boundaries are shown in Figures 3-6 and 3-7.

Figure 3-5 Mean Monthly Evaporation Data





LEGEND

Creek, river, waterbody
Territorial Highway
Secondary road
Trail

Subcatchment boundary
10 Model element (refer to report for data)
Flow between elements
Enclosed basin draining to open pits
Point source
△21 Water quality monitoring station

Elevation contour interval – 500 feet

0 1000 2000 3000
METRES

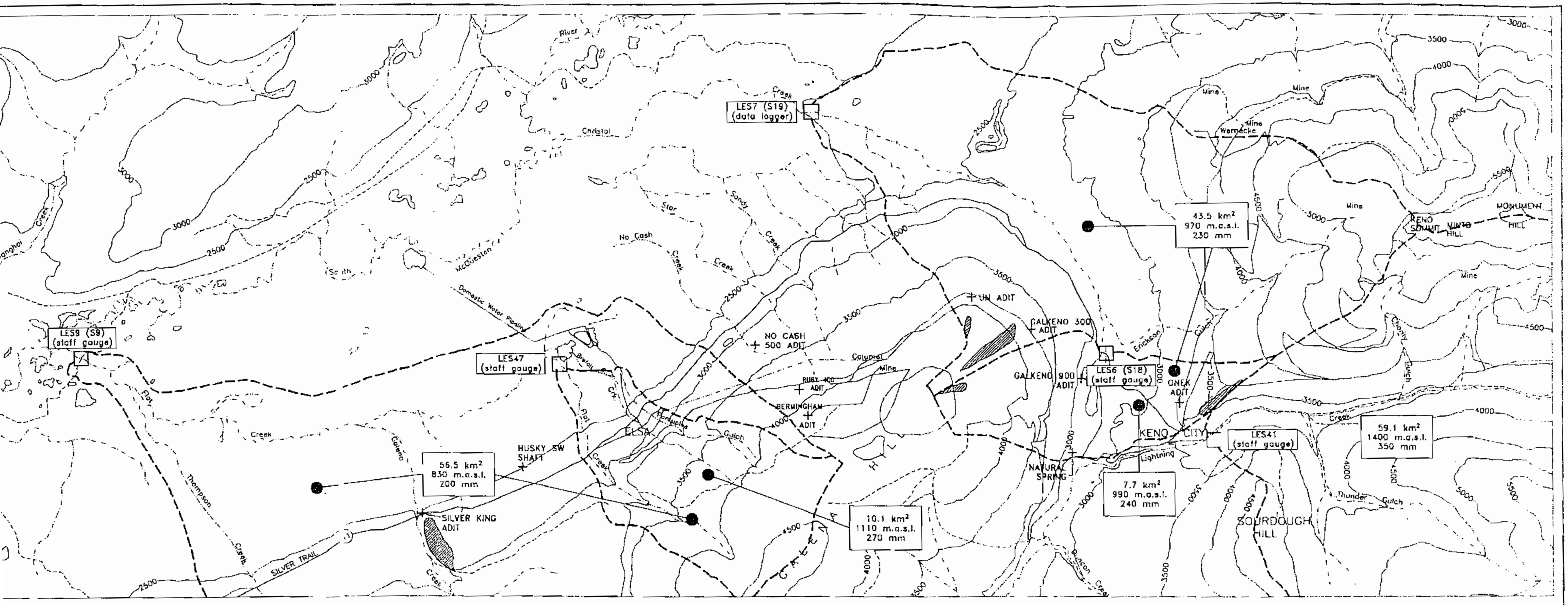
UTM GRID NORTH

UNITED KENO HILL MINES LIMITE

MODEL REPRESENTATION OF MINESITE DRAINAGI WITHIN THE SOUTH MCQUESTEN RIVER WATERSH

ACCESS MINING CONSULTANTS LTD.

SCALE: 1 : 50 000	FILE: 224_1.DWG	DATE: 30/05/
DRAWN:	DWG: 95UK23	FIGURE: 3–6



LEGEND

Creek, river, waterbody

Territorial Highway

Secondary road

Trail

Elevation contour interval – 500 feet

Subcatchment boundary

Streamflow gauging station

Area, median elevation, and mean annual runoff of the gauging station's catchment

Enclosed basin within the catchments of the gauging stations

Point source discharges within the catchments of the gauging stations

LES9 Laberge Environmental Services site description number

(S9) UKHM site description number

0 1000 2000 3000 METRES

UTM GRID NORTH

UNITED KENO HILL MINES LIMITED

LOCATION OF MINESITE STREAMFLOW GAUGING STATIONS

ACCESS MINING CONSULTANTS LTD.

SCALE: 1 : 50 000	FILE: 224_4.DWG	DATE: 30/05/96
DRAWN:	DWG: 95UK23A	FIGURE: 3-7

The site-specific data on their own are inadequate to fully characterize the hydrology of the mine site streams. This is because the spot flow measurements collected at the water quality monitoring stations are sparse and generally do not cover all seasons. Also, the streamflow records at the five mine site gauging stations are still of short length and, in the case of the manual gauges, are also intermittent.

In the absence of long-term and complete records of streamflow for the mine site streams, resort was made to data collected at the hydrometric networks of the Water Survey of Canada (WSC) and the Water Resources Division of DIAND. The streamflow gauges operated by the WSC are typically sited on streams with large catchments (say greater than 500 km^2) and are monitored on a year-round basis. In contrast, the DIAND gauges are normally located on streams with small catchments and are operated seasonally during the period of open water. The networks of both government agencies were examined to identify regional gauging stations which could be useful in characterizing the average flows of the mine site streams. A total of fifteen stations were selected for this purpose, fourteen operated by the WSC and one operated by DIAND. Table 3-6 provides details of these stations, including period of record, catchment area, catchment median elevation, and mean annual runoff (MAR). Median elevation is a physical characteristic of the catchment and is defined as the contour which divides the catchment exactly into halves. The mean annual runoff for each regional gauge is expressed in two types of units, namely a long-term average flow rate and a depth. The latter unit may be interpreted as the depth to which the average annual runoff volume would spread uniformly over the total catchment area.

All of the selected WSC stations gauge unregulated flows, or flows which have been minimally influenced by human activity. The flows measured at the DIAND station, on the other hand, are characterized as being partially regulated owing to the placer mining activity upstream of the gauge.

The data collected by the WSC and DIAND were used to characterize the mine site hydrology using a technique known as regional analysis. Essentially, this involved deriving empirical relationships between the measured streamflow of the regional

Table 3-6 Details of Regional Streamflow Gauging Stations

Streamflow Gauging Station: ID No.	Streamflow Gauging Station: Name	Period of Record	Catchment Area (km^2)	Catchment Median Elevation (m.a.s.l.)	Mean Annual Runoff (m^3/s)	Mean Annual Runoff (mm)
WATER SURVEY OF CANADA						
10MA003	Blackstone River near Chapman Lake Airstrip	1984 - 1994	1130	1400	9.14	255
10MB004	Bonnet Plume River above Gillespie Creek	1981 - 1994	3760	1390	53.2	447
09DA001	Hess River above Emerald Creek	1976 - 1994	4840	1400	80	522
09EB003	Indian River above the mouth	1982 - 1994	2220	770	6.31	90
09EA003	Klondike River above Bonanza Creek	1965 - 1994	7800	1040	63.1	255
09EA005	Little South Klondike River below Ross Creek	1983 - 1994	860	1190	7.07	259
09BB002	MacMillan River near the mouth	1984 - 1994	13800	1130	150	343
09DD004	McQuesten River near the mouth	1979 - 1994	4760 [1]	1030	36.9	245
09EA004	North Klondike River near the mouth	1974 - 1994	1100	1290	13.1	376
09BB001	South MacMillan River at km 407 Canol Road	1974 - 1994	997	1470	20.2	639
09DC003	Stewart River above Fraser Falls	1980 - 1994	30600	1240	383	395
09DC002	Stewart River at Mayo	1949 - 1979	31600	1230	370	370
09DD002	Stewart River at Stewart Crossing	1961 - 1973	35000	1210	415	374
09DD003	Stewart River at the mouth	1963 - 1994	51000	1090	469	290
DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT						
29DC001	Duncan Creek at Mayo Lake Road	1979 - 1982	228	1200	1.8	250 [2]

2870 → 400 km2

Notes:
1. Publications of the Water Survey of Canada show an incorrect catchment area for this station of 2870 km^2.
2. This station was operated on a seasonal basis and has a record with 7 complete months of streamflow data. These data were correlated with the observed flows at neighbouring streamflow gauging stations operated by the Water Survey of Canada. This correlation indicated Duncan Creek has a long-term average flow of approximately 1.8 m^3/s at the DIAND gauging site.

stations and the physical characteristics of the catchments which generated the streamflow. These empirical relationships then formed the basis for estimating flows at ungauged mine site streams (or, as was often the case with the UKHM mine site, streams with limited flow measurements).

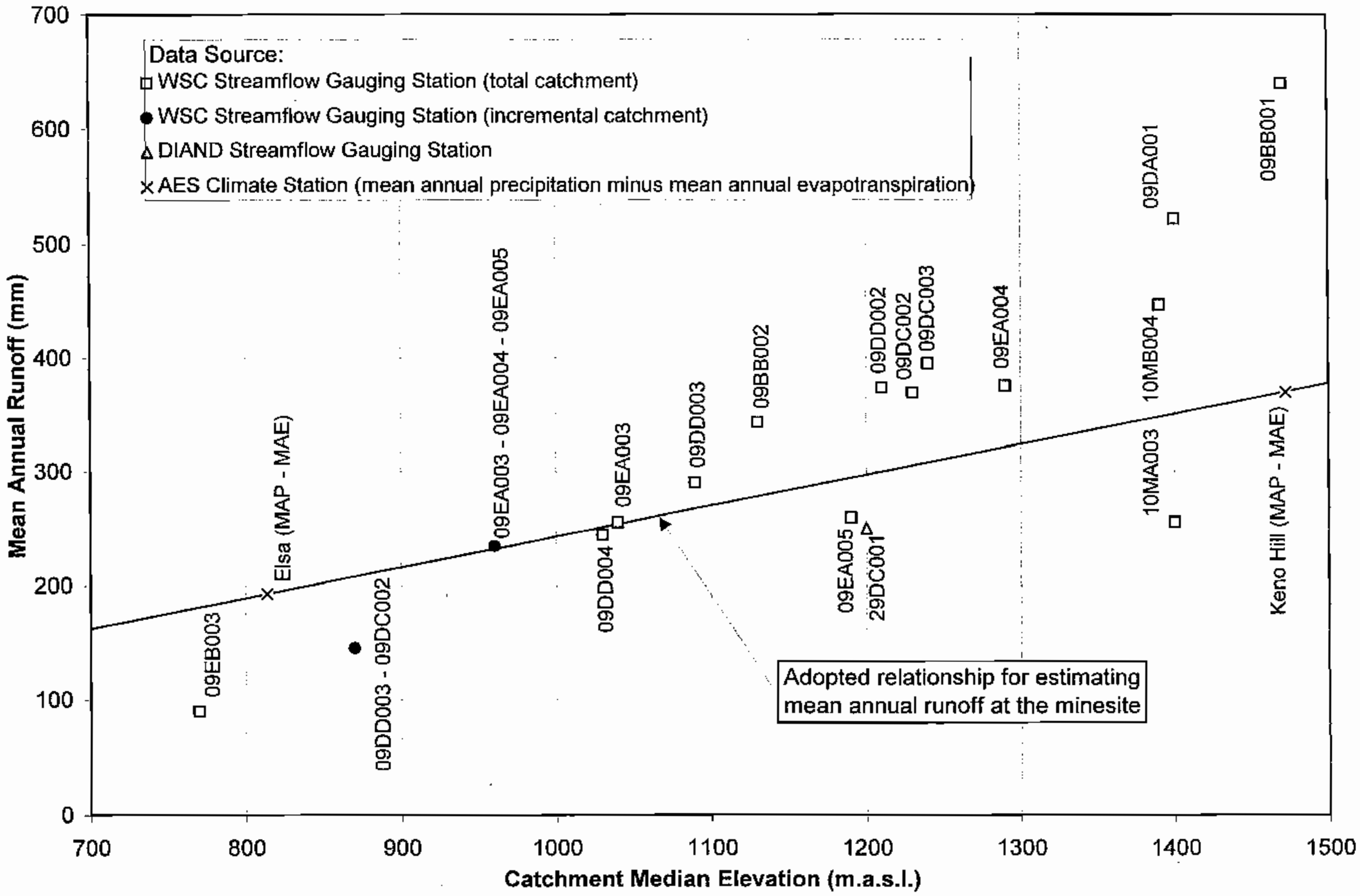
The subsections below describe the steps undertaken to apply the regional analysis to the mine site streams. Missing from these subsections is a discussion of how the site-specific data were used to validate flow estimates made by the regional analysis. In general, the measured flows at the mine site were found to closely match the estimated flows derived by regional analysis.

3.7.3 Mean Annual Runoff

As noted in Section 3.6.3, elevation generally accounts for a large proportion of the variation in mean annual precipitation within a mountainous region. It follows, therefore, that mean annual runoff (MAR) would also be a function of elevation. Figure 3-8 shows how this observation was used to estimate the average flows of the mine site streams. The vertical axis of this figure displays values of MAR expressed as equivalent depths of water. The horizontal axis, on the other hand, shows values of median elevation, which is the variable adopted to characterize the elevation characteristics of the regional and mine site catchments. The following sources of data were assembled to derive a relationship between these two variables for the study area:

- fifteen pairs of MAR and median elevation data provided by the WSC and DIAND stations listed in Table 3-6;
- two pairs of MAR and median elevation values provided by two incremental catchments monitored by the WSC (as explained below); and,
- two point estimates of unit runoff based on the climatic data presented in Section 3.5 (as also explained below).

Figure 3-8 Mean Annual Runoff as a Function of Elevation



Some preparatory work was required to assemble the first source of data. In all but one case, the MAR for the regional station was simply extracted from the agency's published streamflow records. For the one exceptional case, the gauging station was operated on a seasonal basis and, accordingly, a correlation had to be conducted to infill missing data so that the MAR could be estimated. Median elevations for all the stations were measured from topographic maps using a planimeter.

The second source of data is essentially a subset of the first. Where more than one streamflow gauge was located on a stream, it was possible to provide a set of MAR and median elevation values for the intervening catchment area between the gauges. For example, the runoff generated by the lower Stewart River watershed was quantified by subtracting the flows measured at Station 09DC002 from those at Station 09DD003. The median elevation of this incremental catchment was measured by examining only the area which lies between these two gauging stations.

The third source of information made use of climatic data to derive indirect estimates of runoff. Essentially, this was done by subtracting an estimate of average annual evapotranspiration from the average annual precipitation measured at each of the Elsa and Keno Hill climate stations. For example, the Keno Hill station has a MAP of 590 mm and an estimated average annual evapotranspiration of 200 mm. Subtraction of the evapotranspiration rate from the MAP suggests that the area in the immediate vicinity of the Keno Hill station generates an average of 390 mm of runoff per year.

Once all the data were assembled and processed, a curve was fitted to the data to develop a relationship which was believed to represent the conditions at the mine site. Fitting this curve was a somewhat subjective exercise, involving a comparison between the physical characteristics of the WSC and DIAND catchments with those of the mine site catchments. In addition, emphasis was placed on the point estimates of unit runoff derived from the climatic data. In the end, a straight line running through the two estimates provided by the climatic data was adopted to represent the conditions at the mine site. It is of interest to note that this line intersects the data point provided by the WSC station on the McQuesten River, which is of course the catchment which contains the mine site.

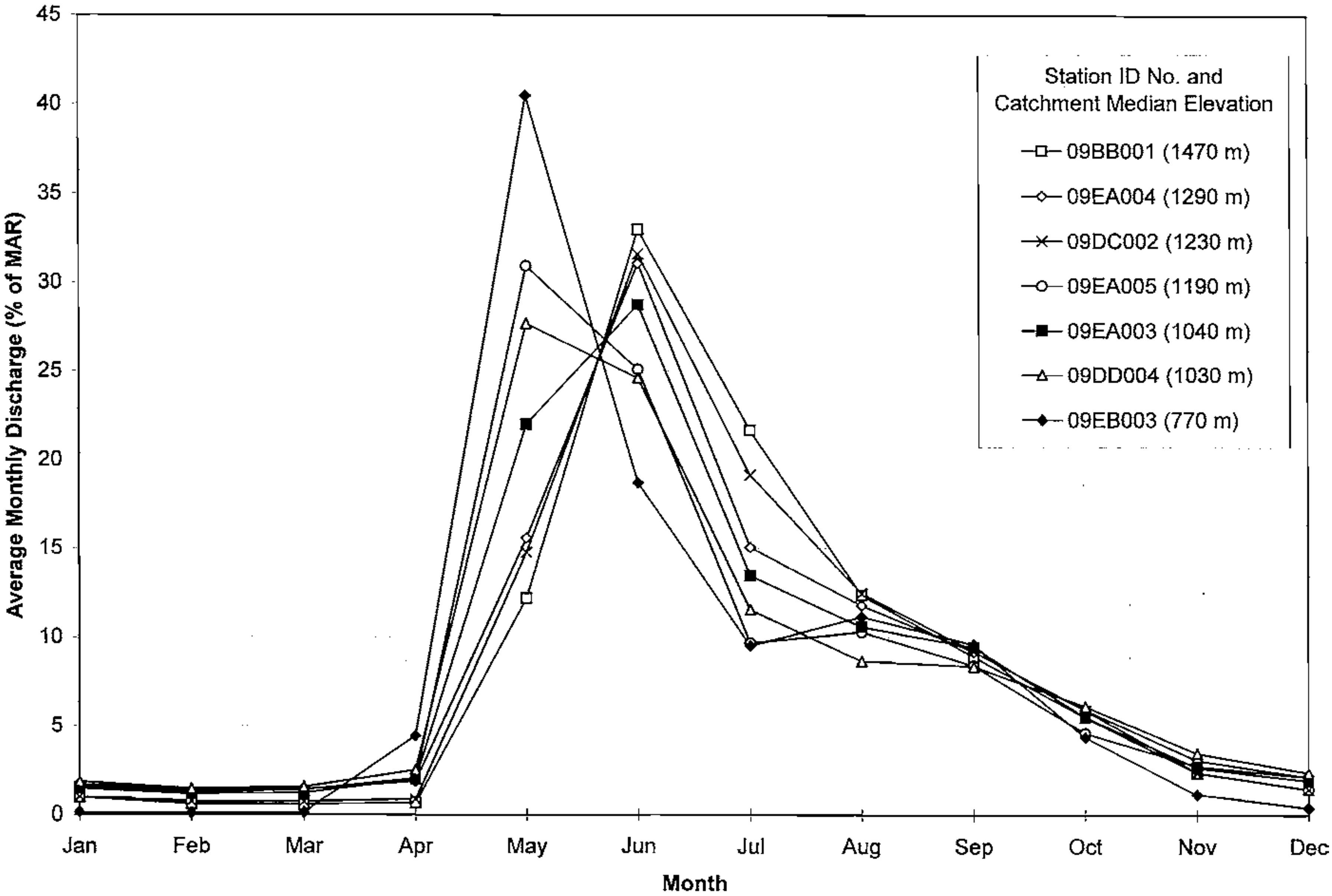
The relationship on Figure 3-8 was used to estimate the average flows on the mine site streams using the following four-step algorithm:

- a point of interest was defined and its catchment boundary outlined on a topographic map;
- using a planimeter, both the catchment area and catchment median elevation were measured;
- the curve on Figure 3-8 was entered at the appropriate value of median elevation and the corresponding unit MAR value was read from the graph's vertical axis; and,
- the product of unit MAR and measured catchment area was calculated to estimate the long-term average annual runoff volume for the point of interest.

3.7.4 Seasonal Runoff Distribution

The runoff pattern at the mine site was estimated by examining the average monthly hydrographs of regional gauging stations. Figure 3-9 graphically presents the monthly distributions, expressed as percentages of MAR, of seven regional stations. These stations were selected to illustrate the distributions from catchments with a broad range of physical characteristics. All distributions are characterized by high spring flows during snowmelt and low winter flows during prolonged freezing conditions. Examination of the distributions indicates median elevation is a reasonably good predictor of the shape of a stream's average monthly hydrograph. Two trends with median elevation are apparent. Firstly, the occurrence of the peak monthly flow is correlated with median elevation. As expected, low elevation catchments generally experience earlier peaks than high elevation catchments. Secondly, the relative magnitude of the winter base flow appears related to elevation. The relative magnitude of the base flow seems to increase as the median elevation increases from about 700 m to 1200 m. Above approximately 1200 m, the trend reverses.

Figure 3-9 Monthly Discharge (MAR)



A comparison between the physical characteristics of the mine site catchments and those of the WSC catchments indicated the McQuesten River (Station No. 09DD004) likely best represents the streamflow distributions of most of the mine site drainages. For some of the higher elevation catchments, such as Lightning Creek, the distribution for the North Klondike River may be more suitable.

3.8 Aquatic Resources

3.8.1 Benthic Invertebrates

The following sections summarize the benthic investigations in the Elsa area. The detailed report on the biological monitoring survey conducted at UKHM in 1994 is provided in Technical Appendix IV.

3.8.1.1 Review of Benthic Community Monitoring

According to licence number Y2S3-2014 effective August 1, 1980 to July 31, 1985 and licence number Y1N85-02RI effective September 26, 1985 to September 25, 1990, benthic fauna sampling was to be conducted by UKHM on an annual basis at four specified locations. These locations were:

- at Elsa Valley tailings decant (2DD-S1);
- Flat Creek upstream from South McQuesten River (2DD-S9);
- South McQuesten River upstream from Flat Creek; and,
- South McQuesten River downstream from Flat Creek (2DD-S11).

UKHM hired various consultants to carry out this program from 1986 to 1990 inclusive, but no mine sponsored invertebrate sampling was conducted from 1980 to 1985 (Northern Biomes Limited, 1986; Northern Biomes Limited, 1987; Leverton and Associates, 1988; Burns 1989; and Burns 1990) Environmental Protection Services carried out biological monitoring at these and other sites in the Elsa area, in 1975, 1985 and 1990 (Environmental Protection Services, 1978; Davidge & MacKenzie Grieve, 1989; and Environmental Protection Services, 1995). UKHM contracted Laberge Environmental Services (LES) in 1994 to carry out a biological monitoring program in the Elsa area.

All of the relevant benthic data from these surveys have been summarized and are presented in Table 3-7. The sampling method, using artificial substrate samplers, was consistent throughout these studies. When assessing benthic communities, usually abundance (total population), diversity (total number of taxonomic groups found at each site) and the composition of the community, are examined. For example, a healthy community found in clean waters would be comprised of many different types of organisms, many individuals would be present, and there would be representation of pollution sensitive species.

Invertebrate abundance has fluctuated over the years and this variance can be attributed to many natural factors such as climate, stream flow, life cycles of various organisms, timing of sampling, as well as the chemistry of the water. Diptera have generally been the dominant organisms throughout the years at all of the stations although species composition within the order Diptera was different between years.

The site on the South McQuesten River upstream of Christal Creek has been sampled for benthic invertebrates on four separate occasions (1975, 1985, 1990 and 1994). This location represents a true background site. The site on the South McQuesten River upstream of Flat Creek is not considered a background site for Flat Creek as this site is impacted further upstream by the Christal Creek drainage. Populations have decreased on the South McQuesten River upstream of Flat Creek from the upper South McQuesten site except for sampling done in 1975. The site on the South McQuesten downstream of Flat Creek is the old licence station 2DD-S11, which is located approximately 100 metres downstream of the confluence with Flat Creek. Some recovery of the benthic communities is noted here.

When compared with the South McQuesten River, two drainages show evidence of reduced taxa and individuals.

The site Christal Creek at the Keno Highway is impacted by Christal Lake which receives discharges from the Galkeno 900 adit. Populations are generally much lower here than in the South McQuesten River sites when compared on an annual basis.

TABLE 3-7 HISTORIC SUMMARY OF BENTHIC ANALYSES

Study & Year	EPS 1975	EPS 1985	N. BIOMES 1986	N. BIOMES 1987	Leverton 1988	Burns 1989	Burns 1990	EPS 1990	LES 1994
S. MCQUESTEN R U/S CHRISTAL CR									
Total # of individuals	357	683						6876	17557
Total taxa	21	26						62	46
Dominance and %	D 81.8	D 76.3						D 86.6	D 89.6
CHRISTAL CR @ KENO RD CROSSING									
Total # of individuals	197	655						496	2478
Total taxa	16	31						41	46
Dominance and %	D 77.7	D 74.2						D 40.7 P 34.7	D 48.3 O 36.3
S. MCQUESTEN R U/S FLAT CR									
Total # of individuals	1129	140	1370	1955	551	996	3516	285	5016
Total taxa	24	20	46	43	36	39	55	41	40
Dominance and %	D 87.9	D 32.9 P 25.7	D 67.9	D 74.4	D 44.5	D 43.9 P 28.0	D 89.4	D 28.4 P 26.3	D 67.5
FLAT CR U/S S. MCQUESTEN R									
Total # of individuals	8	95	3343	1976	282	33	143	166	991
Total taxa	5	14	22	26	20	10	12	24	36
Dominance and %	D 62.5	D 42.1 P 41.1	D 80.7	P 59.4 D 36.2	D 50.3 P 42.2	D 51.5 P 36.4	P 72.7	H 46.4 P 31.3	O 53.7 D 36.6
S. MCQUESTEN R D/S FLAT CR									
Total # of individuals	4390	1492	2056	775	740	636	841	755	13053
Total taxa	15	25	34	37	35	20	45	42	48
Dominance and %	D 98.5	D 92.8	D 64.1 E 21.2	D 46.5 E 22.2	D 40.6 E 27.7	P 75.6	D 71.2	D 58.8	D 89.9

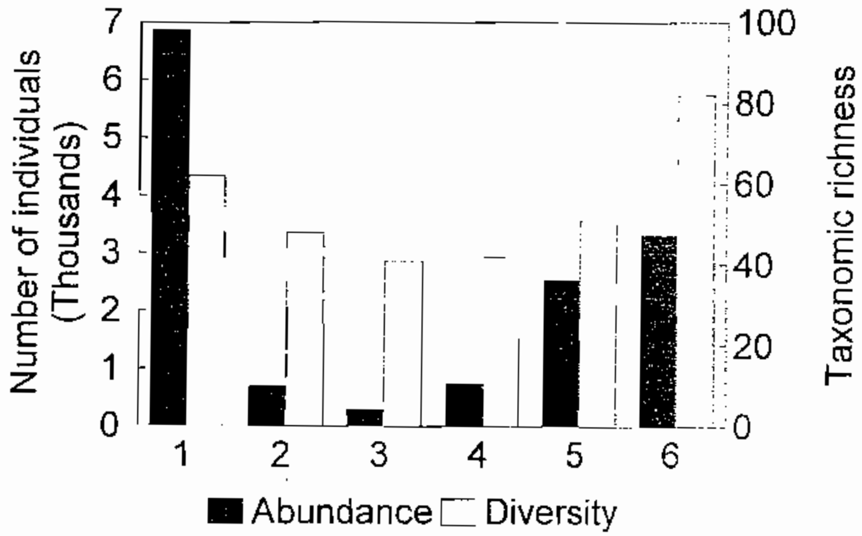
D = Diptera
P = Plectoptera
O = Oligochaeta
H = Homoptera
E = Ephermoptera

The site on Flat Creek receives mine drainage waters from the main tailings ponds. Generally, the lowest populations were observed here. Flat Creek has been impacted from a previous tailings dam failure.

Environment Protection, in 1990, also sampled the benthic communities in the South McQuesten River, nine and 27 kilometres downstream of the Flat Creek confluence. Their data, reproduced below, shows that both abundance and diversity decrease after the confluence with Christal Creek, however, the sites start to recover downstream of Flat Creek and continue to improve to the site 27 kilometres downstream of Flat Creek (Environment Canada, 1995). Specifically the sites sampled were:

1. South McQuesten River approximately 1.5 kilometres upstream of Christal Creek;
2. South McQuesten River at the pumphouse (2DD-S10), approximately 6 kilometres downstream of Christal Creek;
3. South McQuesten River approximately 15 metres upstream of Flat Creek;
4. South McQuesten River approximately 2 kilometres downstream of Flat Creek;
5. South McQuesten River approximately 9 kilometres downstream of Flat Creek; and,
6. South McQuesten River approximately 27 kilometres downstream of Flat Creek.

ABUNDANCE AND DIVERSITY
on the South McQuesten River, 1990



3.8.1.2 Benthic Communities in 1994

A biological monitoring survey was done in the Elsa area on Flat Creek, Christal Creek and the South McQuesten River in the field season of 1994. A total of seven sites were sampled. These sites correspond to the water quality stations LES 1, 3, 4, 5, 6, 7 and 9.

Populations at all of the sites, especially those in the South McQuesten River, were very high compared to other years. This may be partially due to the hot dry summer experienced in this area in 1994, which could have increased productivity in these waters. Both the Flat Creek and Christal Creek drainages also reported improved community abundance and diversity.

The 1994 data are examined in detail in Technical Appendix IV.

3.8.1.3 Summary

There appears to be a general trend of increased recovery in the benthic communities as one progresses further downstream on the South McQuesten River from the Christal Creek and Flat Creek confluences. The Flat Creek and Christal Creek drainages are the most impacted drainages in terms of benthic communities. This data correlates well with water quality and metal loadings data collected at these sites.

It appears that the benthic populations have improved at most of the sites over the past few years, based on diversity and abundance data. However, many variables can contribute to benthic community diversity and abundance including climatic and flow conditions, time of season sampled and the life cycles of the various organisms, disturbance of the substrate by anthropogenic or natural sources, and the quality of the water and the stream sediments. It is not possible to accurately state whether any of these or other factors may have played a role in the general enhancement of the benthic communities.

3.8.2 Fisheries

3.8.2.1 Introduction

White Mountain Environmental Consulting (WMEC) conducted fisheries investigations in the waters influenced by mining near United Keno Hill Mines property at Elsa, Yukon between August of 1994 and August of 1995. The following discussion summarizes the results of these investigations. The detailed report is provided in Technical Appendix V.

The goal of these preliminary investigations was to obtain current data in order to assess habitat availability and utilization. Comprehensive studies on the fish resources in this area had not been conducted previous to this investigation. The only other information was reports of fish occurrence from DFO files.

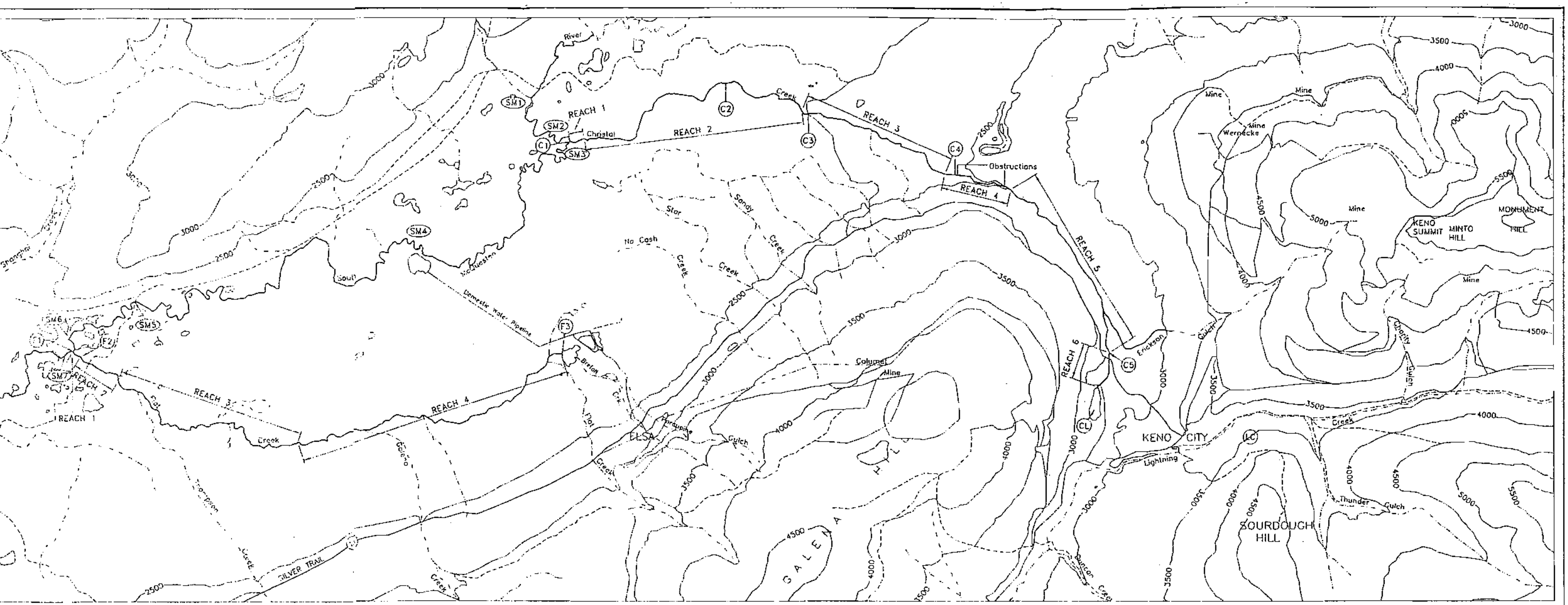
3.8.2.2 Study Area

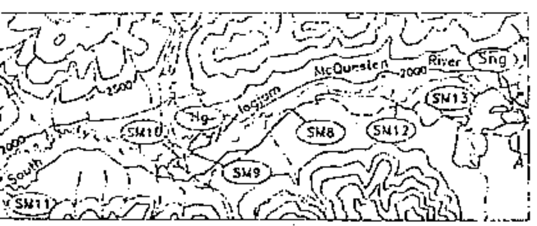
The principal areas of study for this investigation were the drainages influenced by historic and current mining activities, as shown in Figure 3-10. Benthic invertebrate and water quality data assisted in determining these drainages for fisheries investigations. These include Christal Creek, Flat Creek and the receiving waters of the South McQuesten River. Lightning Creek in the Mayo River drainage was also investigated.

Christal Creek was investigated from Christal Lake to its mouth at the South McQuesten River. Flat Creek was investigated from the point immediately below UKHM's settling ponds to its mouth at the South McQuesten River. The South McQuesten River was investigated from McQuesten Lake to Seattle Creek. Investigations into Lightning Creek were restricted to a reach that extended from 350 m upstream of the outlet of Thunder Gulch to the confluence with Duncan Creek.

3.8.2.3 Methods

Fish habitat and utilization assessments on the South McQuesten River, Flat Creek, Christal Creek, Christal Lake and Lightning Creek were conducted at three different seasonal periods to provide a representation of spring, summer and fall utilization.





SCALE: 1 : 250 000

Match line

LEGEND

Creek, river, waterbody

Territorial Highway
Secondary road
Trail

Study creek

Sample site

Elevation contour interval - 500 feet

0 1000 2000 3000
METRES

UTM GRID NORTH

UNITED KENO HILL MINES LIMITED

1994-95 UKHM FISHERIES INVESTIGATIONS
WHITE MOUNTAIN ENVIRONMENTAL SERVICES

ACCESS MINING CONSULTANTS LTD.

SCALE: 1 : 50 000	FILE: 224_2.DWG	DATE: 30/05/96
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Fall work was conducted between September 13 and 16, 1994. Spring investigations included two separate periods of investigation. The first period ran from May 19 to 23, 1995, and the second period from to June 1 to 4, 1995. Summer investigations were conducted between July 14 and 21, 1995.

Habitat assessments were conducted by walking the length of each creek and recording the general characteristics of each reach of creek. Mapping habitat types, included an assessment of; depth, flow, velocity, bottom substrates, terrestrial and aquatic vegetation, bank stability and structure, and channel configuration. Anomalies and obstructions were also recorded.

Sampling for utilization was conducted at selected locations on each drainage. The mouths of both Flat and Christal were intensively investigated as were two other sites on Flat Creek and 4 other sites on Christal Creek. Christal Lake was also investigated. A total of 14 sites on the South McQuesten were sampled intensively. These included assessments above the influence of Christal Creek, between Christal and Flat Creeks and at three sites below the mouth of Flat Creek (Figure 3-10).

Most of the utilization assessments included repeat sampling four to seven days after the original sampling during all three sample periods. This was done in order to address a concern raised by DFO relating to the tendencies of many of the fish in these areas to school.

A variety of techniques were used during the investigations to determine the presence and abundance of fishes; these were; seine nets, electro-shocker, gill nets, angling, surber sampling, visual observations, and two different types of minnow trap baiting.

3.8.2.4 Summary of Findings

The South McQuesten River and its tributaries Christal and Flat Creeks contain a wide variety of fish habitats and fish species typical of those found in the Yukon River drainage. In total 5,316 fish were recorded during the course of this study representing a total of 11 different species, including; Arctic grayling, slimy sculpin, round whitefish, northern pike, Arctic lamprey, chinook salmon, burbot, long nose sucker, least cisco and lake chub.

Slimy sculpins were the most widely dispersed species in the study area, and Arctic grayling were the most abundant. Both grayling and longnose sucker fry were typically encountered in groups or schools. Chinook salmon fry were found in the South McQuesten River, but not above the mouth of Haggart Creek. The extent of chinook utilization of the South McQuesten River is poorly understood Other species recorded were found in small numbers, usually as individuals and in specific habitats.

The mouths of clear water tributaries were found to play an important role as rearing habitat. This may be because the tributaries provide a source of oxygenated water, nutrients and cover from larger predatory fish. The mouths of both Christal and Flat Creeks exemplify this situation and were shown to be important rearing areas for Arctic grayling fry.

Flat Creek

Flat Creek was divided into five reaches, four of these were studied. The lowest reach within 40 meters of the South McQuesten River offers the best available habitat on Flat Creek. This reach has predominantly cobble gravel substrates with pool riffle sequences. Above this reach the channel flows through a reach with heavy willow and alder growth which forms a canopy cover over much of the creek. A 4,000 meter reach above this flows through mature forest, with steam substrates comprised mostly of gravel, sand and silt. Open pools and riffles offer some fish habitat, however this type of habitat is dispersed and infrequent. Above the forested reach, Flat Creek flows for five km through an open wetland to just below UKHM's tailings pond. This reach offers very little in the way of fish habitat, substrates consist entirely of silts (possibly old tailings from early mine works) and the narrow deep channels offer poor cover.

Utilization of Flat Creek was restricted to the lowest 400 meters of the creek. The lowest 40 meters, the mouth area, was utilized extensively by grayling fry and to a lesser degree by sculpins, northern pike and burbot. A single grayling fry was found 350 meters upstream of the mouth and a single sculpin was captured 470 meters up from the mouth in a small pool created by an old bridge. No fish were observed or captured above this point.

Christal Creek

Christal Creek has a variety of habitats throughout its 15 km reach. The lower reach consists of a mix of gravel bottomed runs, riffles and silt bottomed deep pools, a narrow channel with well defined banks and several beaver ponds. The mid reach area has gravel bottomed riffle, run, pool sequences with fast flowing waters. The upper reaches have both steep sided canyons with large boulders and more gentle sloped meandering stretches with gravel bottoms. A canyon area in the mid reach of the creek has two bridges that have partly collapsed and created barriers to fish passage into the upper reach of the creek. A small pool near the confluence with the South McQuesten River provides important habitat.

Fine solids, thought to be tailings transported from Christal Lake area during the 1950's can be seen in the bottom substrate of the creek at various places. Tailings migration into the creek resulted in a "hard pan" layer in most of the creek. Over time this layer has been broken up by ice action and currently exists as remnants along the creeks length and creek substrates have mostly returned to a natural state.

Juvenile Arctic grayling, burbot and slimy sculpins were found in the lowest reaches adjacent to the South McQuesten River. During summer and fall adult Arctic grayling were found utilizing larger pool areas as far up stream as the obstruction below the canyon. Results indicated that adult grayling do not overwinter in Christal Creek, however individuals may become trapped behind beaver dams, and forced to overwinter.

Significant numbers of grayling fry were found utilizing the mouth of Christal Creek during the summer and fall, although the extent of this utilization was limited to within 30 meters of the mouth. Several fry were observed 2 km upstream of the mouth and a single fry was captured near the Hanson Lake Road. Slimy sculpins were the only fish found above the canyon and the obstructions, but were not abundant.

Christal Creek has many areas of good habitat above the canyon that did not appear to be utilized.

Christal Lake

Christal Lake a small, shallow, sub-alpine lake has an organic silt bottom overlaying a heavy tailings sludge. The tailings were likely placed in the lake during the later part of the 1950's, when a grizzly mill was located on the east side of the lake. Reports of tailings deposition into Christal Lake have not been confirmed.

Several large adult slimy sculpin (18 grams) were captured from the lake. No other fish species were encountered in Christal Lake.

South McQuesten River

This river system contains a wide variety of fish habitats and fish species typical of those found elsewhere in the Yukon River drainage. A variety of flow regimes occur along the river in the study area, the most predominant being gravel bottomed riffle/ glide areas followed by deep, often silted pools.

Fish were encountered at all sites sampled on the South McQuesten River. All species recorded were found utilizing the South McQuesten River. Most species occurred at all sample sites. The exceptions were least cisco found only at the outlet of McQuesten Lake, lake chubb found only upstream of Christal Creek, and chinook salmon which were not found upstream of the confluence with Haggart Creek.

Lightning Creek

The reach of Lightning Creek surveyed extends from a point just below the town site of Keno City, then upstream to a point approximately 200 meters above the influence of Thunder Gulch, which is placer mined. Typical of creeks with placer mining influence, adult Arctic grayling were found upstream of the influence of turbid water from Thunder Gulch and sub-adult Arctic grayling were encountered in the turbid waters below the influence of Thunder Gulch.

3.8.2.5 Heavy Metal Fish Samples

Samples of fish from Flat Creek, Christal Creek, and the McQuesten River upstream of the confluence with Christal Creek were sent to Quanta Trace Labs for analysis of heavy metal content, a total of 57 metals were sampled for. The results of these analysis showed that some samples from this area had elevated zinc levels in comparison to fish from other locations in the Yukon. For comparison purposes, Table 3-8 summarizes metals data from this study, while Table 3-9 summarizes fish metals data from other areas in the Yukon. These tables are also contained in Technical Appendix V, (Table 9 and Table 11), but have been converted to express all results in wet weights. It should be noted in reviewing the tissue metals data that metals levels in sculpin or arctic grayling are not reported in Table 3-9. Table 3-9 provides an indication of fish tissue metal levels from selected lakes around the territory.

The highest levels of metals were found in a slimy sculpin taken from Christal Creek near the Keno Road crossing (187.06 μg/g wet weight). Sculpins from Christal Lake had the next highest levels of metals (91.8 μg/g wet weight). Slimy sculpin are bottom dwelling fish feeding mainly on aquatic insert larvae. This fish species is not harvested commercially.

Grayling taken from Christal Creek below the canyon had levels higher than those from fish taken in Flat Creek and the South McQuesten River. Samples collected from South McQuesten River fish above the influence of Christal Creek had the lowest levels of any of the fish analyzed during this investigation.

Studies have shown that Arctic grayling will avoid waters with high zinc levels. It appears that arctic grayling captured from Christal Creek do not show this behaviour. These fish may have developed a tolerance to zinc. Chronic effects on fish from exposure to zinc is unclear at present.

Table 3-8 Metal levels (ug/g wet weight) recorded from fish tissues, Sept. 1994.

Location	Sample	Description	Zn	Cu	Pb	As	Cd	Cr	Co	Hg	Ni	Moisture
Christal Ck	CDS 1	muscle	35.39	0.43	0.27	0.53	0.02	0.27	0.11	0.03	0.11	73.39
	CDS 2	muscle	31.83	0.45	0.25	0.51	0.02	0.25	0.03	0.03	0.61	74.74
	CDS 3	muscle	36.07	0.42	0.26	0.52	0.04	0.26	0.08	0.03	0.16	73.86
replicate	CDS 4	muscle	54.38	0.24	0.47	0.47	0.05	0.42	0.09	0.02	0.19	76.46
	CDS 4	muscle	51.55	0.24	0.47	0.47	0.04	0.33	0.07	0.02	0.21	76.46
	CDS 5	muscle	29.65	0.36	0.26	0.51	0.02	0.23	0.05	0.03	0.15	74.44
	CC1	whole fish	72.54	0.73	1.00	1.00	0.32	0.23	0.03	0.03	0.25	74.90
	CC2	whole fish	41.35	0.96	0.51	0.51	0.13	0.18	0.05	0.03	0.10	74.63
	CC3	whole fish	187.06	1.34	14.91	3.95	1.03	0.68	0.18	0.02	1.10	78.07
	CC4	whole fish	78.07	0.55	2.16	1.44	0.23	0.31	0.14	0.02	0.60	75.98
Christal Lk	CLk1	whole fish	78.51	0.44	0.24	0.97	0.04	0.22	0.10	0.02	0.24	75.77
	CLk2	whole fish	76.43	0.54	0.24	0.97	0.05	0.22	0.07	0.02	0.34	75.66
	CLk3	whole fish	91.04	0.60	0.25	1.01	0.08	0.23	0.10	0.03	0.40	74.85
replicate	CLk3	whole fish	91.80	0.60	0.25	0.75	0.07	0.25	0.13	0.03	0.38	74.85
	CLk4	whole fish	78.44	0.62	0.46	1.15	0.07	0.21	0.09	0.02	0.23	76.93
S. McQuest	SMR1	muscle	19.32	0.45	0.24	0.47	0.02	0.19	0.02	0.05	0.09	76.35
	SMR2	muscle	21.41	0.56	0.25	0.51	0.03	0.23	0.05	0.03	0.15	74.72
	SRM3	muscle	30.23	0.60	0.25	0.50	0.07	0.25	0.07	0.05	0.15	75.02
	SRM4	muscle	29.40	0.65	0.48	0.48	0.06	0.24	0.05	0.02	0.12	75.90
	SRM5	muscle	22.51	0.60	0.24	0.48	0.02	0.21	0.10	0.02	1.07	76.13
Flat Creek	FCk1	whole fish	48.03	1.14	5.69	0.74	0.25	0.25	0.02	0.02	0.15	75.24
	FCk2	whole fish	63.39	1.18	9.36	0.72	0.36	0.24	0.02	0.02	0.24	75.99
	FCk3	whole fish	63.83	1.69	13.26	1.72	0.44	0.29	0.05	0.02	0.22	75.45
	FCk4	whole fish	76.69	3.47	29.39	3.47	0.59	0.32	0.05	0.03	0.21	73.28
	FCk5	whole fish	46.36	1.14	6.20	1.24	0.25	0.25	0.02	0.02	0.15	75.21
	FCk6	whole fish	37.76	1.06	3.09	0.66	0.18	0.20	0.04	0.02	0.18	77.92
Christal Ck	CDS 1-5	liver composite	34.30	4.75	0.27	0.54	2.54	0.11	0.35	0.03	0.14	72.99
	CDS 1-5	liver replicate	36.46	4.94	0.27	0.54	2.64	0.11	0.35	0.03	0.14	72.99
S.McQuest	SMR 1,2,5	liver composite	28.17	3.90	1.12	0.84	0.73	0.14	0.56	0.03	0.47	72.11

Table 3-9. Heavy metal levels found in fish from selected Yukon locations. Mean concentration of metals expressed as ug/g wet weight.

Location	Date	Species	Sample Description	Cu	As	Zn	Pb	Cd	Cr	Co	Hg	Ni
Mayo Lake	1990/91	lake trout	liver	23.36	1.21	41.0	nd	0.12	nd	2.67	0.15	nd
			muscle	0.20	nd	11.7	nd	0.03	nd	0.08	0.11	nd
		Northern Pike	liver	10.50	0.80	42.5	nd	0.10	0.045	0.85	0.05	nd
			muscle	0.25	0.74	6.1	nd	0.07	0.069	0.07	0.11	nd
		lake whitefish	liver	10.23	0.71	27.7	nd	0.19	0.07	0.98	0.12	nd
			muscle	0.14	1.59	16.0	nd	0.03	nd	0.091	0.06	nd
		burbot	liver	5.75	nd	17.3	nd	0.05	nd	0.50	0.03	nd
			muscle	0.205	0.75	4.3	0.75	0.0007	0.10	0.14	0.11	nd
Wareham Lake	1995	Whitefish	liver	8.88	-	31.8	nd	0.30	-	-	0.07	-
			muscle	0.32	-	33.2	nd	0.0035	-	-	0.04	-
		Northern Pike	liver	10.95	-	40.5	nd	0.12	-	-	0.04	-
			muscle	0.19	-	16.1	nd	0.006	-	-	0.11	-
Aishihik Lake	1990/91	lake trout	liver	10.15	0.88	4.5	0.42	0.13	10.1	0.07	0.11	0.06
			muscle	1.05	0.93	11.7	nd	nd	1.05	nd	0.09	nd
		Northern Pike	liver	6.93	0.88	66.6	0.74	0.07	0.24	0.05	0.11	0.09
			muscle	0.59	nd	10.8	0.09	nd	0.13	nd	0.13	nd
		lake whitefish	liver	15.16	1.10	35.4	0.59	0.19	0.19	0.07	0.08	0.06
			muscle	0.61	0.67	7.3	nd	0.01	0.08	nd	0.04	nd

nd = non-detectable
- = not reported

Data compiled from report entitled "Survey of Metal Contaminants in Fish Species from Aishihik, Canyon, Kloo, Mayo, Sekulmun, Tatlmain and Wareham Lakes, Yukon Territory 1990-1995". Fish and Wildlife Branch, Department of Renewable Resources, Whitehorse, Yukon, April 1996. Internal report.

3.8.3 Stream Sediments

3.8.3.1 Methods

Composite sediment samples were collected in July 1994 from each of the sites listed in Table 3-10. Sample sites were selected from an exposed area of the stream bank, generally characterized by the finest grain size evident at the site. All samples were of recently actively transported stream bed load. Samples were collected with a stainless steel trowel and placed in zip-lock plastic bags. The samples were packed on ice when shipped to Quanta Trace Laboratories in B.C.

The samples were dried, passed through a 100 mesh (0.15 mm) stainless steel sieve, and then run through an ICAP analysis to determine total metals levels, using methods found in *Standard Methods for the Examination of Water and Wastewater 17th Edition* (Clesceri et. al., 1989) and U.S. EPA protocols found in *Test Methods for Evaluating Solid Waste, Physical Chemical Method, SW846*.

3.8.3.2 Results

The stream sediment samples were analyzed for 33 metals. These data are presented in Appendix IV. Table 3-10 presents data from the seven receiving water sites in the South McQuesten River, Flat Creek and Christal Creek for the five metals, arsenic, cadmium, copper, lead and zinc. These metals were selected because of their likely occurrence in the area as well as their potential for toxicity to aquatic life.

Since the study area lies within an area of mineralization, it is not surprising that the background site (Station 1 on the South McQuesten River upstream of Christal Creek) is relatively high in all these metals with the exception of lead. The remaining samples suggest that there has been considerable transport of metal into streams of the district as the levels are many times background. It seems likely that this metal was transported as particulate matter rather than precipitated from the water column since lead is elevated to levels nearly half that of zinc. The very high metal levels in Flat Creek suggests the presence of tailings as there have been many instances of tailings loss to Flat Creek reported over the years.

Table 3-10 Stream Sediment Metal Concentrations For Selected Metals

STATION NUMBER	STATION DESCRIPTION	ARSENIC (ug/g)	CADMIUM (ug/g)	COPPER (ug/g)	LEAD (ug/g)	ZINC (ug/g)
1	S. McQuesten R. u/s Christal Cr	18	1.6	22.4	10	310
3	S. McQuesten R. u/s Flat Cr	210	17.00	49.4	1100	1610
4	S. McQuesten R. d/s Flat Cr (S-11)	166	18.5	41.9	980	1640
5	S. McQuesten R. d/s 9 km d/s Flat Cr	116	8.6	29.2	344	1150
6	Christal Cr @ Keno Hwy (S-18)	128	15.2	34.5	260	2090
7	Christal Cr @ Hanson Road (S-19)	174	12.4	27.9	680	1950
9	Flat Cr u/s S. McQuesten R (S-9)	395	51.3	116	4520	5180

Sediment samples were collected at these seven sites in 1985 and 1990 by Environment Protection of Whitehorse. Table 3-11 and Figures 3-11 and 3-12 show a comparison of these data with the 1994 data collected for this study. The results suggest that the increasing trend in metal content at several sample sites between 1985 and 1990 may have reversed itself or may not have been a meaningful trend at all. The metal content of stream sediments appears to be slowly decreasing however the trends are inconsistent. The high levels of metal in Christal Creek and the South McQuesten River were noted in the early 1960's sediment survey of the area by the Geological Survey of Canada. While levels are lower now, it appears that high metal levels in sediments will be present for many years to come.

Table 3-11 Comparisons Of Metals In Stream Sediments From 1985, 1990 And 1994 At UKHM

STATION NUMBER		CADMIUM (mg/kg)			COPPER (mg/kg)			LEAD (mg/kg)			ZINC (mg/kg)		
		1985	1990	1994	1985	1990	1994	1985	1990	1994	1985	1990	1994
	upstream												
1	S. McQuesten R. u/s Christal Cr	0.7	5.7	1.6	23.9	22.3	22.4	24	22	10	169	212	310
3	S. McQuesten R. u/s Flat Cr	29.1	21.4	17.0	35.8	40.1	49.4	877	791	1,100	1,830	1,220	1,610
4	S. McQuesten R. d/s Flat Cr (S-11)	62.8	20.6	18.5	116.6	51.7	41.9	3,723	1,110	980	3,380	1,490	1,640
5	S. McQuesten R. d/s 9 km d/s Flat Cr	8.9	17.0	8.6	50.6	48.2	29.2	242	493	344	642	1,082	1,150
	downstream												
6	Christal Cr @ Keno Hwy (S-18)	12.5	32.2	15.2	43.1	39.6	34.5	149	86	260	2,323	8,967	2,090
7	Christal Cr @ Hanson Road (S-19)	96.3	53.9	12.4	93.4	50.5	27.9	4,040	1,088	680	6,097	10,400	1,950
9	Flat Cr u/s S. McQuesten R (S-9)	103.5	130.7	51.3	161.3	171.3	116.0	5,063	4,580	4,520	6,533	9,247	5,180

Note: Values for 1985 and 1990 and the mean for triplicate samples, the values for 1994 are for one composite sample.

Figure 3-11

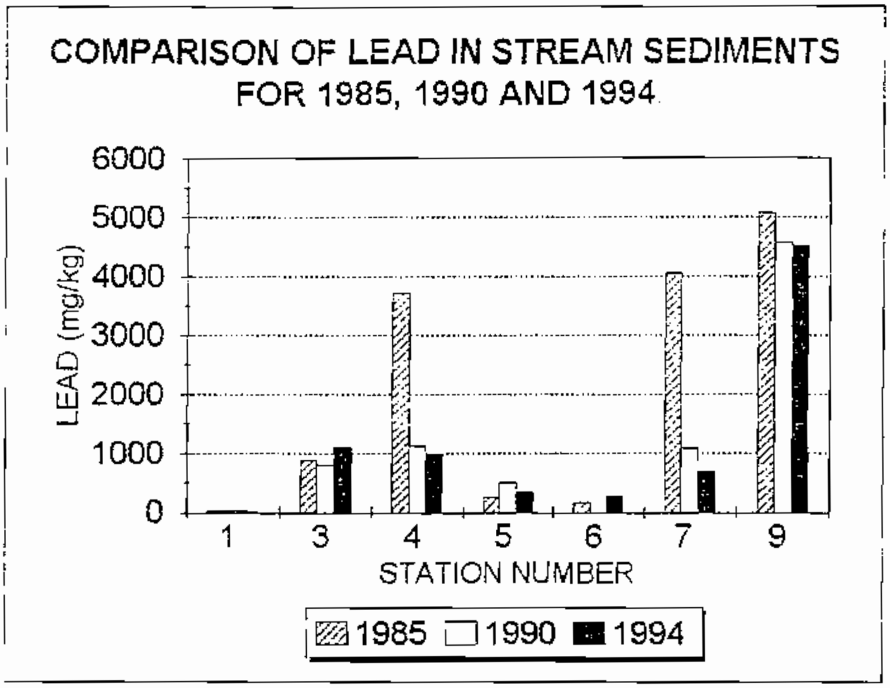
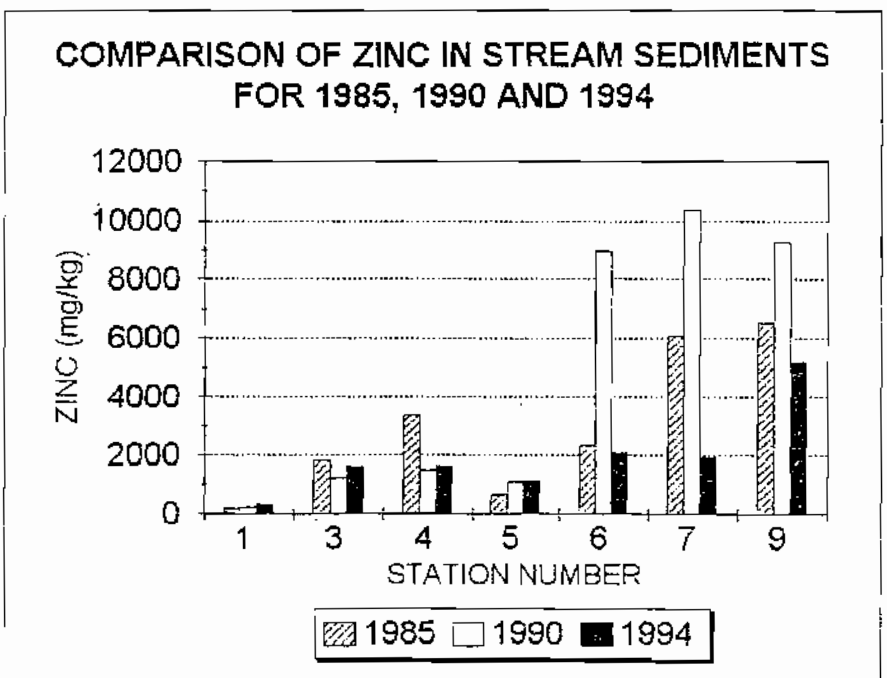


Figure 3-12



4. Land Use and Socio-Economic

4.1 Regional Land Use

The Elsa Keno Hill area has a long history of occupation and development. The area has seen significant increases in local population as a result of mining activities in the area. Additional infrastructure, services and residential development followed with this population influx.

Historically:

- the area has been utilized by first nations for centuries;
- a variety of anthropogenic activities have occurred throughout the region including both hardrock and placer mining, forestry, hunting, transportation, recreation and residential;
- a total of 5 trapline concessions fall entirely or partially within the regional area; and,
- the area has potential for significant tourism development.

Today the hamlets of Elsa and Keno City are much smaller than they were historically and no major population influx is expected in these communities. The maintenance of a dedicated community to support mining activity is now considered inappropriate for a mining company. Any increase in development activity could impact on the community of Mayo which is now considered the major population center for the area.

Increased human activity in the area may have negatively impacted local trapping concessions in the area. This is not considered a long term impact as local community populations have been reduced. Continued efforts to improve wildlife habitat will also improve trapping efforts.

The region once supported numerous small scale logging operations mainly to provide timber for mine development. Local estimates for timber use in underground developments border near 5 million board feet. The potential for further logging exists as the area has regenerated well over the years.

It is also expected that the area will continue to see an increase in both tourism and recreational potential. The local tourism association is actively pursuing options for development in these area. The remnants of past mining activities could enhance some of these initiatives in this regard.

4.2 Impacts on Local Community

The study area has been the focus of intensive and wide spread mining and mining related activities for the past eighty or so years. Consequently, the intervening years can be characterized as a time when mining and related activities have replaced virtually all other activities in the area. Thus, the area is seen as having a low potential for the establishment of traditional aboriginal uses. Similarly, and in spite of the fact that there will be an effort to improve the general quality of the area, it is extremely unlikely that any interest will be developed in the establishment of outfitter or hunting and fishing camps in the area. Currently, the land use is primarily for trapping and hunting by members of the local community.

With the shutdown of the mining operations in the 1980's, there was a rapid decrease in the population of the Hamlet of Elsa, its housing stock, and much of the domestic infrastructure that was in place when the community flourished. Road access to Keno City has not changed, nor has the power and other services to Keno City. Road access to the workings on Galena Hill, Sourdough Hill and Keno Hill is currently maintained as required and such access for other legitimate mining interests should not be impaired. Access for potential users of other resources in the area such as forestry, recreation, and the like, is available since all access through the property to Keno City and beyond, or to the Hanson Lakes and beyond, is on government roads.

4.3 Public Consultation

UKHM enjoys a long, cordial and productive relationship with local communities and residents. This relationship is characterized by the on-going contact between UKHM and locals. For example, UKHM has had many visits from locals over the past number of years and has conducted tours for locals, including the First Nation specifically related to the development of the abandonment of the plan. As well, UKHM has had tours for members of the Water Board and for members of the Regional Environmental Review Committee.

Over the past several years, UKHM has had numerous meetings with the Na Cho Nyak Dun, the Council of Mayo, members of the District Renewable Resources Council and many others. The status of the mine and the abandonment plan has been the focus of discussion at the Technical Advisory Group; a group called together by UKHM and involving the Na Cho Nyak Dun, the Regional Environmental Review Committee and technical representatives of both governments.

5. Site Description

5.1 General Description

The UKHM property covers an area of approximately 9500 ha in an east-west trending belt 19 km long and 5 km wide (Figure 2-2). The property includes a mining and milling complex with a long history of operation involving various owners. The general nature of the district has already been presented in Chapter 3. This chapter looks at the individual components of the property, e.g. the individual mines, mill sites, tailings sites, in more detail.

Considerable effort has been made to concisely present a great deal of information about a variety of localities. A series of tables for each component outlines history, quantities of ore production, waste type, and waste rock quantity, etc. Each component is shown graphically in a series of line maps made from air photographs flown in 1995 specifically for this project. The location of each of these detailed line maps is shown on Figure 5-1. In addition to the site plans in this Chapter, there are cross and longitudinal sections of the mines. Some of these may not be completely up to date, but illustrate the sites well. The drawings will be of considerable help to the reader in forming an impression of the extent of underground and open pit development in this historic mining district.

Each subsection that follows is arranged with a short introductory text, a summary table, and the overview plan. These sections are arranged first by “hill”; Galena Hill, Sourdough Hill, and Keno Hill; then alphabetically by site name on each hill. Table 5-1 summarizes the development on each hill.

Appendix B of UKHM’s 1990 Abandonment Plan, namely Environmental and Stability Assessment of Dumps and Tailings by Trimble and Watson (1968) was the source of some of the information compiled herein. That document contains an excellent series of photographs, many of which are still relevant. It may be helpful to look at that document in conjunction with this Chapter.

The bulk of the information was gathered from current and former employees of UKHM whose co-operation was essential, freely given, and most appreciated.

Table 5-1 in conjunction with Figures 5-2 a, b and 5-3 a, b, and c present an overview of the mining developments and associated waste rock deposits in the camp. Figure 5-2 a and b show graphically total ore tonnage mined and the open pit ore tonnage respectively mined at each site described in the following sections. Figures 5-3 a, b, and c show graphically the sizes of rock waste piles at adit portals, rock waste dumps derived from the open pits and tailings deposits respectively. for comparison the size of selected other Yukon mine waste deposits is also shown. It can be seen that most sites in the district are relatively small, particularly on a territory-wide basis.

5.2 Mine Descriptions

Important mining development occurred on Keno Hill, though less extensive that on Galena Hill. Mining began here and continued intermittently throughout the history of the camp. Permafrost is widely developed in the camp, but appears to be particularly common in the higher elevation mines of Keno Hill.

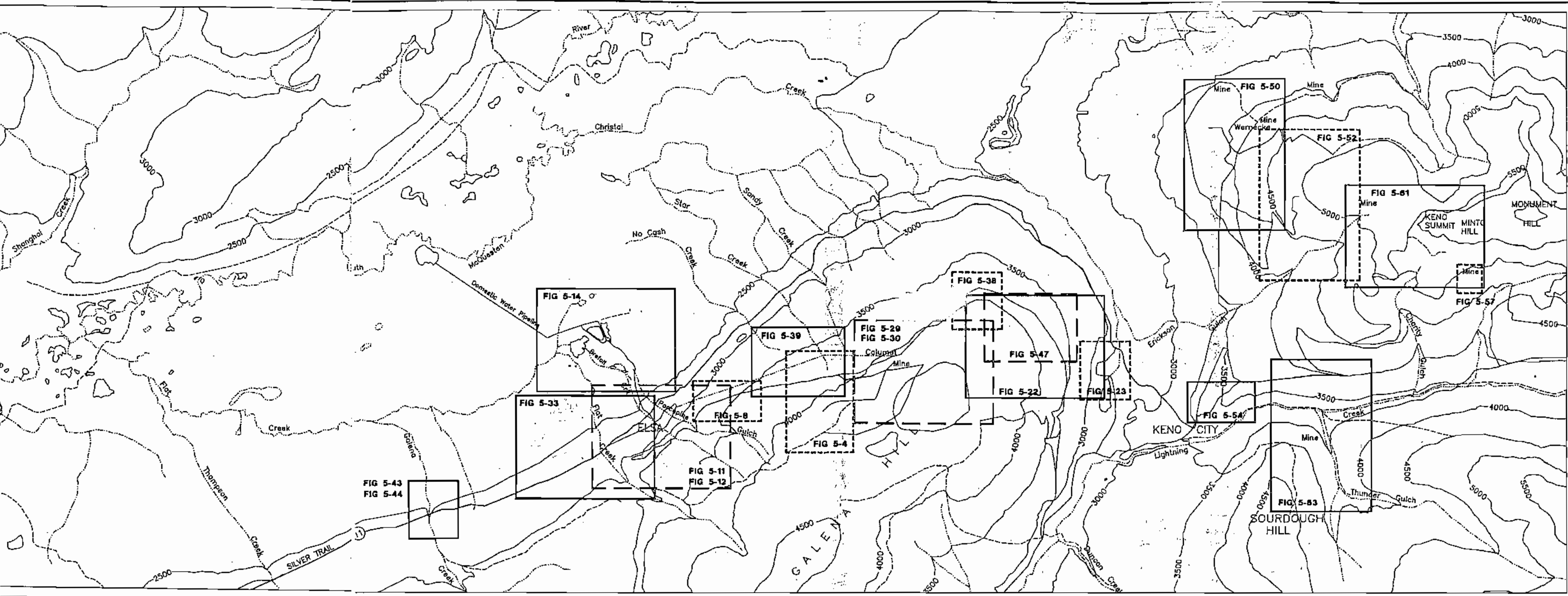
Some of the veins on Keno Hill contain calcite, for example, Lucky Queen, which has a quartz-calcite breccia with galena and sphalerite. Galena Hill veins, in contrast, have iron-rich carbonate rather than calcite.

TABLE 5-1

Summary of Development									
Mine	**Open Pit**	**Underground # levels**	**Shafts, Raises Adits**	**Bldgs and Equip.**	**Rock Piles waste, ore**	**Tailings**	**Mill or Plant**	**Other**	**Townsite**
Galena Hill									
Bermingham	2 178,512 t mined	3 for 250 ft depth 7,754 t mined	8 shaft 1 adit	3 bldg @adit	3 continuous 1,000,000t@pit 7,000@adit	-	-	-	-
Calumet	3 108,547 t mined	1300 ft depth extensive UG, many lev,2.6Mt	1 shaft 1 adit	none	3@pits,1@adit 1,110,000@pits 198,000t@adit	-	-	head of tramway	removed
C-structure	1 2,392 t	0			1 28,000 t				
Dixie	-	1 23,872 t	1 adit 1 shaft	1 bldg	1 @ adit 19,800 t	-	-	-	-
Elsa	-	7@+50,100,200 200,400,525,650 &775; 491,009t	6 adits 1 internal shaft >2 raises		3 51,650 t	3 dams existing + old tlgs	existing	-	existing
Galkeno	-	6@100,200,300 400,500,900 167,063 t	5 adits 2 internal shaft 1 external shaft	old bldgs	4 total 171,400t	3,000 to 5,000 t old	removed	treatment plus ponds 900 level	
Husky	-	4@125, 250,375 &450; 429,367 t	1 shaft	H.frame	1WR 4,600 t				
Husky SW		3 @ 250, 400, &530; 10,461 t	1shaft	H.frame, blast.	1WR, 1Ore 17,000 t	-	-	-	-
Miller	1 9,263 t	1 in open pit minimal prdn.	1 old shaft (open pitted)		1 @ pit 63,000 t				
No Cash		4@100,200,300 300 & 500 levels 166,530 t mined	1 raise, 1 shaft 2 adits	h. frame, bldg	1 138,100@500L 6,500 @ 100 L			tram station	-
Ruby		1 @400 level 40,652 t mined	1 raise, 1 adit	1 bldg	1 WR, cribbing 29,800 t	-		power, tracks	-
Silver King	1 6,631 t mined	3 for 325 ft 200,982 t mined	2 shafts, 4 adits 3 raises		2 rock, 1 ore 43,000t@adit 120,000t@pit	-	-	treatment plus ponds	-
Sime	3 47,304 t	0 (see Galkeno)			3 450,000 t	-			
Townsite	-	1 adit 18,570 t	1 adit 1 raise	1 bldg	1 14,300 t	-	-	cribbing	1
UN	-	1 adit (no ore mined)	1A		1 3,200 t				

TABLE 5-1

Summary of Development									
Mine	**Open Pit**	**Underground # levels**	**Shafts, Raises Portals, Adits**	**Bldgs and Equip.**	**Rock Piles waste, ore**	**Tailings**	**Mill or Plant**	**Other**	**Townsite**
Sourdough Hill									
Bellekeno	-	9	4 adits	@625 portal	4	-		treatment	
		40,502 t mined			63,950 t				
Keno Hill									
Black Cap	1	2 ?	2 adits		1				
	47,497 t	1,079 t			390,000 t @ pit				
Flame & Moth	1	1	1 adit		1 small			remaining	
	1,590 t	(small)						reserves	
Comstock-Keno	1	3	3 adits	2 @portals	2				
Porcupine	4,253 t	22,863 t ?	1 raise		1@pit, 1@UG				
					6,500 t				
Keno 700 &		8	4 adits, 2 shafts	several	2			several veins	1 camp
Shamrock "J"		283,517 t	several raises		42,100 t total			mined	
Lucky Queen	1	4	1 shaft, 1 adit	1 @500 portal	2				
	(small pit)	123,530 t mined			66,900 t				
Onek	1	4 for 400 ft	2 shafts		3; 7,500 @ adit	-			
	62,254 t	33,036 t	1 adit		600,000 t @ pit				
Sadie Ladue		6	1 adit	1	2	1		loadout	
		244,330 t mined			44,000 t				
Shamrock	2	3	1 shaft	shaft bldg	2				
		5,035 pit + UG	2 adits		9,000 t				



LEGEND

Creek, river, waterbody

Territorial Highway
Secondary road
Trail

Fig 5-4

Area of detailed site plan with Figure Number indicated
Lines solid or dashed to distinguish different areas

Elevation contour interval – 500 feet

0 1000 2000 3000
METRES

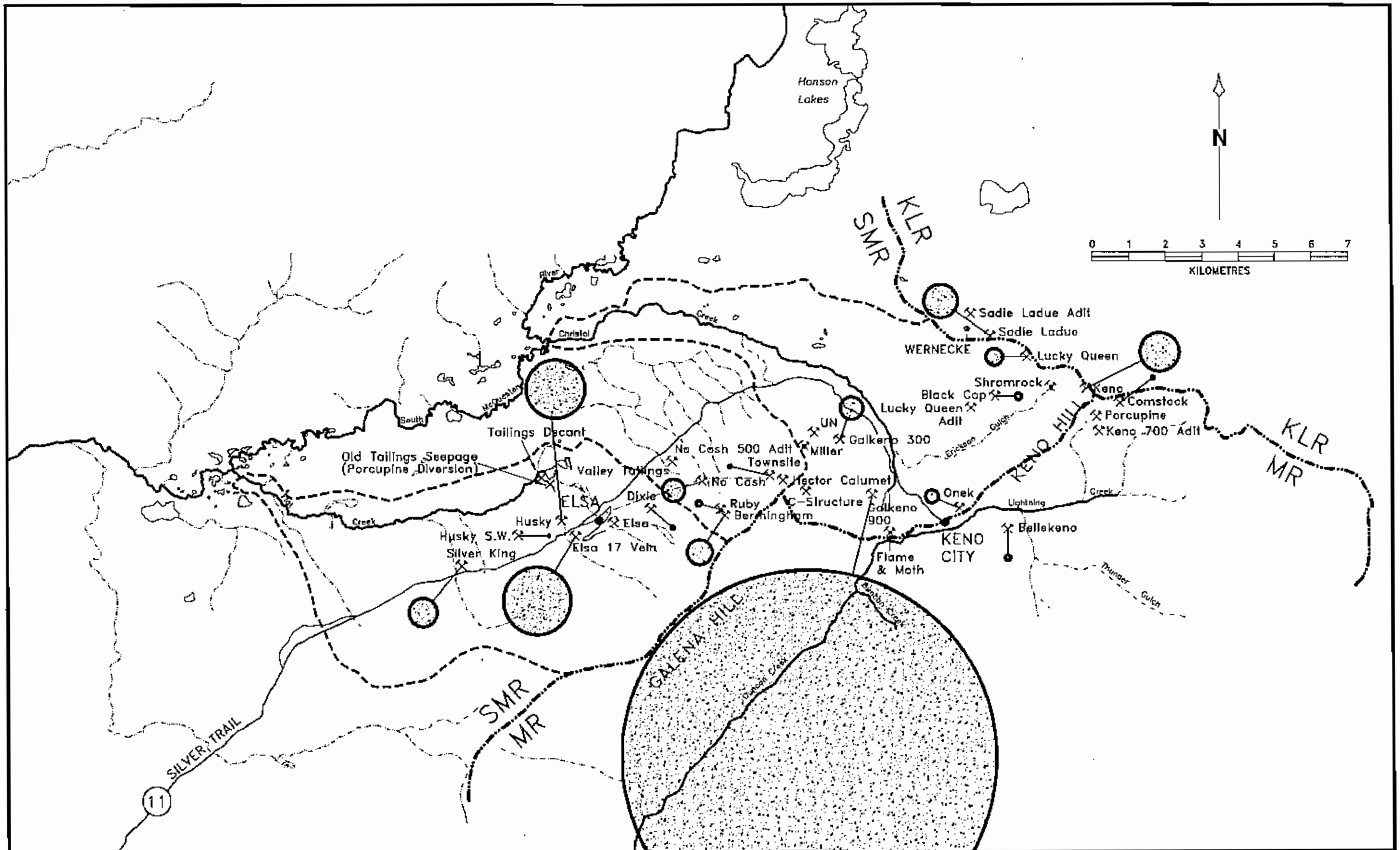
UTM GRID NORTH

UNITED KENO HILL MINES LIMITED

KEY TO DETAILED SITE PLANS
FIGURE LOCATIONS

ACCESS MINING CONSULTANTS LTD.

SCALE: 1 : 50 000	FILE: CDET_LCT.DWG	DATE: 28/05/96
DRAWN: LCP Consult	DWG: 95UK26C1	FIGURE: 4–1



100,000 TONS

500,000 TONS

1,000,000 TONS

0 500,000 1,500,000 2,500,000 TONS

LEGEND

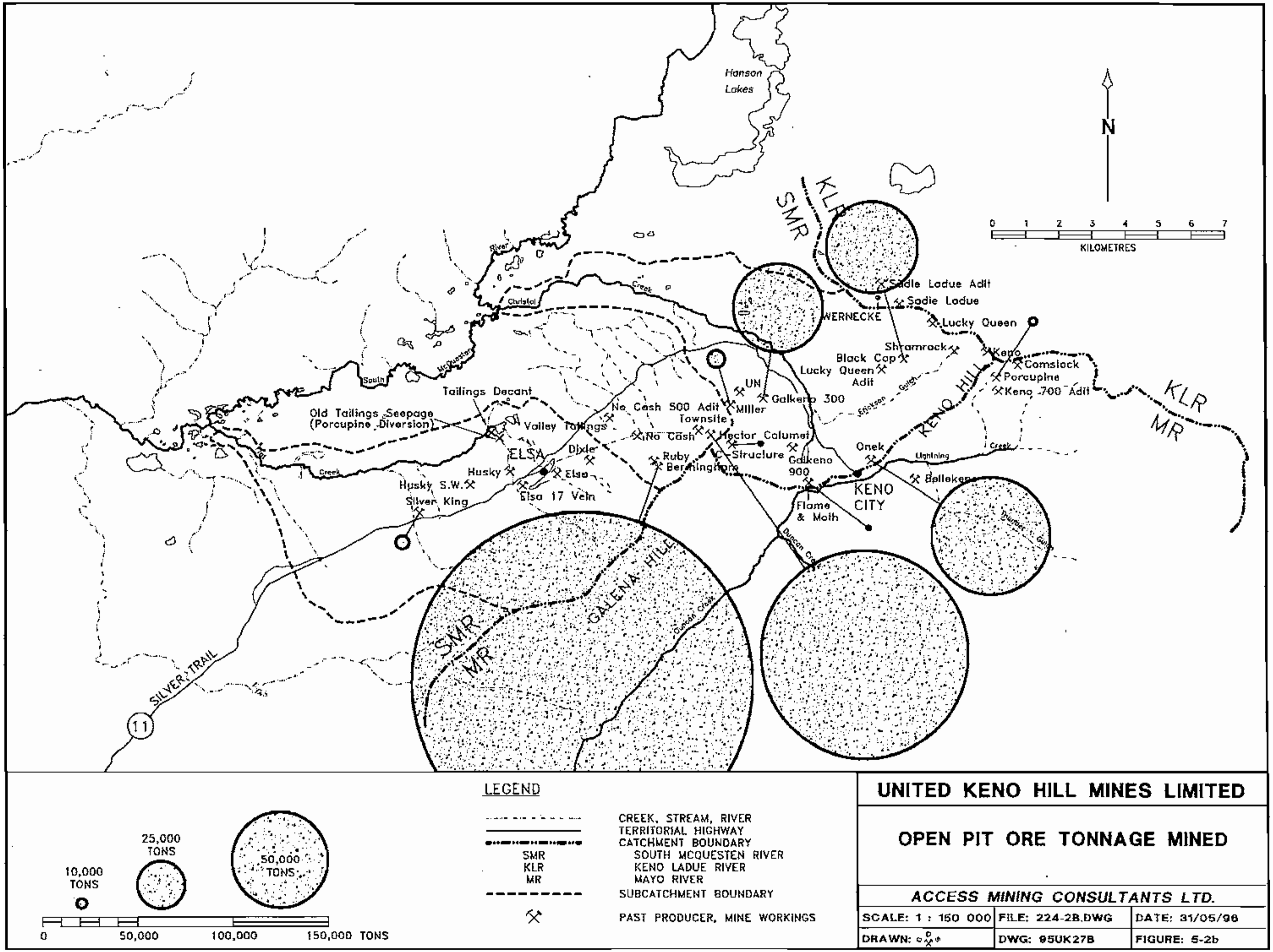
- - - - - -	CREEK, STREAM, RIVER
——————	TERRITORIAL HIGHWAY
-·-·-·-·-	CATCHMENT BOUNDARY
SMR	SOUTH MCQUESTEN RIVER
KLR	KENO LADUE RIVER
MR	MAYO RIVER
— — — —	SUBCATCHMENT BOUNDARY
⚒	PAST PRODUCER, MINE WORKINGS

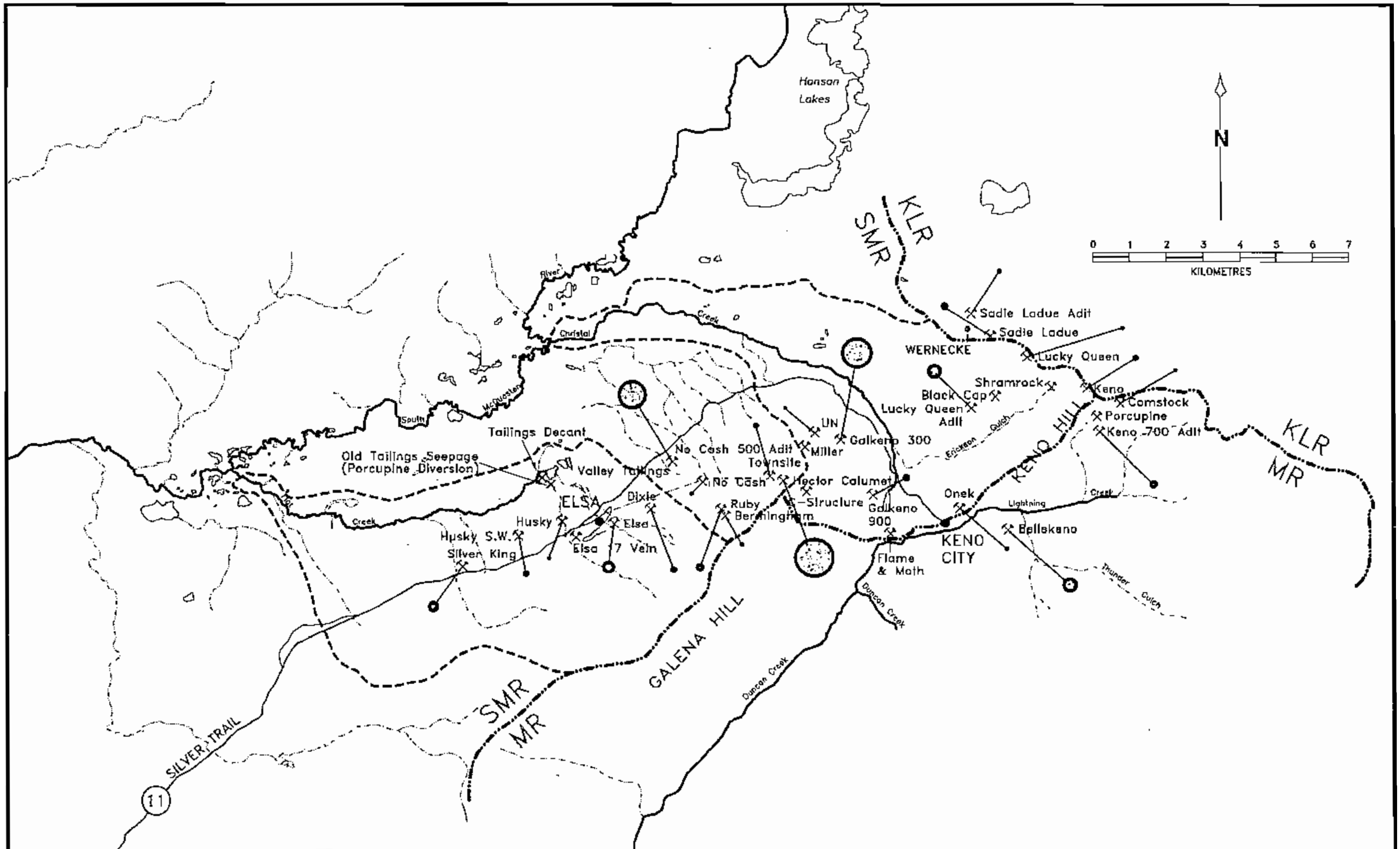
UNITED KENO HILL MINES LIMITED

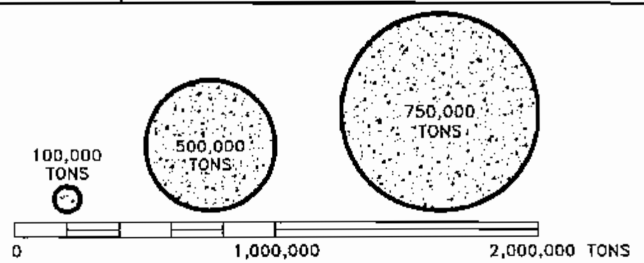
TOTAL ORE TONNAGE MINED

ACCESS MINING CONSULTANTS LTD.

SCALE: 1 : 150 000	FILE: 224-2A.DWG	DATE: 31/05/96
DRAWN:	DWG: 95UK27A	FIGURE: 5-2a


Hanson Lakes
N
0 1 2 3 4 5 6 7
KILOMETRES
SMR
KLR
MR
Sadie Ladue Adit
Sadie Ladue
Lucky Queen
WERNECKE
Shamrock
Black Cap
Lucky Queen Adit
Keno
Comstock
Porcupine
Keno 700 Adit
KENO HILL
UN
Galkeno 300
Miller
Tailings Decant
Old Tailings Seepage (Porcupine Diversion)
Valley Tailings
No Cash 500 Adit
Townsite
No Cash
Hector Calumet
C-Structure
Galkeno 900
Onek
Lightning Creek
Bellekeno
ELSA
Dixie
Ruby
Bermingham
Husky
Elsa
Husky S.W.
Elsa 17 Vein
Silver King
KENO CITY
Flame & Moth
Duncan Creek
GALENA HILL
SILVER TRAIL
11
River
Christal
Creek
South McQuesten
LEGEND
CREEK, STREAM, RIVER
TERRITORIAL HIGHWAY
CATCHMENT BOUNDARY
SMR SOUTH McQUESTEN RIVER
KLR KENO LADUE RIVER
MR MAYO RIVER
SUBCATCHMENT BOUNDARY
PAST PRODUCER, MINE WORKINGS
10,000 TONS
25,000 TONS
50,000 TONS
0 50,000 100,000 150,000 TONS
UNITED KENO HILL MINES LIMITED
OPEN PIT ORE TONNAGE MINED
ACCESS MINING CONSULTANTS LTD.
SCALE: 1 : 150 000
FILE: 224-2B.DWG
DATE: 31/05/96
DRAWN:
DWG: 95UK27B
FIGURE: 5-2b





LEGEND

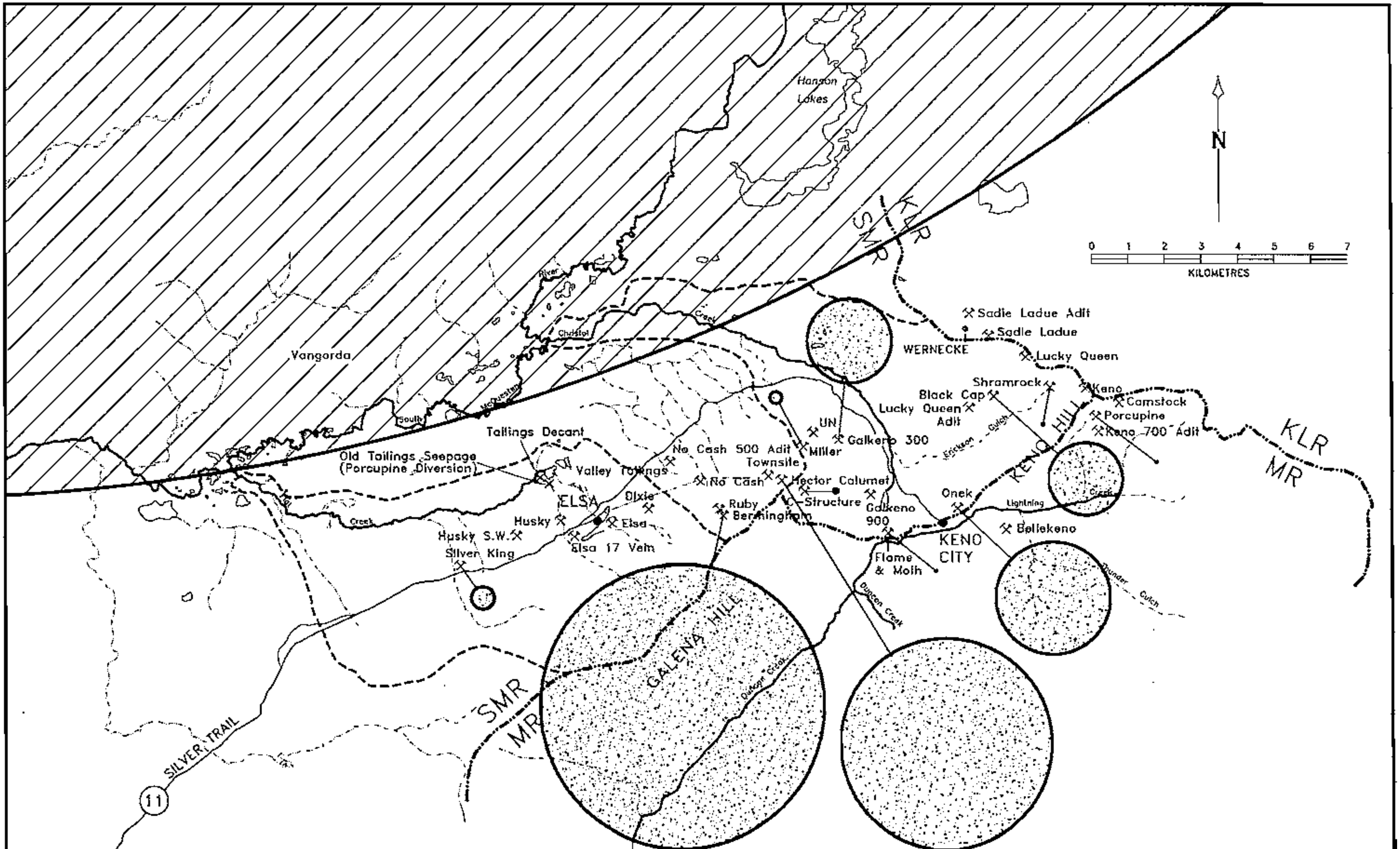
- - - - -	CREEK, STREAM, RIVER
———	TERRITORIAL HIGHWAY
—•—•—	CATCHMENT BOUNDARY
SMR	SOUTH MCQUESTEN RIVER
KLR	KENO LADUE RIVER
MR	MAYO RIVER
— — — —	SUBCATCHMENT BOUNDARY
⚒	PAST PRODUCER, MINE WORKINGS

UNITED KENO HILL MINES LIMITED

UNDERGROUND WASTE DUMPS

ACCESS MINING CONSULTANTS LTD.

SCALE: 1 : 150 000	FILE: 224-3A.DWG	DATE: 31/05/96
DRAWN:	DWG: 95UK27C	FIGURE: 5-3a



LEGEND

(dash-dot line)	CREEK, STREAM, RIVER
(solid line)	TERRITORIAL HIGHWAY
(heavy dash-dot line)	CATCHMENT BOUNDARY
SMR	SOUTH MCQUESTEN RIVER
KLR	KENO LADUE RIVER
MR	MAYO RIVER
(dashed line)	SUBCATCHMENT BOUNDARY
⚒	PAST PRODUCER, MINE WORKINGS

100,000 TONS

500,000 TONS

750,000 TONS

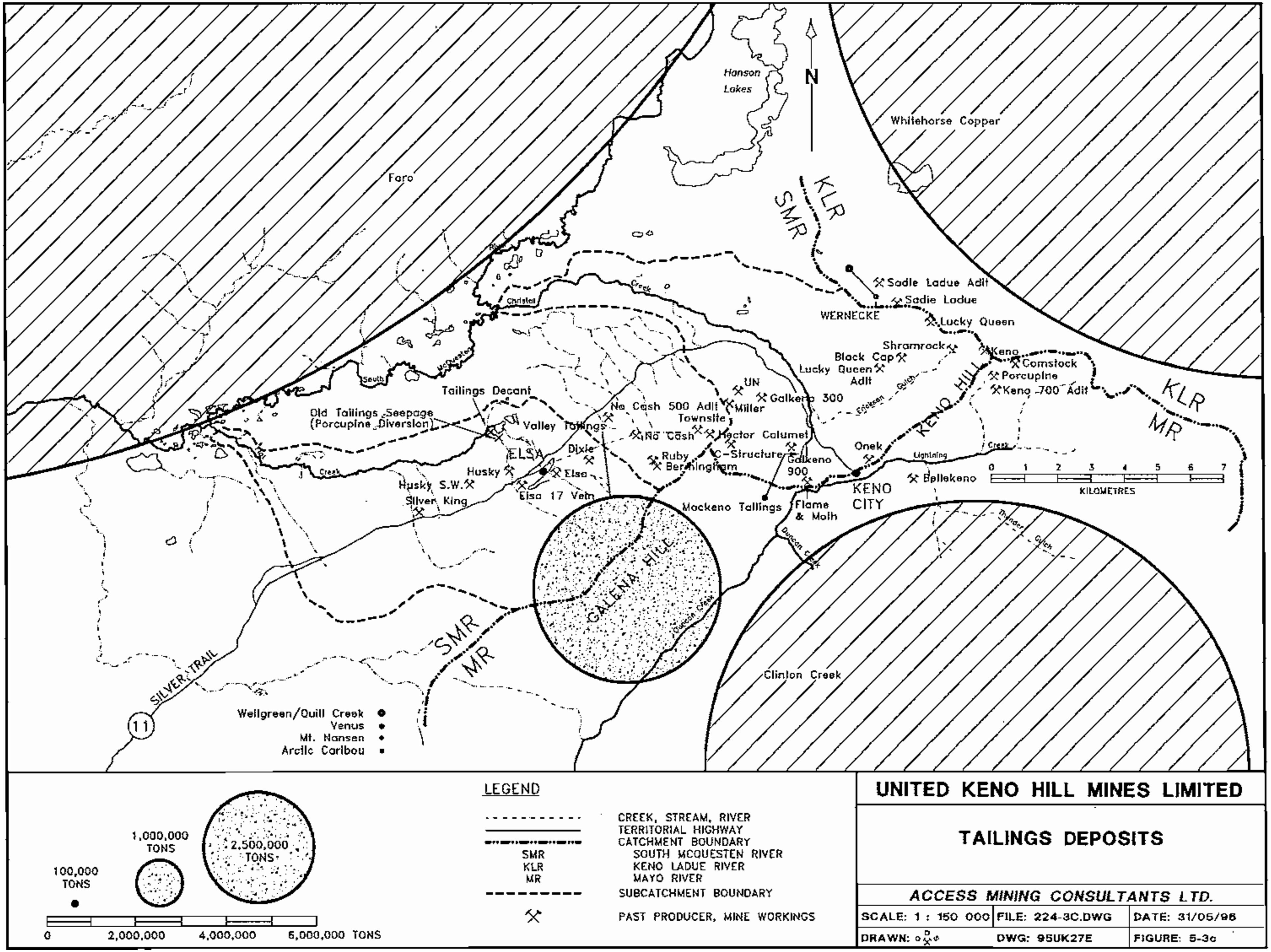
0 — 1,000,000 — 2,000,000 TONS

UNITED KENO HILL MINES LIMITED

OPEN PIT WASTE DUMPS

ACCESS MINING CONSULTANTS LTD.

SCALE: 1 : 150 000	FILE: 224-3B.DWG	DATE: 31/05/98
DRAWN: [illegible]	DWG: 95UK27D	FIGURE: 5-3b



Hanson Lakes
N
Whitehorse Copper
Faro
KLR
SMR
Sadie Ladue Adit
Sadie Ladue
WERNECKE
Lucky Queen
Shamrock
Keno
Comstock
Porcupine
Keno 700 Adit
Black Cap
Lucky Queen Adit
UN
Galkeno 300
Miller
No Cash 500 Adit
Townsite
Tailings Decant
Old Tailings Seepage (Porcupine Diversion)
Valley Tailings
No Cash
Hector Calumet
C-Structure
Ruby
Bermingham
Galkeno 900
Dixie
ELSA
Elsa
Husky
Husky S.W.
Silver King
Elsa 17 Vein
Mackeno Tailings
Flame & Moth
Onek
KENO CITY
Bellekeno
KENO HILL
KLR
MR
Christal
McQuesten
South
Creek
Lightning
Erickson Gulch
Duncan Creek
Thunder Gulch
KILOMETRES
0 1 2 3 4 5 6 7
GALENA HILL
SMR
MR
SILVER TRAIL
11
Clinton Creek
Wellgreen/Quill Creek
Venus
Mt. Nansen
Arctic Caribou
100,000 TONS
1,000,000 TONS
2,500,000 TONS
0 2,000,000 4,000,000 6,000,000 TONS
LEGEND
CREEK, STREAM, RIVER
TERRITORIAL HIGHWAY
CATCHMENT BOUNDARY
SMR SOUTH MCQUESTEN RIVER
KLR KENO LADUE RIVER
MR MAYO RIVER
SUBCATCHMENT BOUNDARY
PAST PRODUCER, MINE WORKINGS
UNITED KENO HILL MINES LIMITED
TAILINGS DEPOSITS
ACCESS MINING CONSULTANTS LTD.
SCALE: 1 : 150 000
FILE: 224-3C.DWG
DATE: 31/05/96
DRAWN:
DWG: 95UK27E
FIGURE: 5-3c

5.2.1 Bermingham Mine

Development: Table 5-2

Figures: Figure 5-4 Site Plan
Figure 5-5 Ruby-Bermingham Composite Plan
Figure 5-6 Bermingham Long Section, Looking Northwest
Figure 5-7 Bermingham Cross-Section, Looking Northeast

The Bermingham Mine complex is the largest open pit mine and the second to be mined by UKHM in the late 1970's. It comprises two open pits and underground workings, with a general arrangement as shown in Figures 5-4 and 5-5.

Figures 5-6 and 5-7 show sections through the main pit and the underground workings.

There is one adit, the Bermingham 200 Adit shown on Figures 5-5 and 5-7, which has caved and has a wooden door to block access.

Level plans show that there were eight shafts associated with the Bermingham underground workings. Four of these daylighted within the larger Bermingham pit, and one in the smaller Bermingham Southwest pit. Rock sloughing from the pit walls has filled and covered most of these shafts, with the exception of the No. 1 on the northwest side of the main pit. This shaft is partially collapsed.

Two of the eight shafts are external to the pits. The Bleiler Shaft is located to the east of the main pit and extends about 40 feet in depth to a small underground working isolated from the rest of the underground development, as shown in Figure 5-6. The No. 2 shaft is located at the western edge of the Bermingham SW open pit.

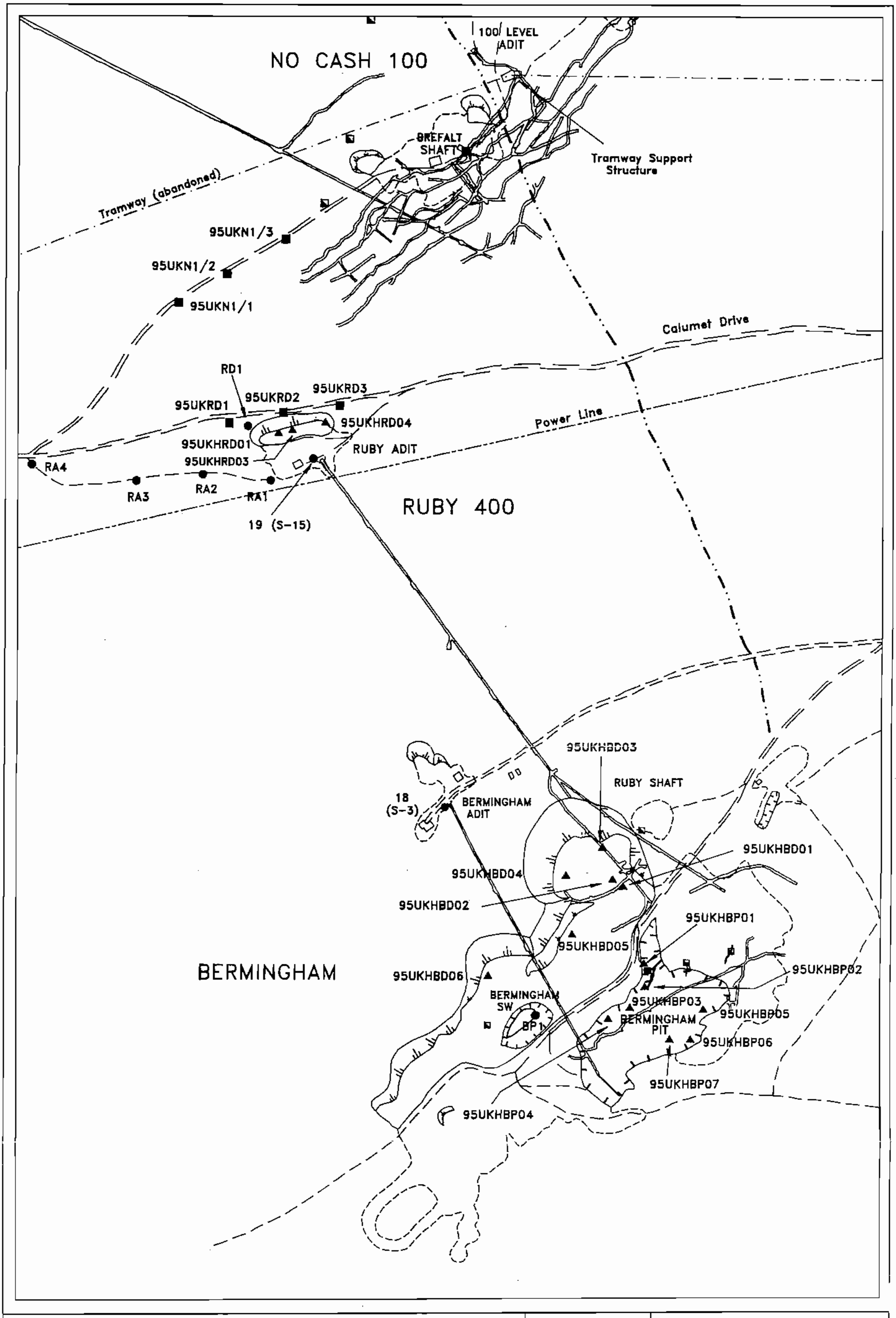
TABLE 5-2

Mine Development

Mine:	Bermingham
Location:	Galena Hill
Period of Development:	1977 to 1979
Developed by:	UKHM
Monitoring at:	S-3

Development at Bermingham

	Open Pit	Underground	Shafts, Raises Portals, Adits	Bldgs and Equip.	Rock Piles pit dump	adit dump	Other
Period of Development	1977 to 1979	1925 to 1951	1950's	1950's	1977 to 1979	1950's	
Production or Tonnage	Total = 186,266 tons 166,782 t = main pit 11,730=SW pit	7,754 t			Total of 1,500,000 tons	7,000 tons	
Features	first pit mined by UKHM on Galena Hill vein highly ox.		drains into portal dump	3 at the adit		1.71 oz Ag/ton 0.37% Pb 0.29% Zn	
Geometry	shaft daylights in pit		driven to intersect Vein adit 1450' long 1500' lateral dev.		3 dumps combined ave. slope 36° cracks at crest from 1979/80	slopes 30°	
Drainage	main pit does not hold water drains to UG SW pit holds water	probably none of workings is flooded	from adit through dump				
Remarks	West wall of pit is in part vein wall		#1 shaft daylights on NW side of pit, raise to UG in SW corner of pit		Dumps contain a skim of ore where stockpiles were, sampled	primarily schist	



LEGEND

- ■ Soil test pit with piezometer
- ▲ Waste rock sample
- ● Water quality sample site
- Disturbed area
- Building
- Power Line
- Telephone Line
- Highway #11
- Road
- Trail
- Stream or River
- Underground Workings
- Open pit, trench
- Waste rock dump
- Tailings area
- Adit entrance
- Shaft location

UTM N, TN, MN

METRES

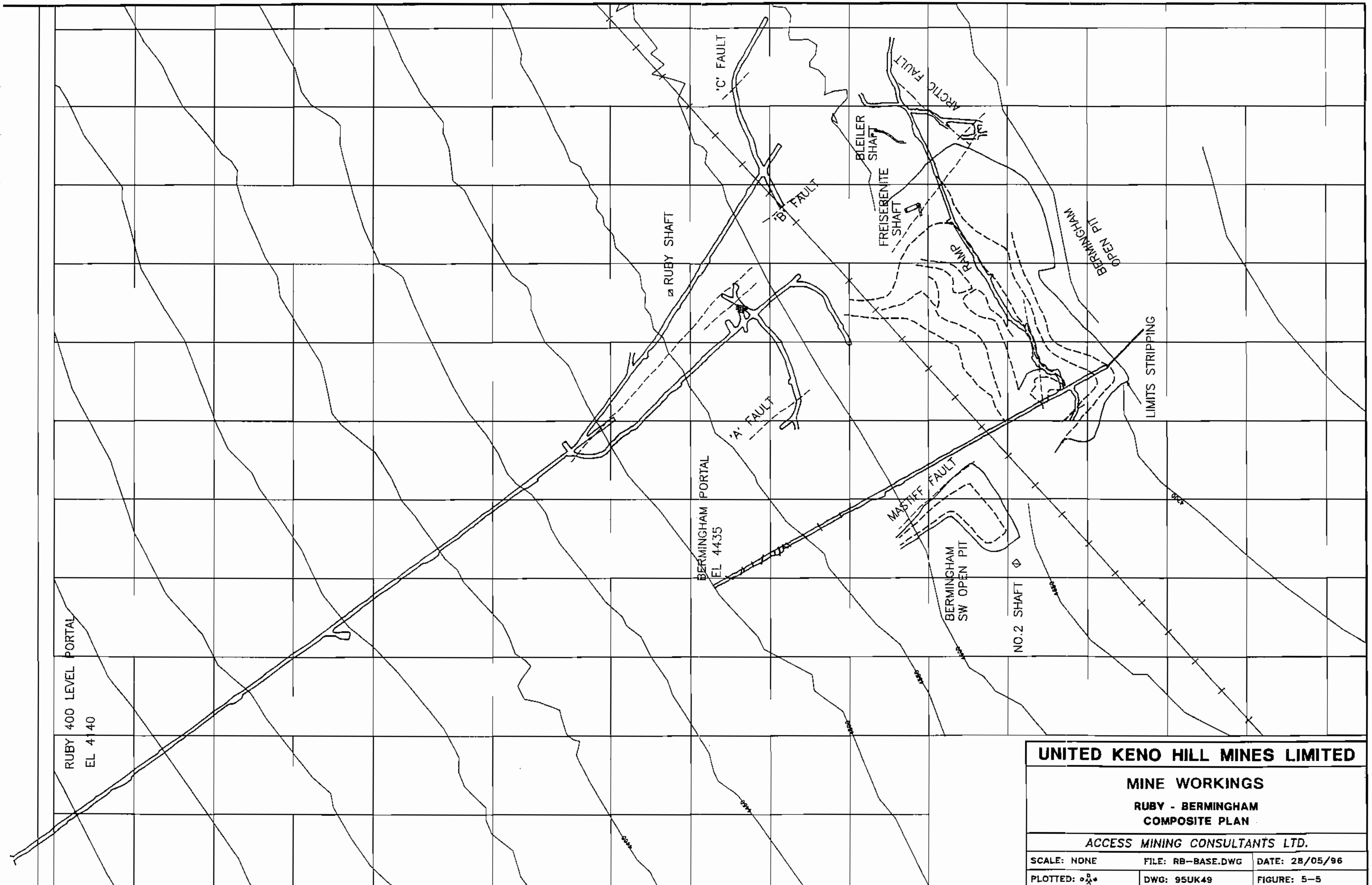
UNITED KENO HILL MINES LIMITED

NO CASH, RUBY, and BERMINGHAM SITE PLAN

Access Mining Consultants Ltd.

DWG: 95UK14

FIGURE 5-4



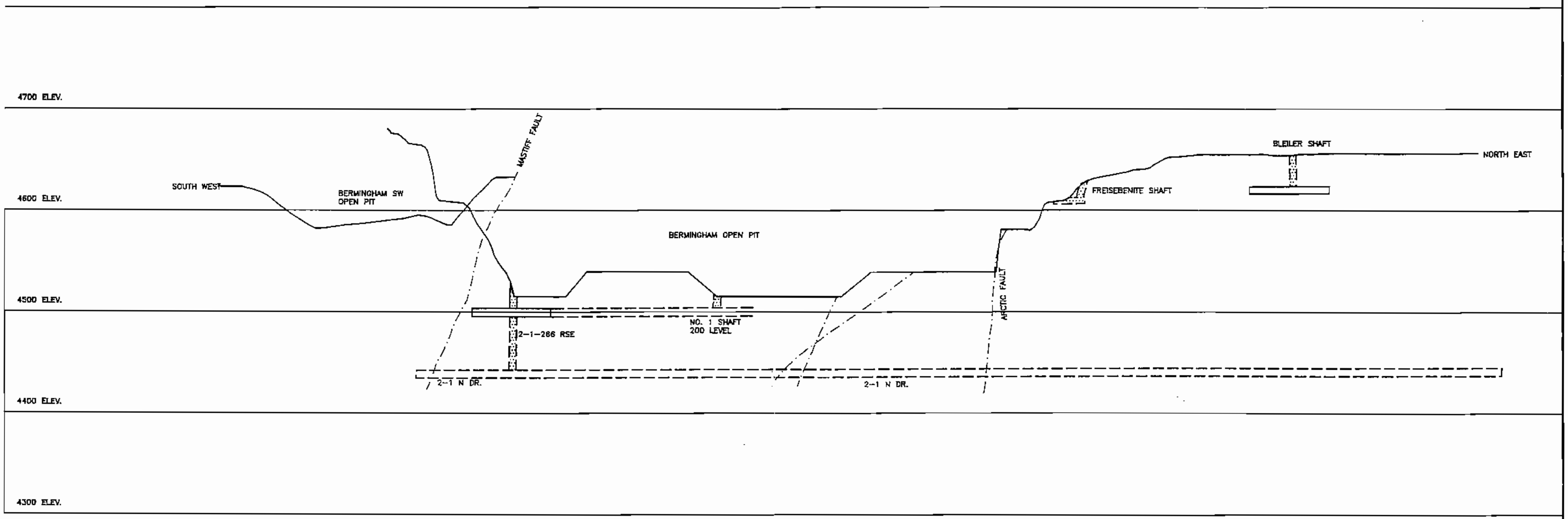
UNITED KENO HILL MINES LIMITED

MINE WORKINGS

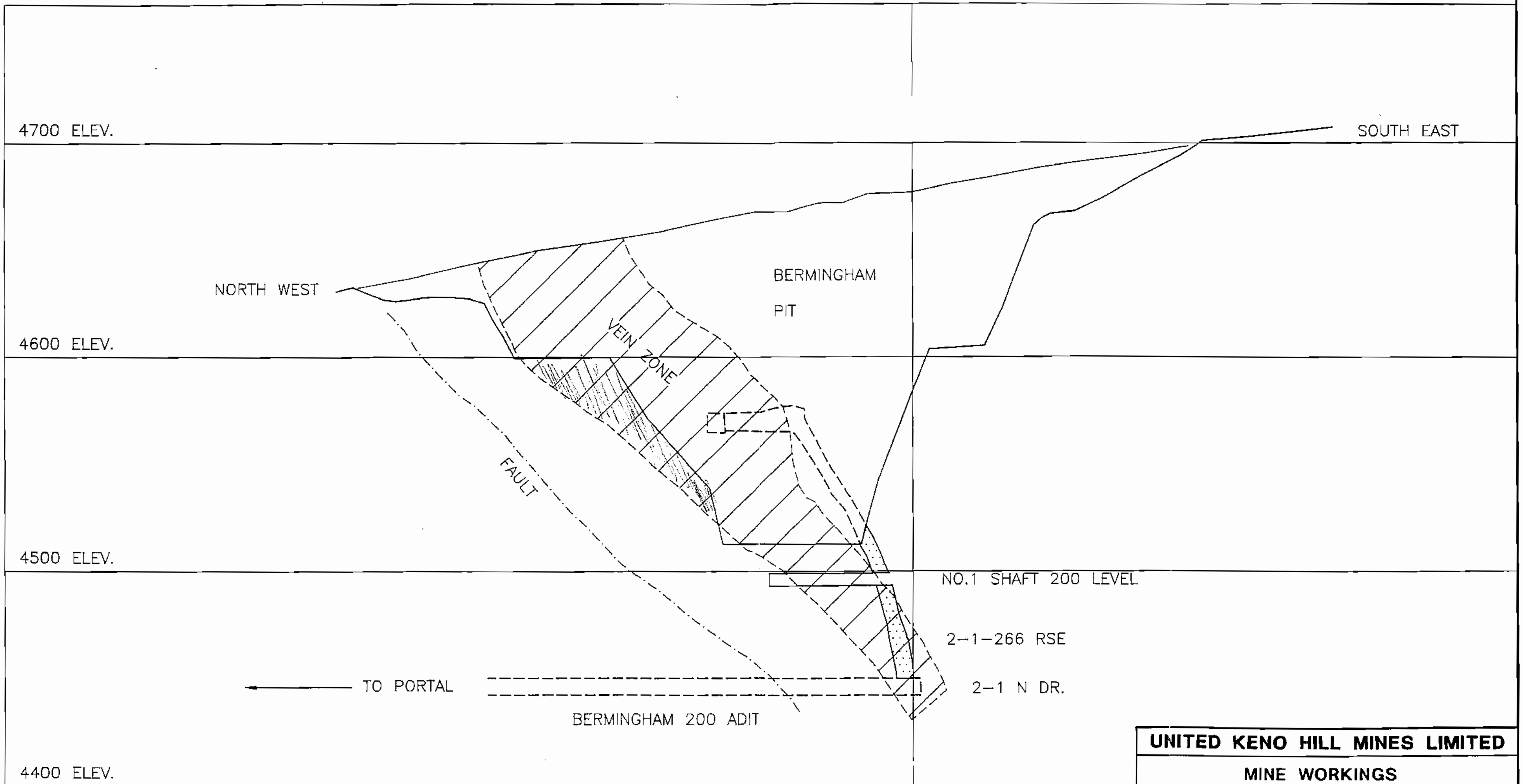
RUBY - BERMINGHAM
COMPOSITE PLAN

ACCESS MINING CONSULTANTS LTD.

SCALE: NONE	FILE: RB–BASE.DWG	DATE: 28/05/96
PLOTTED:	DWG: 95UK49	FIGURE: 5–5



UNITED KENO HILL MINES LIMITED		
MINE WORKINGS **BERMINGHAM** **VERTICAL LONGSECTION (Looking Northwest)**		
ACCESS MINING CONSULTANTS LTD.		
SCALE: NONE	FILE: RBLONG.DWG	DATE: 28/05/96
PLOTTED:	DWG: 95UK50	FIGURE: 5-6



UNITED KENO HILL MINES LIMITED

MINE WORKINGS

BERMINGHAM MINE
CROSS SECTION (Looking Northeast)

ACCESS MINING CONSULTANTS LTD.

SCALE: NONE	FILE: RBXSEC.DWG	DATE: 28/05/96
PLOTTED:	DWG: 95UK51	FIGURE: 5-7

5.2.2 Dixie

Development: Table 5-3

Figures: Figure 5-8 Site Plan
Figure 5-9 Dixie Mine, Plan
Figure 5-10 Elsa and Dixie Mines, Vertical Longitudinal Section

The small Dixie underground workings were developed by UKHM in the 1970's, and produced about 24,000 tons of ore. There is one adit at the 200 level and two raises to surface. Doors are installed at the portal to block access. Reports show that the raises have also been secured.

There is a cribbed loadout platform at the Dixie adit which was filled with waste (development) rock, with additional waste rock deposited around the platform. Downslope from the waste rock there is an area of surface silt accumulation and dead vegetation. The area appears to have been affected by erosion from spring runoff from upslope, in the dump glaciation, or possibly acidity from rocks in the dump.

However, anecdotal evidence indicates that the dead vegetation may in part be associated with the high flows of water from two periods of underground dewatering, prior to mining. The adit is now essentially dry, and has not discharged water in recent memory.

There are also some older underground workings at the Dixie Mine, as shown on Figure 5-9. These were accessed via the Dixie shaft. The shaft is located to the northwest of the portal (Figure 5-8). The condition of this shaft will be confirmed, although it is reported to be caved.

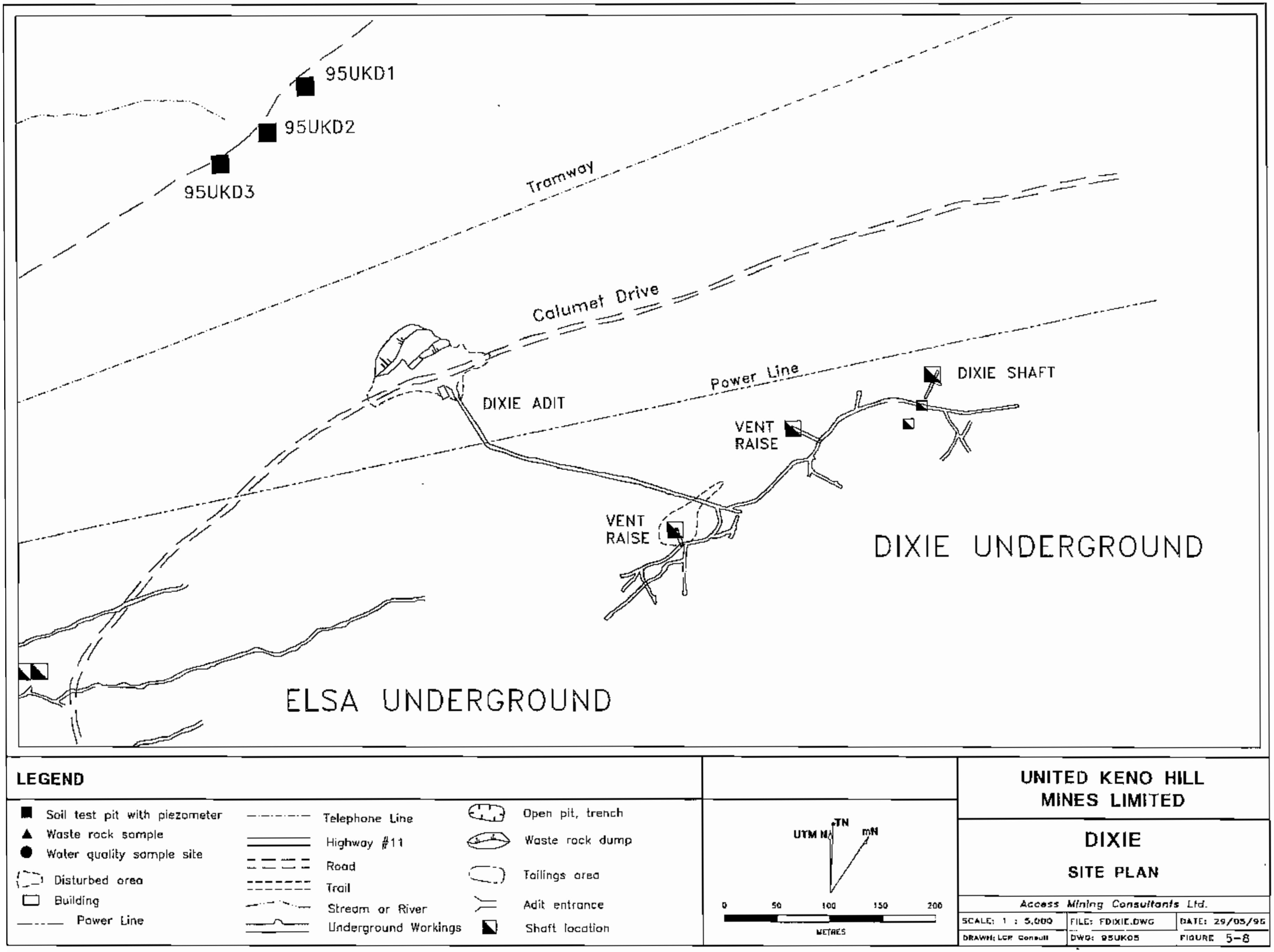
TABLE 5-3

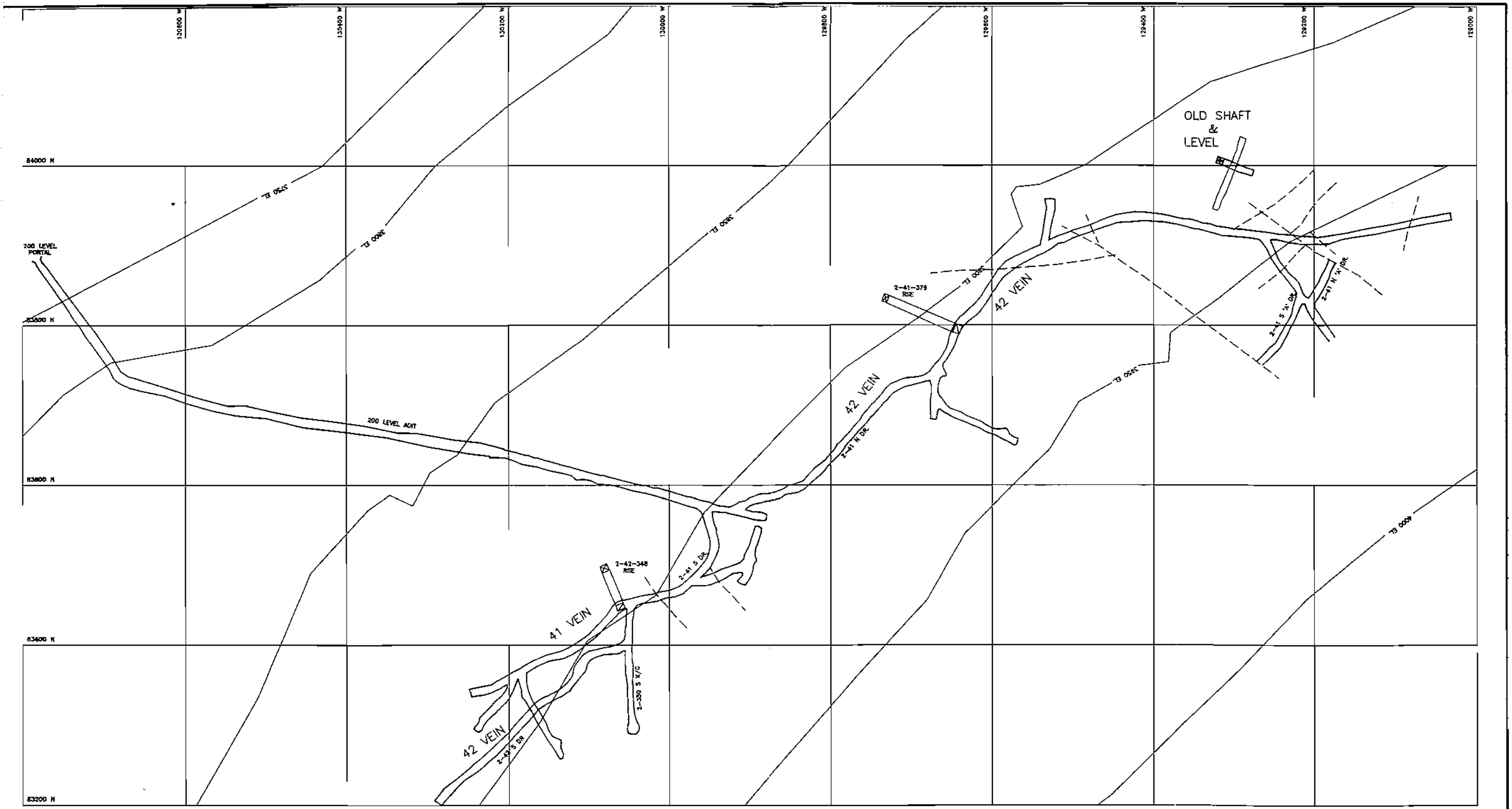
Mine Development

Mine:	Dixie	
Location:	Galena Hill	
Period of Development:		pre-1960's, then 1970's
Developed by:	others then UKHM	

Development at Dixie

	Underground	Shafts, Raises Portals, Adits	Bldgs and Equip.	Rock Piles waste, ore	Other	Townsite
Period of Development	1972 to 1978 pre-1960's		1970's	1972 to 1978	cribbed platform	
Production or Tonnage	23,872 tons ore			19,800 tons waste		
Features		200 level adit 2 raises 1 shaft	1 metal bldg	base of pile is country rock from drift overlain by waste vein material		
Geometry			adit 1000' long shaft 75' deep			
Drainage		No discharge				
Remarks				Dead vegetation downstream of dump due to dewatering during operation and to erosion or glaciation		


95UKD1
95UKD2
95UKD3
Tramway
Calumet Drive
Power Line
DIXIE ADIT
DIXIE SHAFT
VENT RAISE
VENT RAISE
DIXIE UNDERGROUND
ELSA UNDERGROUND
LEGEND
Soil test pit with piezometer
Waste rock sample
Water quality sample site
Disturbed area
Building
Power Line
Telephone Line
Highway #11
Road
Trail
Stream or River
Underground Workings
Open pit, trench
Waste rock dump
Tailings area
Adit entrance
Shaft location
UTM N
TN
mN
0
50
100
150
200
METRES
UNITED KENO HILL MINES LIMITED
DIXIE
SITE PLAN
Access Mining Consultants Ltd.
SCALE: 1 : 5,000
FILE: FDIXIE.DWG
DATE: 29/05/96
DRAWN: LCP Consult
DWG: 95UK05
FIGURE 5-8



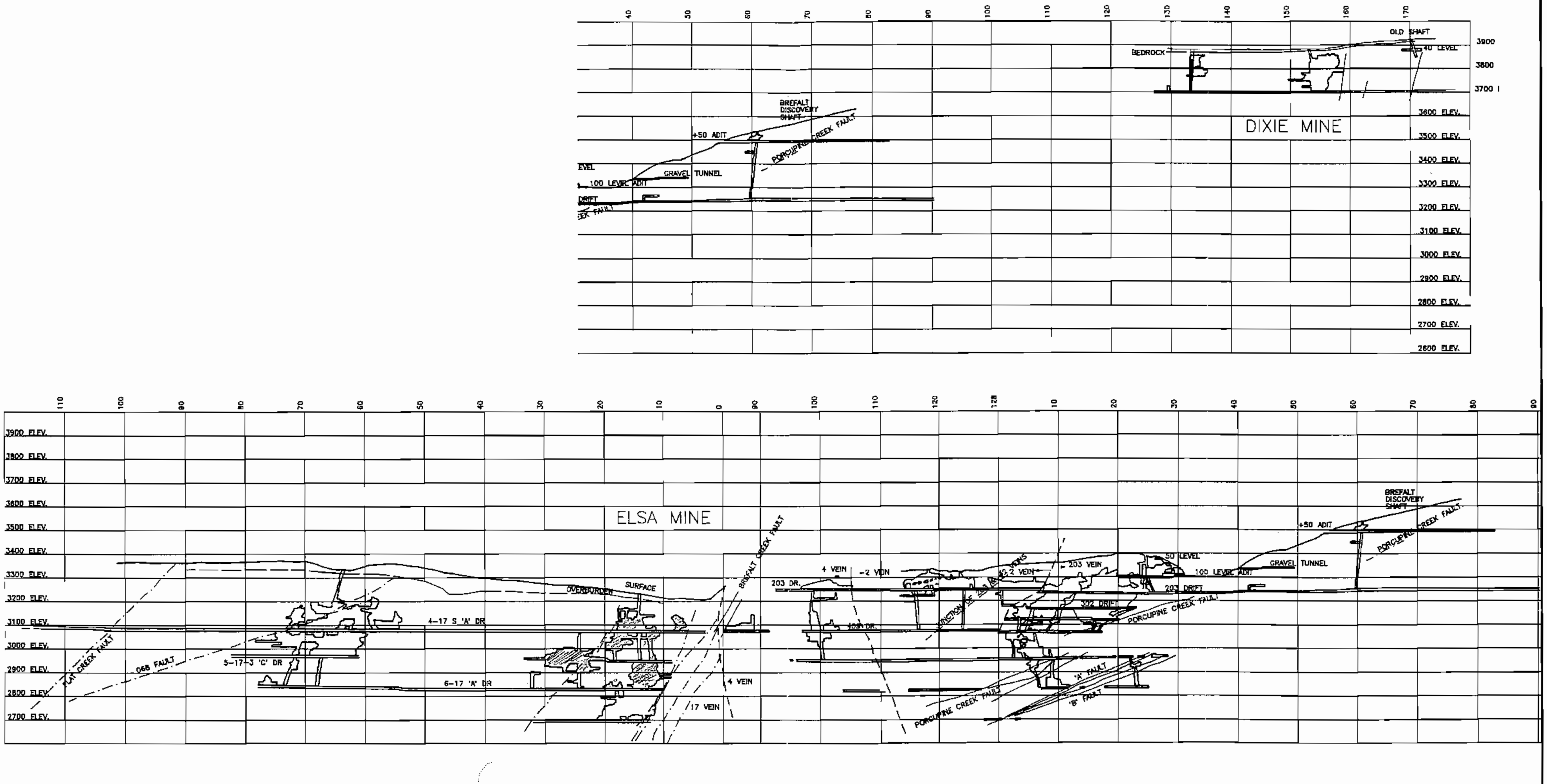
UNITED KENO HILL MINES LIMITED

MINE WORKINGS

DIXIE MINE
PLAN

ACCESS MINING CONSULTANTS LTD.

SCALE: NONE	FILE: DIXIEPLN.DWG	DATE: 28/05/96
PLOTTED:	DWG: 95UK29	FIGURE: 5-9



UNITED KENO HILL MINES LIMITED

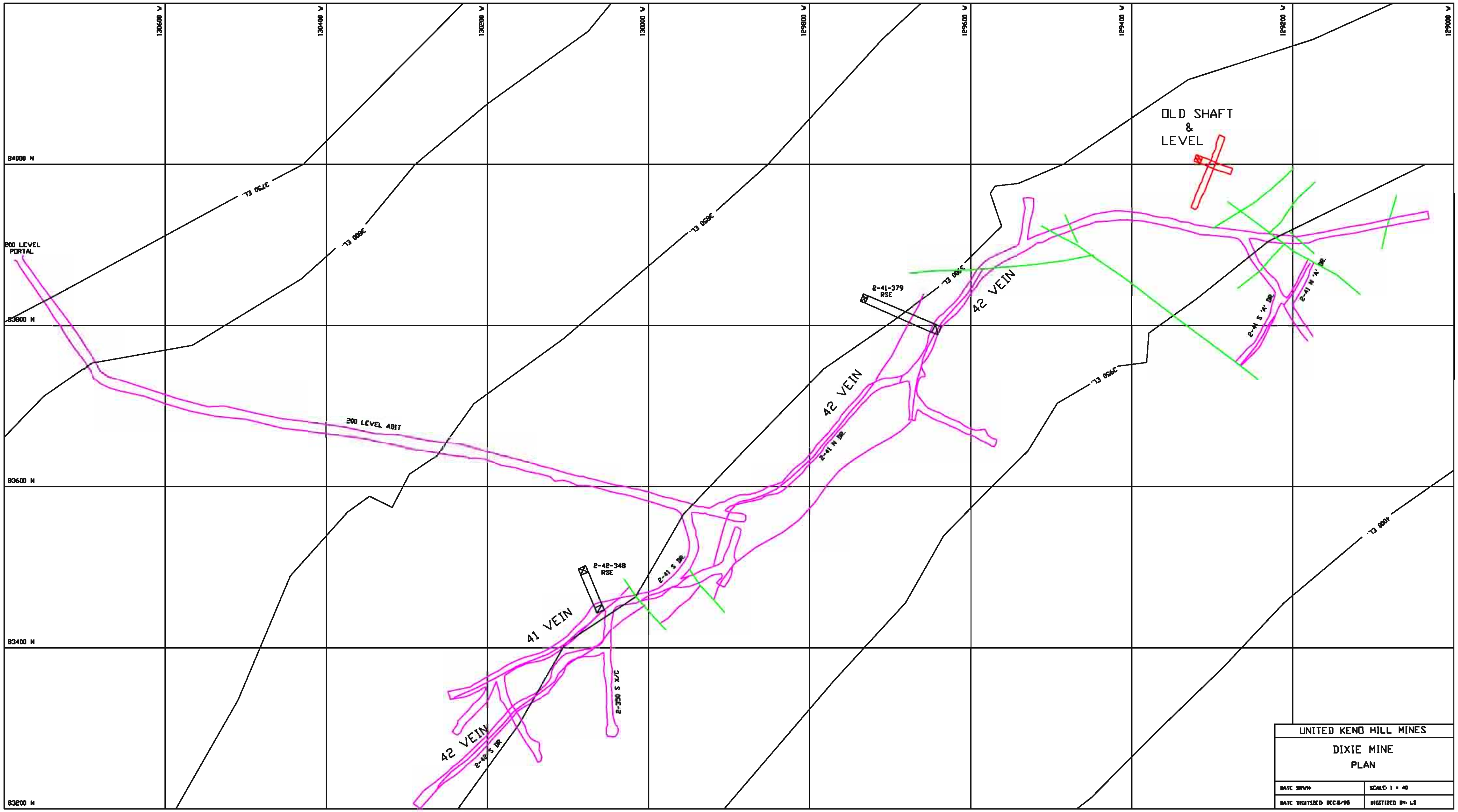
MINE WORKINGS

ELSA AND DIXIE MINES

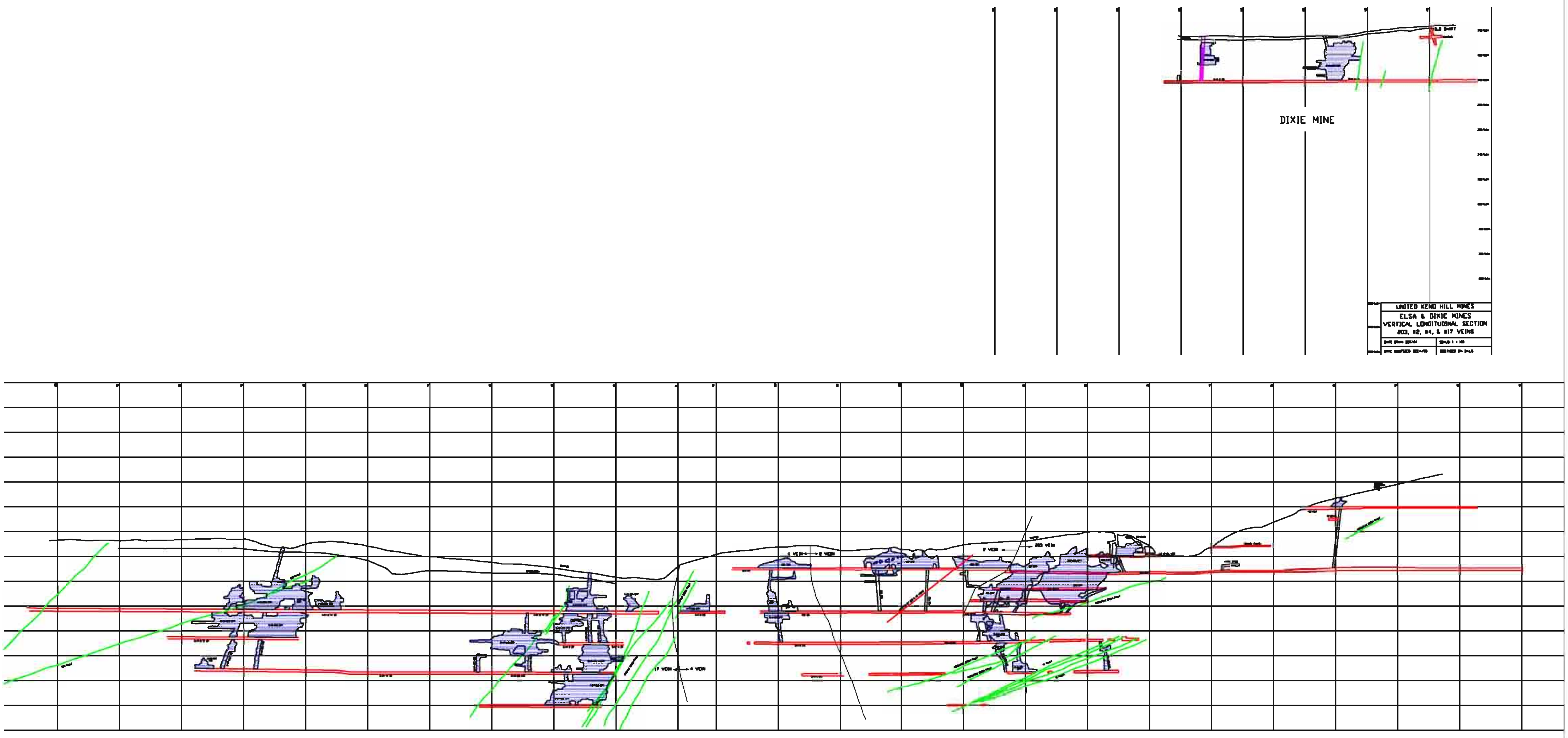
VERTICAL LONGITUDINAL SECTION - 203, 2, 4 & 17 VEINS

ACCESS MINING CONSULTANTS LTD.

SCALE: NONE	FILE: ELSACOML.DWG	DATE: 28/05/96
PLOTTED:	DWG: 95UK30	FIGURE: 5-10



OLD SHAFT & LEVEL
200 LEVEL PORTAL
200 LEVEL ADIT
42 VEIN
42 VEIN
41 VEIN
42 VEIN
2-41-379 RSE
2-42-348 RSE
2-41 N DR.
2-41 S DR.
2-42 S DR.
2-350 S X/C
2-41 S 'A' DR.
2-41 N 'A' DR.
3750 EL.
3800 EL.
3850 EL.
3900 EL.
3950 EL.
4000 EL.
84000 N
83800 N
83600 N
83400 N
83200 N
UNITED KENO HILL MINES
DIXIE MINE
PLAN
DATE DRWN:
SCALE: 1 = 40
DATE DIGITIZED: DEC.8/95
DIGITIZED BY: LS


DIXIE MINE
UNITED KENO HILL MINES
ELSA & DIXIE MINES
VERTICAL LONGITUDINAL SECTION
203, #2, #4, & #17 VEINS

5.2.3 Elsa Mine

Development: Table 5-4

Figures: Figure 5-11 Site Plan

Figure 5-12 Site Plan

Figure 5-13 Elsa Mine Composite Plan

Figure 5-10 Elsa & Dixie Mines Vertical Longitudinal Section 203, No.2, No.4, & No.17 Veins

The Elsa underground mining area is the oldest and second most extensive of the mining areas, and was the second largest underground producer of the district, after Hector-Calumet. First mined from three levels in the 1930's, UKHM worked the 400 and 200 levels until 1988. Mining was done on a total of eight levels, representing about 800 feet in elevation.

There are six adits associated with the Elsa Mine (+50, 50, 100, 200, 400 and Gravel) as shown in Figure 5-12. Most of the adits are timbered at the portal, and have ice year-round. The older +50, 50, and 100 portals are reported caved. Metal gates have been installed on the 400 and 200 portals.

The only shaft at Elsa was an internal shaft. There are, however, raises to surface associated with both the old and newer workings. This is shown in the mine section, Figure 5-10. The status of the old raises is unknown and will be investigated. Locations are shown on Figure 5-10. The two raises associated with the new workings are also shown in Figure 5-10. One is covered by a small shed. The status of the other is unknown. It is assumed that closure measures are required for both.

The only adit with any significant waste rock production was at the 400 level. Most of this rock has since been used as fill or road material around the mill and camp and no significant waste rock piles remain.

The Elsa mine workings are drained to some extent from the 400 level. There is a gravity fed sump on 400 level and the water from it is pumped into the shaft. It is anticipated that the majority of the underground water reports from the shaft to the

Husky workings, via the Brefalt Creek Fault. This assumption is based on the records of development and dewatering of Husky, and on the observations of site geologists. It is believed water from Elsa also flows via the Brefalt Creek fault and comes out on surface just above Highway No. 11 between the Husky Mine turnoff and the old Elsa school.

TABLE 5-4

Mine Development

Mine: Elsa
Location:
Period of Development: 1930's to 1980's
Developed by: others then UKHM
Monitoring at: S-16

Development at Elsa

	Underground	Shafts, Raises Portals, Adits	Bldgs and Equip.	Rock Piles @400 adit	@200 adit	@+50 adit	Tailings	Mill or Plant
Period of Development		adit 1931		1932 to 1941 1947 to 1982 1985 to 1988	1930's 1947 to 1982	1930's	1936 to 1942 1947 to 1989	
Production or Tonnage	491,009 tons			44, 100 tons	6,000 tons	1,550 tons	4,128,000 tons	
Features			1 bldg @ 100 L	no low grade in dump - all milled due to proximity	3.42 oz Ag/t	0.95 oz Ag/t		Built directly in front of 400 adit.
Geometry		adit @+50 750' long adit @50 30' long adit @100 200' long adit @200 600' long adit @400 1050' long (Internal) shaft 375' deep Gravel adit	SW of Brefalt Creek fault					
Drainage	Water collected in sump at 400 L then pumped to shaft and reports to Husky							
Remarks		Elsa was the 2nd largest producer of the district.		400 adit was main haulage way to mill		Vegetation, adit overgrown		

LEGEND

- ■ Soil test pit with piezometer
- ▲ Waste rock sample
- ● Water quality sample site
- Disturbed area
- Building
- Power Line
- Tramway Line
- Highway #11
- Road
- Trail
- Stream or River
- Underground Workings
- Open pit, trench
- Waste rock dump
- Tailings area
- Adit entrance
- Shaft location

1. Mill
2. Smelter
3. Geology / Engineering Office
4. Bunkhouse
5. Snack Bar
6. Warehouse
7. Framing Shop
8. School
9. Curling Rink
10. General Store

UTM N TN MN

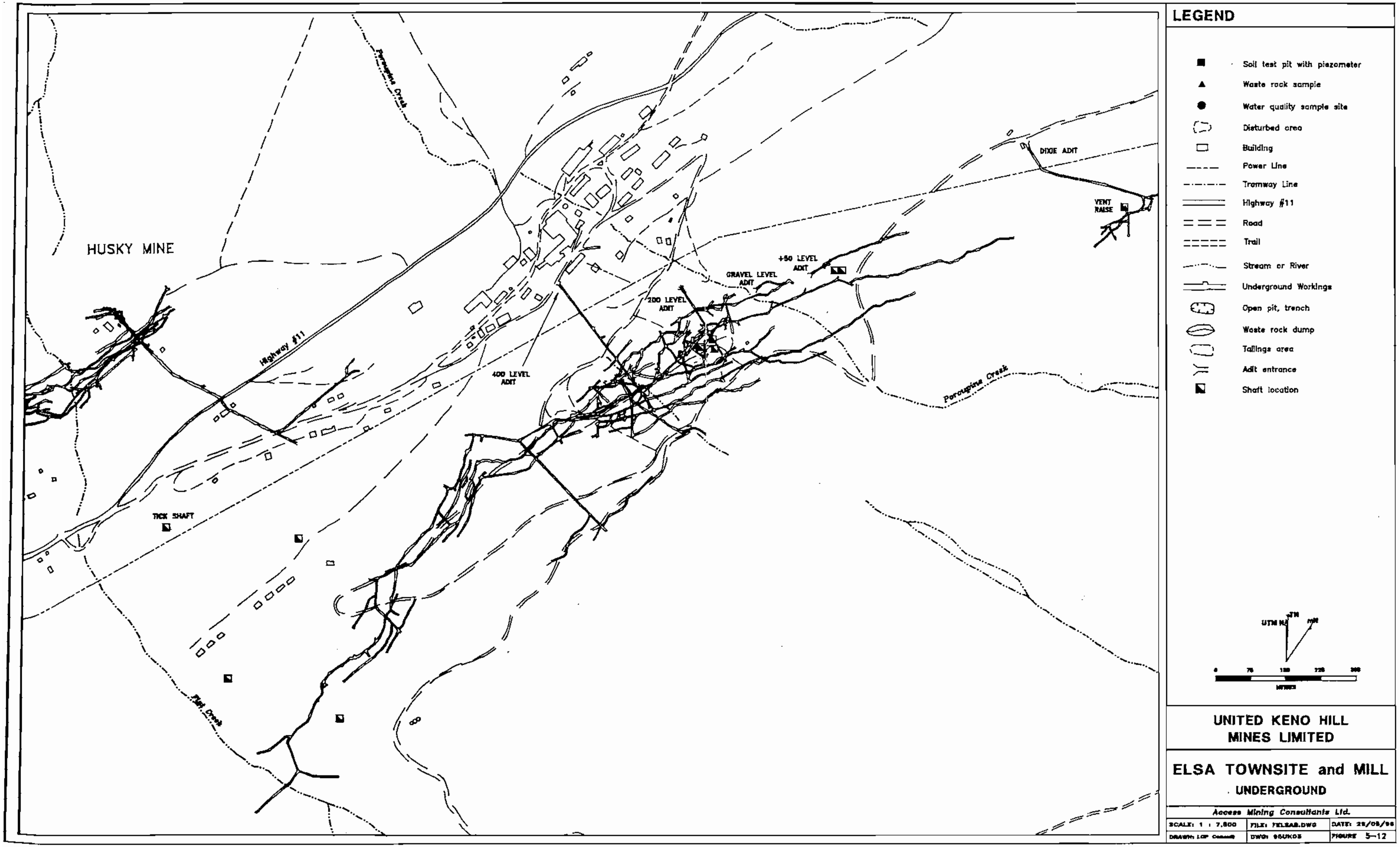
UNITED KENO HILL MINES LIMITED

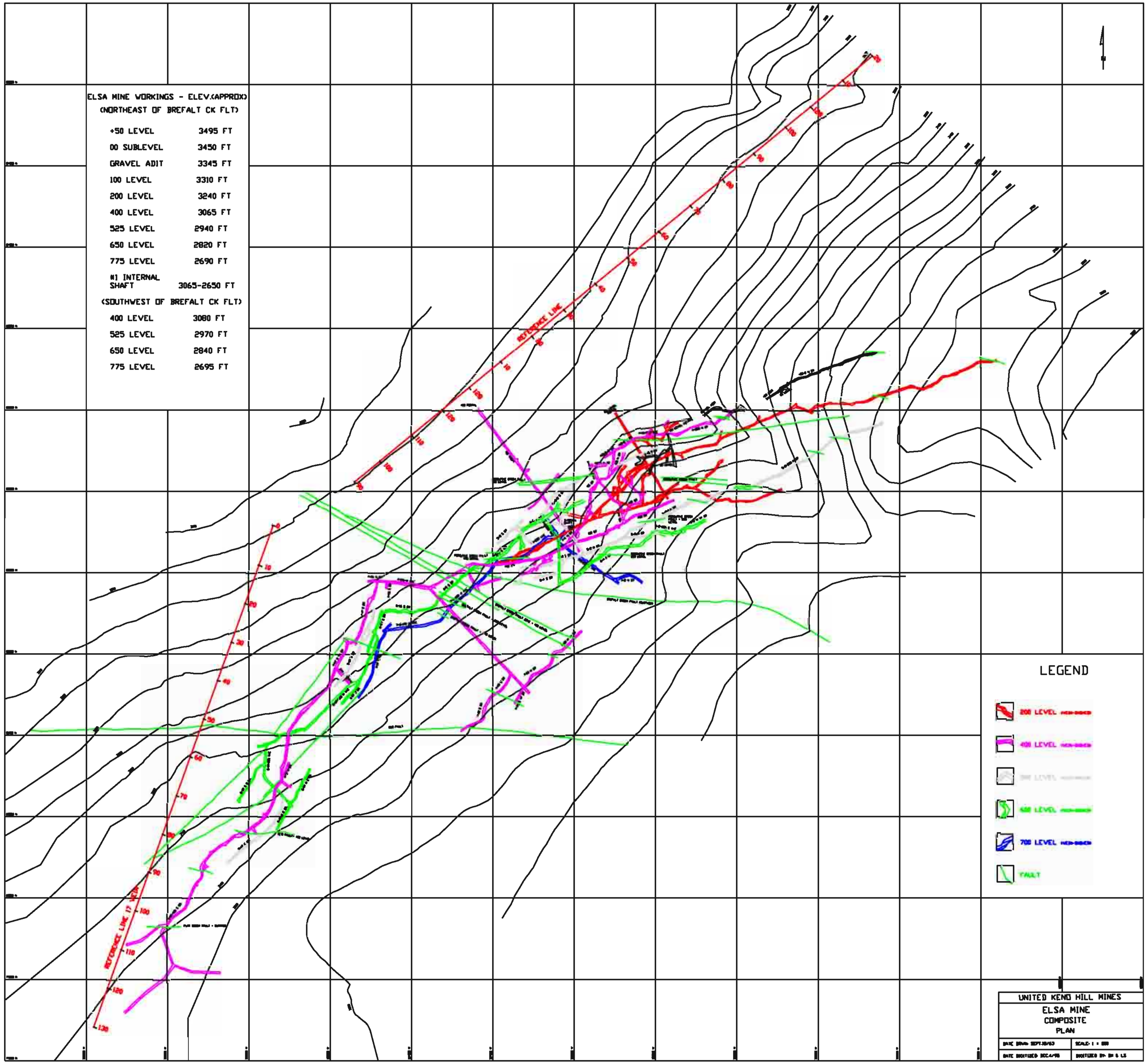
ELSA TOWNSITE and MILL

SITE PLAN

Access Mining Consultants Ltd.

SCALE: 1 : 7,500	FILE: FFLSAA.DWG	DATE: 29/05/96
DRAWN: LCP	DWG: 95UKO2	FIGURE 5-11


HUSKY MINE
Highway #11
Porcupine Creek
TICK SHAFT
Flat Creek
400 LEVEL ADIT
200 LEVEL ADIT
GRAVEL LEVEL ADIT
+50 LEVEL ADIT
DIXIE ADIT
VENT RAISE
Porcupine Creek
LEGEND
Soil test pit with piezometer
Waste rock sample
Water quality sample site
Disturbed area
Building
Power Line
Tramway Line
Highway #11
Road
Trail
Stream or River
Underground Workings
Open pit, trench
Waste rock dump
Tailings area
Adit entrance
Shaft location
UNITED KENO HILL
MINES LIMITED
ELSA TOWNSITE and MILL
UNDERGROUND
Access Mining Consultants Ltd.
SCALE: 1 : 7,500
FIGURE 5-12


ELSA MINE WORKINGS - ELEV.(APPROX)
(NORTHEAST OF BREFALT CK FLT)
+50 LEVEL 3495 FT
00 SUBLEVEL 3450 FT
GRAVEL ADIT 3345 FT
100 LEVEL 3310 FT
200 LEVEL 3240 FT
400 LEVEL 3065 FT
525 LEVEL 2940 FT
650 LEVEL 2820 FT
775 LEVEL 2690 FT
#1 INTERNAL SHAFT 3065-2650 FT
(SOUTHWEST OF BREFALT CK FLT)
400 LEVEL 3080 FT
525 LEVEL 2970 FT
650 LEVEL 2840 FT
775 LEVEL 2695 FT
REFERENCE LINE
REFERENCE LINE 17 VEIN
LEGEND
200 LEVEL
400 LEVEL
700 LEVEL
FAULT
UNITED KENO HILL MINES
ELSA MINE
COMPOSITE
PLAN

5.2.4 Elsa Mill and Tailings

Figures: Figure 5-14 Site Plan
Figure 5-15 (from EBA Report)
Figure 5-16
Figure 5-17
Figure 5-18
Figure 5-19
Figure 5-20
Figure 5-21

In 1932, the old Sadie Ladue Mill from Wernecke Camp was moved to Elsa and used there until 1942. Tailings from this mill reported to the hillside adjacent to Porcupine Creek.

The new Elsa Mill was commissioned in 1949, and ran, with some modifications and temporary shut downs, until the mine's cessation in 1988. During this period, over four million tons of tailings were deposited in the valley. Figure 5-14 shows the tailings facility today, consisting of three earth fill dams that impound the partially submerged tailings.

Dam No. 1 was originally constructed in 1968, and fortified after a failure in 1972. Dam No. 2 was also constructed in 1972. Dam No. 3 was constructed from local sand and gravel till in 1979. Porcupine Creek was diverted from the valley tailings area via the Porcupine Diversion ditch.

The EIsa tailings are located in the Flat Creek valley bottom below the Elsa mill site. The major accumulation of tailings is upstream from the main stem of Flat Creek in a swampy area draining into Flat Creek. Porcupine Creek passes through the tailings area. An additional area of older tailings is perched on the hillside above the valley bottom south of Porcupine Creek and just below the highway to Keno City. The areal extent of tailings is relatively well known from recent air photography. The total surface area of the impoundment is approximately 185 acres (75 ha). However, the depth of the material is uncertain.

Considerable drilling was done in the tailings area by UKHM in a number of campaigns. The tailings form in two lobes, the northern one, behind the #1 dam, is more recent than the other, more southerly one near Porcupine Creek, which expands down to the #3 pond. An isolated area of old tailings occurs just below the highway near Porcupine Creek. A capsule history of tailings deposition can be found in the 1990 plan. Some tailings were from cyanide leach operations whereas other years no cyanidation was carried out. It appears that the tailings from open pit operations are largely behind the #1 dam and uphill from there.

Porcupine Creek appears to have jumped its banks occasionally and eroded tailings from the old deposit. These events may have carried tailings into the area of the #3 pond and/or beyond.

The dams have been reviewed by EBA Engineering in a 1983 report "Geotechnical Evaluation of Existing Tailings Dams." Figures 5-15 through 5-21 illustrating the dams are from that report. Most of the dams are of unzoned construction and were built on frozen peat-rich soils overlying fill. The soils have since thawed causing subsidence of the dams. An engineering investigation of the dams is in progress the evaluate the current stability, and requirements for both future operation and for closure to ensure long-term stability.

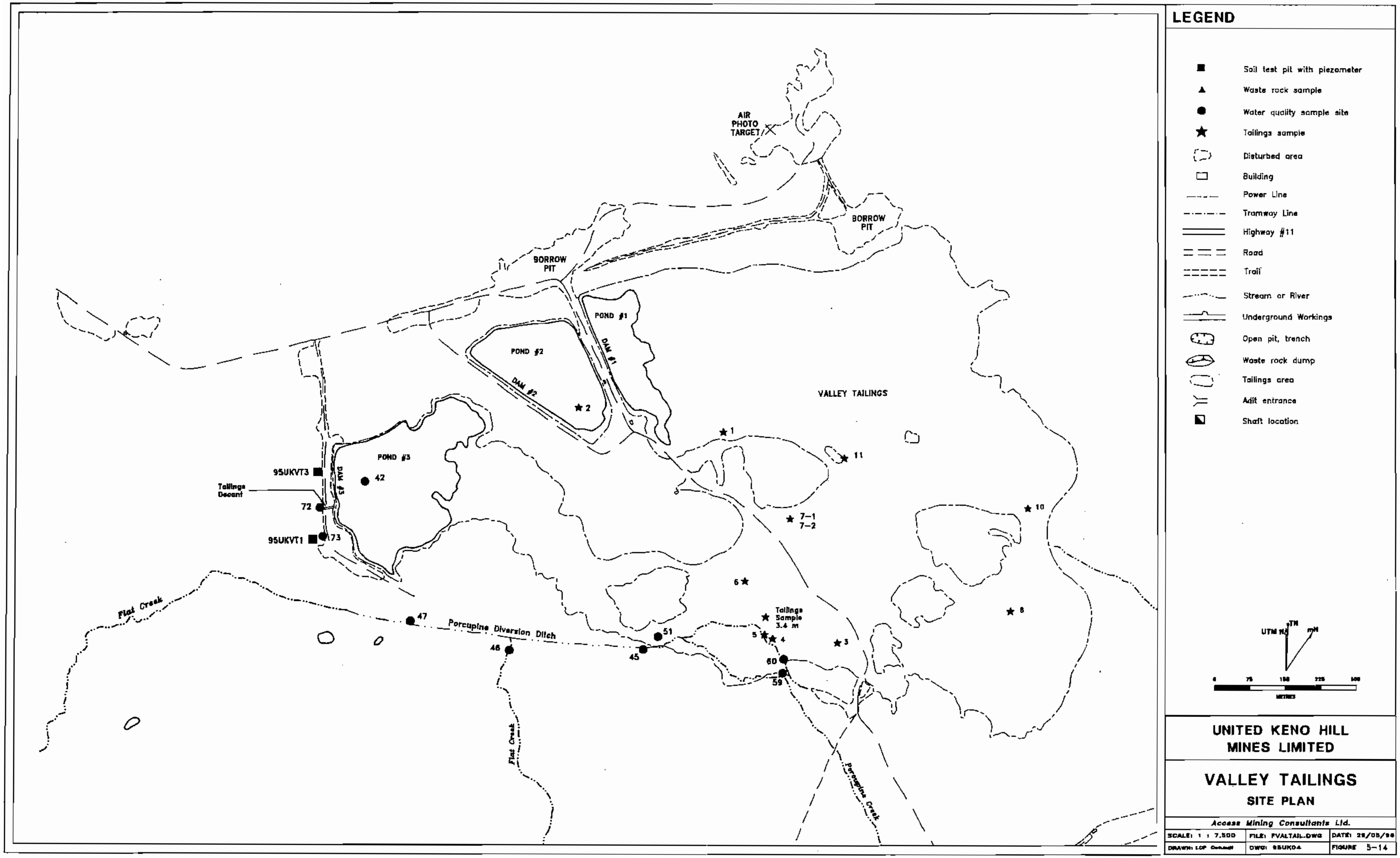
UKHM has kept up with the subsidence by adding mine rock to the low points every few years. Results of inspections of the dams can be found in a series of reports by EBA Engineering, the most recent of which is dated 1994. These inspection reports note on-going subsidence of the structures. The difficult foundation conditions of the dam sites have been a complicating factor for the closure plan.

The incomplete diversion of Porcupine Creek around the tailings is another complicating factor for closure. The central 400 m of the creek appears to pass over the south edge of the tailings. Most times of the year Porcupine Creek is dry, but as noted above, occasional floods (before 1984) appear to have entered the tailings area and may have eroded nearly a meter of tailings. Sand and gravel locally deposited on the tailings (by the floods) has developed good vegetative, zinc enriched, seepage emerges from the tailings and flows down lower Porcupine diversion to enter Flat Creek below #3 Pond.

Unquantified seepage passes beneath the dams. During 1994-95, Dam #1 was commonly observed to decant approximately 5 l/s whereas dam #2 did not decant at all. At the same time Dam #3 decanted 1-2 l/s.

The tailings behind Dam #1, where wet, have developed lush vegetation but the dry, sandy, upper part of the tailings deposit is barren. The dry tailings are subject to wind erosion from time to time.

The tonnage of tailings indicated by these drill results apparently reconciled well with the milled tonnage. However, recent backhoe excavations in the tailings area has thrown some doubt on the thickness indicated by previous drilling, since it was possible to excavate through the tails to the original ground surface. Only a third of the expected thickness was found to be present in some of those areas. The Elsa tailings are discussed further in the Field Investigations Report, Technical Appendix VI.



LEGEND
Soil test pit with piezometer
Waste rock sample
Water quality sample site
Tailings sample
Disturbed area
Building
Power Line
Tramway Line
Highway #11
Road
Trail
Stream or River
Underground Workings
Open pit, trench
Waste rock dump
Tailings area
Adit entrance
Shaft location
AIR PHOTO TARGET
BORROW PIT
BORROW PIT
POND #1
POND #2
POND #3
DAM #1
DAM #2
DAM #3
VALLEY TAILINGS
95UKVT3
95UKVT1
Tailings Decant
Tailings Sample 3.4 m
Flat Creek
Flat Creek
Porcupine Diversion Ditch
Porcupine Creek
UTM N
TN
MN
METRES
UNITED KENO HILL MINES LIMITED
VALLEY TAILINGS
SITE PLAN
Access Mining Consultants Ltd.
SCALE: 1 : 7,500
FILE: FVALTAIL.DWG
FIGURE 5-14

Figure 5-15

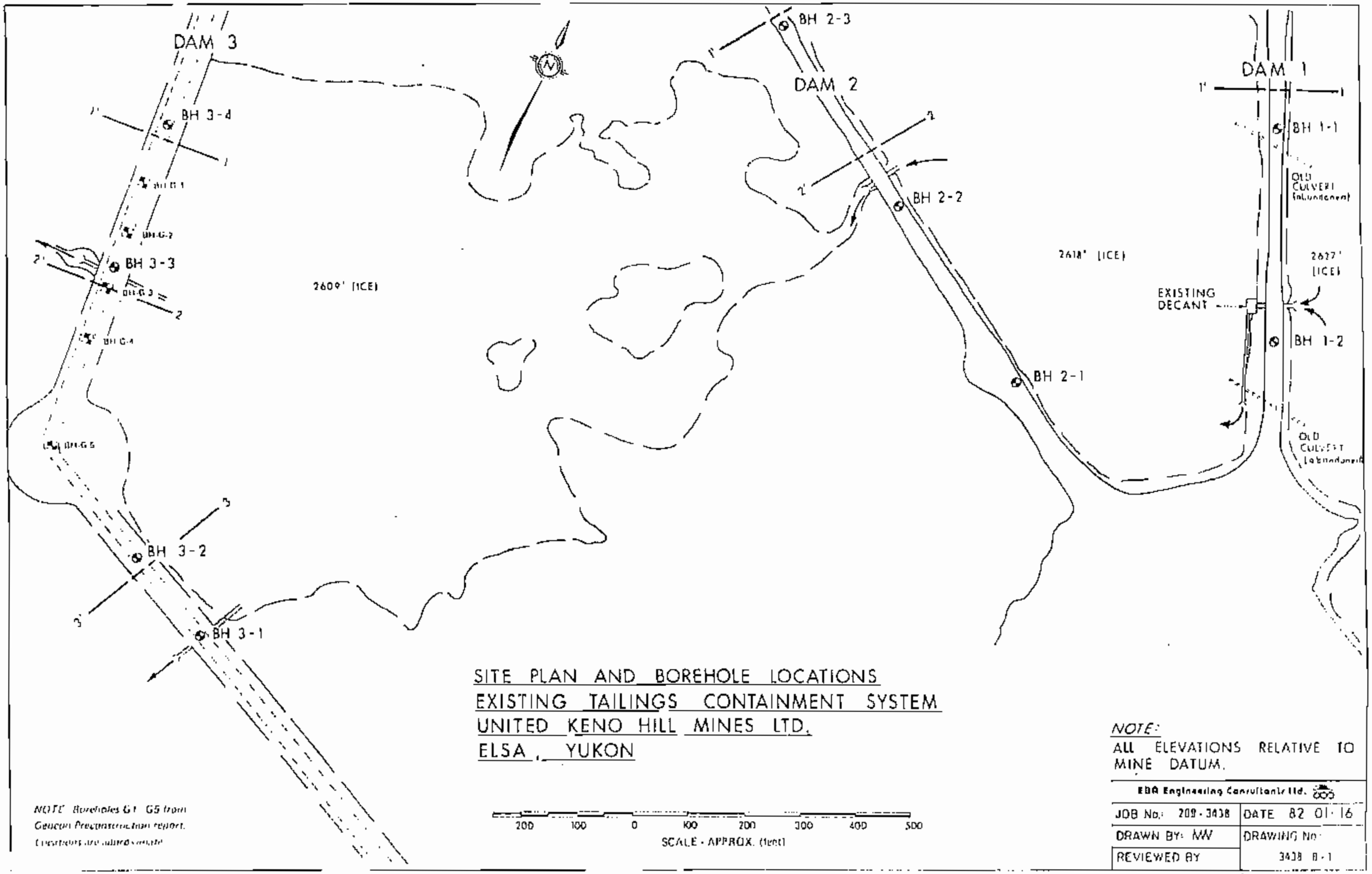

DAM 3
DAM 2
DAM 1
BH 2-3
BH 3-4
BH 1-1
BH 2-2
BH 3-3
2609' (ICE)
2618' (ICE)
2627' (ICE)
OLD CULVERT (abandoned)
EXISTING DECANT
BH 1-2
BH 2-1
BH 3-2
BH 3-1
SITE PLAN AND BOREHOLE LOCATIONS
EXISTING TAILINGS CONTAINMENT SYSTEM
UNITED KENO HILL MINES LTD.
ELSA, YUKON
NOTE:
ALL ELEVATIONS RELATIVE TO MINE DATUM.
200 100 0 100 200 300 400 500
SCALE - APPROX. (feet)
EBA Engineering Consultants Ltd.
JOB No.: 209-3438
DATE 82 01 16
DRAWN BY: MW
DRAWING No:
REVIEWED BY
3438 B-1

Figure 5-16

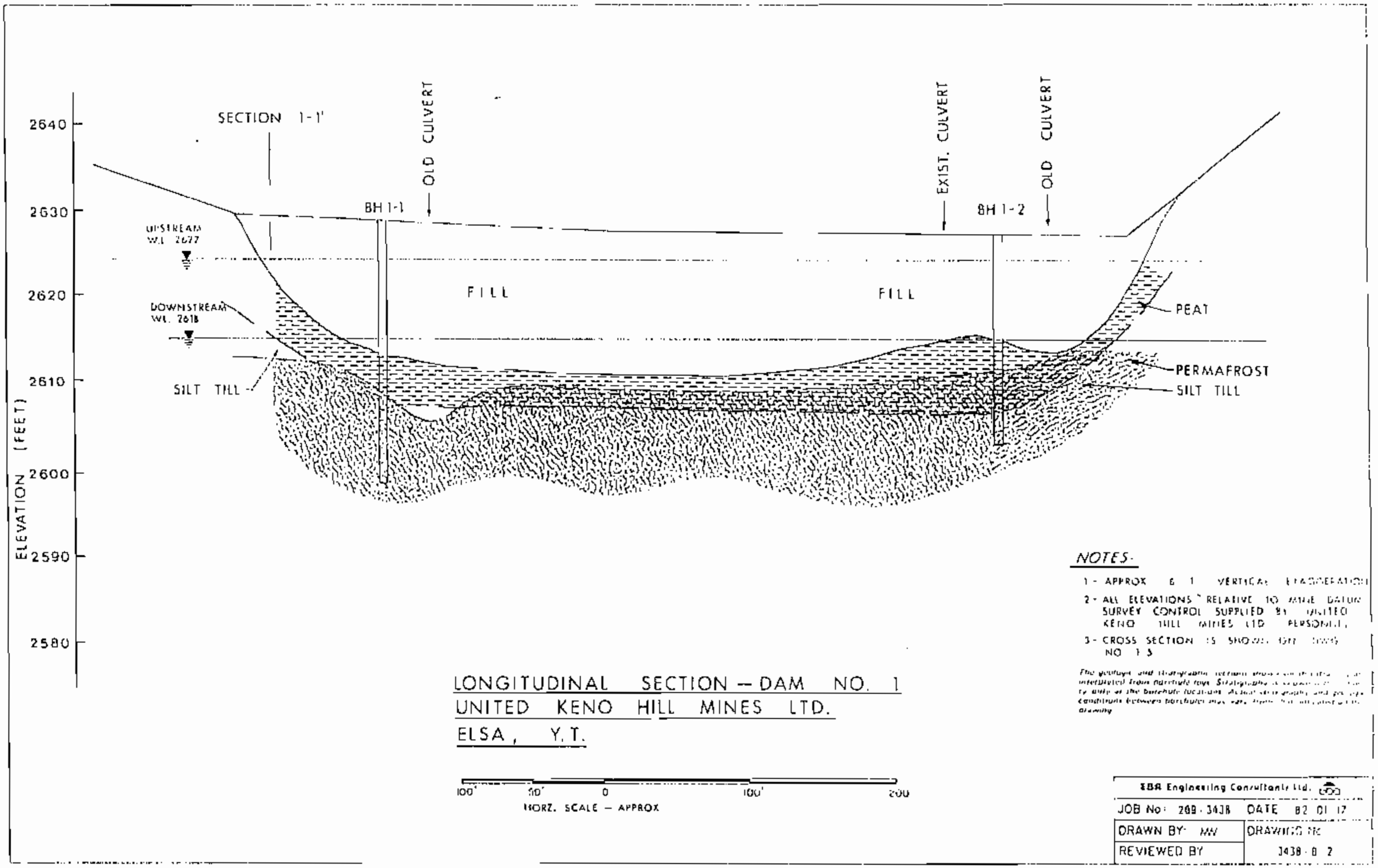

SECTION 1-1'
OLD CULVERT
EXIST. CULVERT
OLD CULVERT
BH 1-1
BH 1-2
2640
2630
2620
2610
2600
2590
2580
ELEVATION (FEET)
UPSTREAM W.L. 2627
DOWNSTREAM W.L. 2618
FILL
FILL
PEAT
PERMAFROST
SILT TILL
SILT TILL
NOTES
1 - APPROX 6 1 VERTICAL EXAGGERATION
2 - ALL ELEVATIONS RELATIVE TO MINE DATUM SURVEY CONTROL SUPPLIED BY UNITED KENO HILL MINES LTD PERSONNEL
3 - CROSS SECTION IS SHOWN ON DWG NO 1 3
LONGITUDINAL SECTION – DAM NO. 1
UNITED KENO HILL MINES LTD.
ELSA, Y.T.
100' 50' 0 100' 200
HORZ. SCALE – APPROX
EBA Engineering Consultants Ltd.
JOB No: 209-3438 DATE 82 01 17
DRAWN BY: MW
REVIEWED BY
DRAWING No
3438-B 2

Figure 5-17

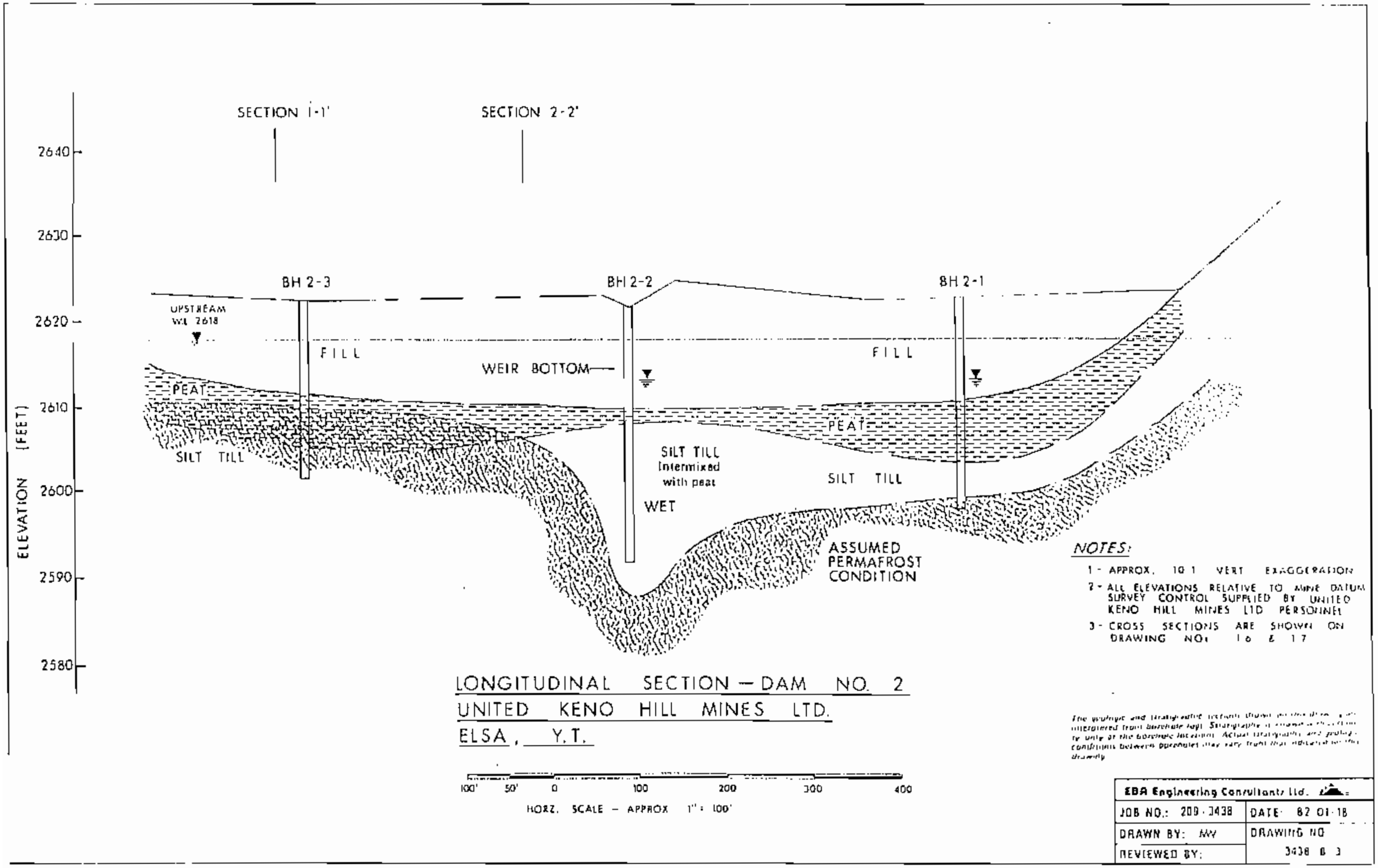

SECTION 1-1'
SECTION 2-2'
2640
2630
2620
2610
2600
2590
2580
ELEVATION (FEET)
BH 2-3
BH 2-2
BH 2-1
UPSTREAM
WL 2618
FILL
WEIR BOTTOM
FILL
PEAT
PEAT
SILT TILL
SILT TILL
Intermixed
with peat
WET
SILT TILL
ASSUMED
PERMAFROST
CONDITION
NOTES:
1 - APPROX. 10:1 VERT EXAGGERATION
2 - ALL ELEVATIONS RELATIVE TO MINE DATUM SURVEY CONTROL SUPPLIED BY UNITED KENO HILL MINES LTD PERSONNEL
3 - CROSS SECTIONS ARE SHOWN ON DRAWING NO. 16 & 17
LONGITUDINAL SECTION – DAM NO. 2
UNITED KENO HILL MINES LTD.
ELSA, Y.T.
100' 50' 0 100 200 300 400
HORZ. SCALE – APPROX 1" = 100'
EBA Engineering Consultants Ltd.
JOB NO.: 209-3438
DATE: 82 01 18
DRAWN BY: MY
DRAWING NO
REVIEWED BY:
3438 8 3

Figure 5-18

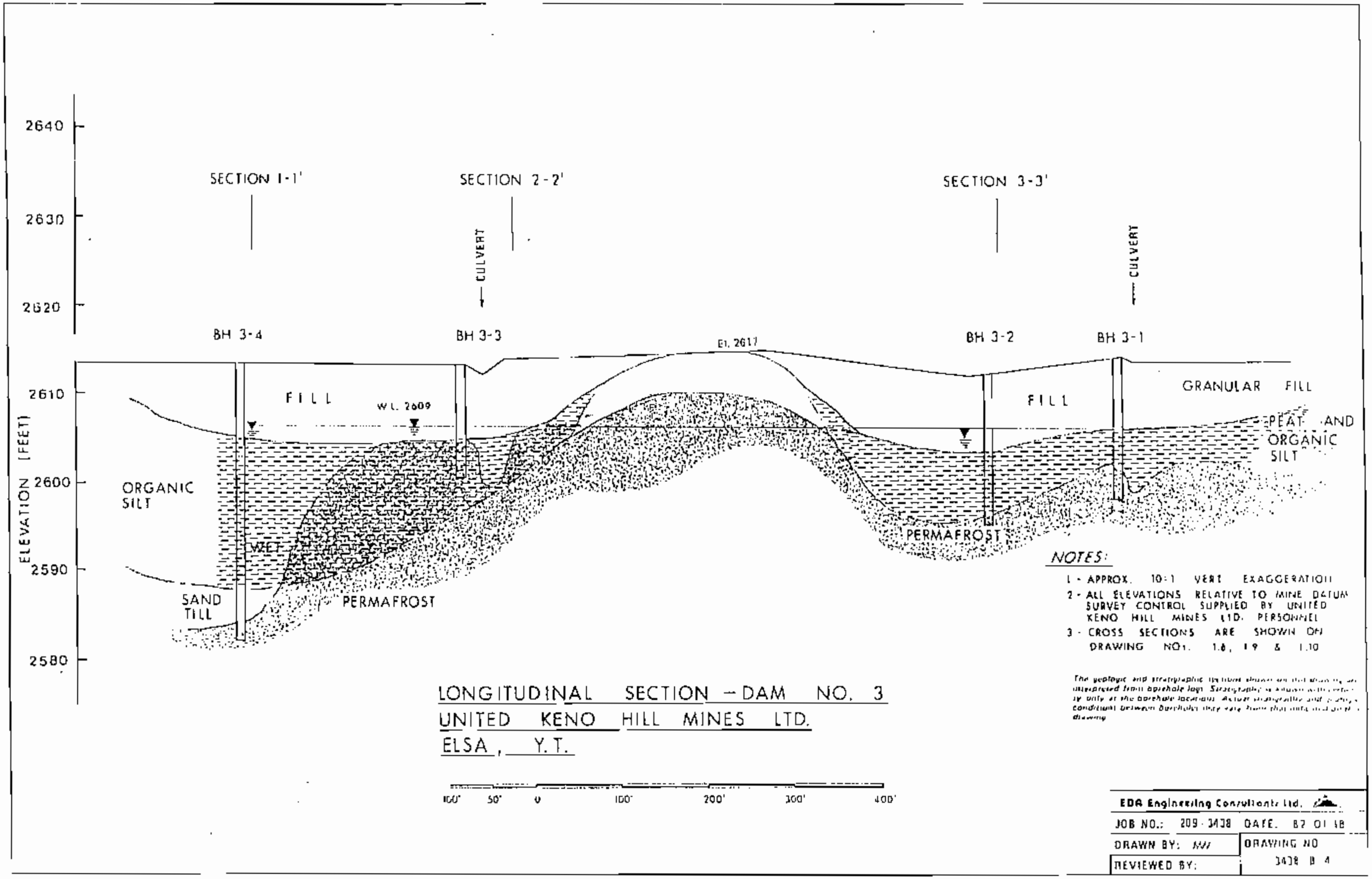
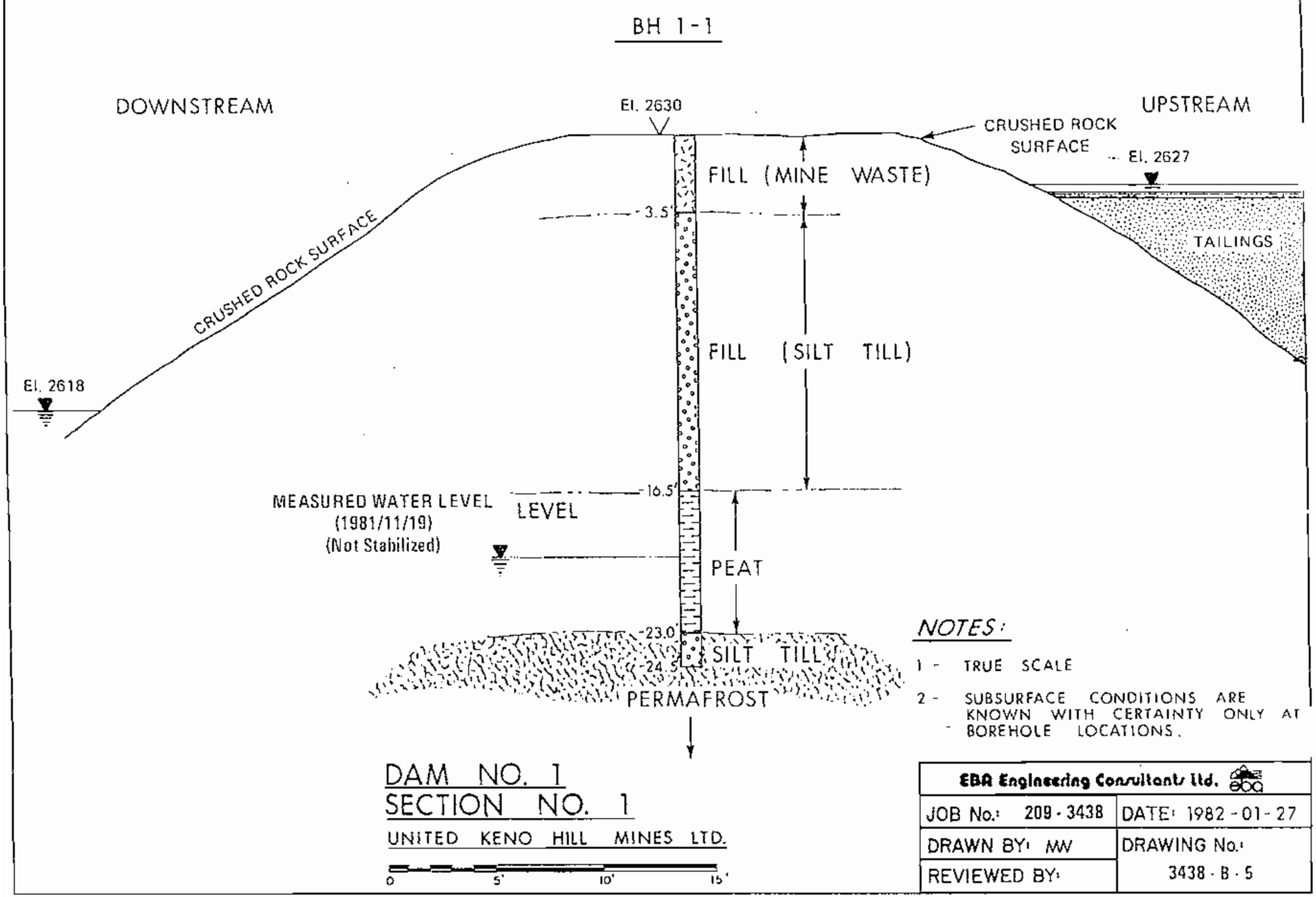

2640
2630
2620
2610
2600
2590
2580
ELEVATION (FEET)
SECTION 1-1'
SECTION 2-2'
SECTION 3-3'
CULVERT
CULVERT
BH 3-4
BH 3-3
BH 3-2
BH 3-1
EL. 2617
FILL
W.L. 2609
FILL
GRANULAR FILL
PEAT AND ORGANIC SILT
ORGANIC SILT
WET
SAND TILL
PERMAFROST
PERMAFROST
NOTES:
1 - APPROX. 10:1 VERT EXAGGERATION
2 - ALL ELEVATIONS RELATIVE TO MINE DATUM SURVEY CONTROL SUPPLIED BY UNITED KENO HILL MINES LTD. PERSONNEL
3 - CROSS SECTIONS ARE SHOWN ON DRAWING NO. 1.8, 1.9 & 1.10
LONGITUDINAL SECTION - DAM NO. 3
UNITED KENO HILL MINES LTD.
ELSA, Y.T.
100' 50' 0 100' 200' 300' 400'
EBA Engineering Consultants Ltd.
JOB NO.: 209-3438
DATE. 87 01 18
DRAWN BY: MW
DRAWING NO
3438 B 4
REVIEWED BY:

Figure 5-19



NOTES:

1 - TRUE SCALE

2 - SUBSURFACE CONDITIONS ARE KNOWN WITH CERTAINTY ONLY AT BOREHOLE LOCATIONS.

DAM NO. 1
SECTION NO. 1
UNITED KENO HILL MINES LTD.

EBA Engineering Consultants Ltd.	
JOB No.: 209 - 3438	DATE: 1982 - 01 - 27
DRAWN BY: MW	DRAWING No.:
REVIEWED BY:	3438 - B - 5

Figure 5-20

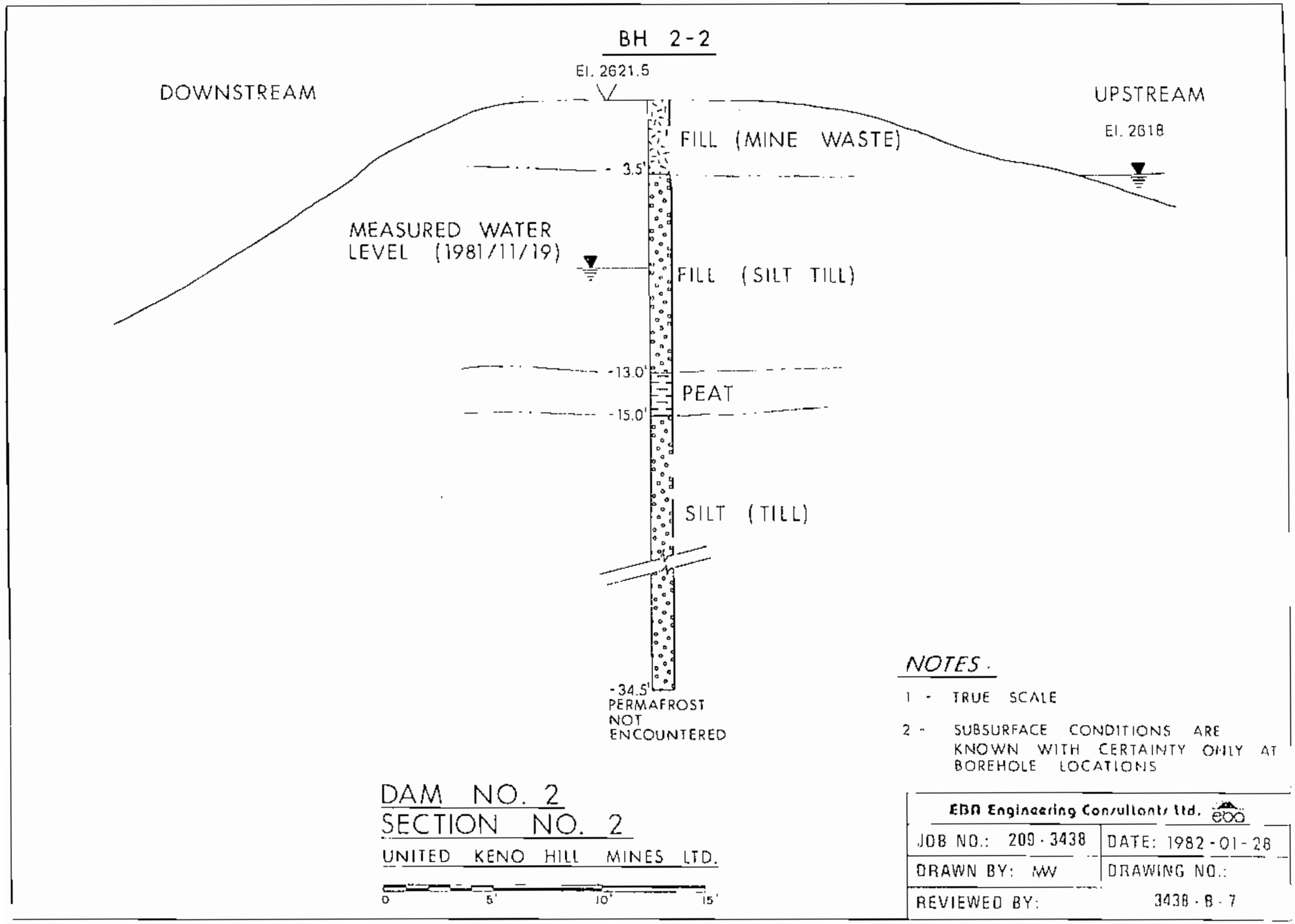
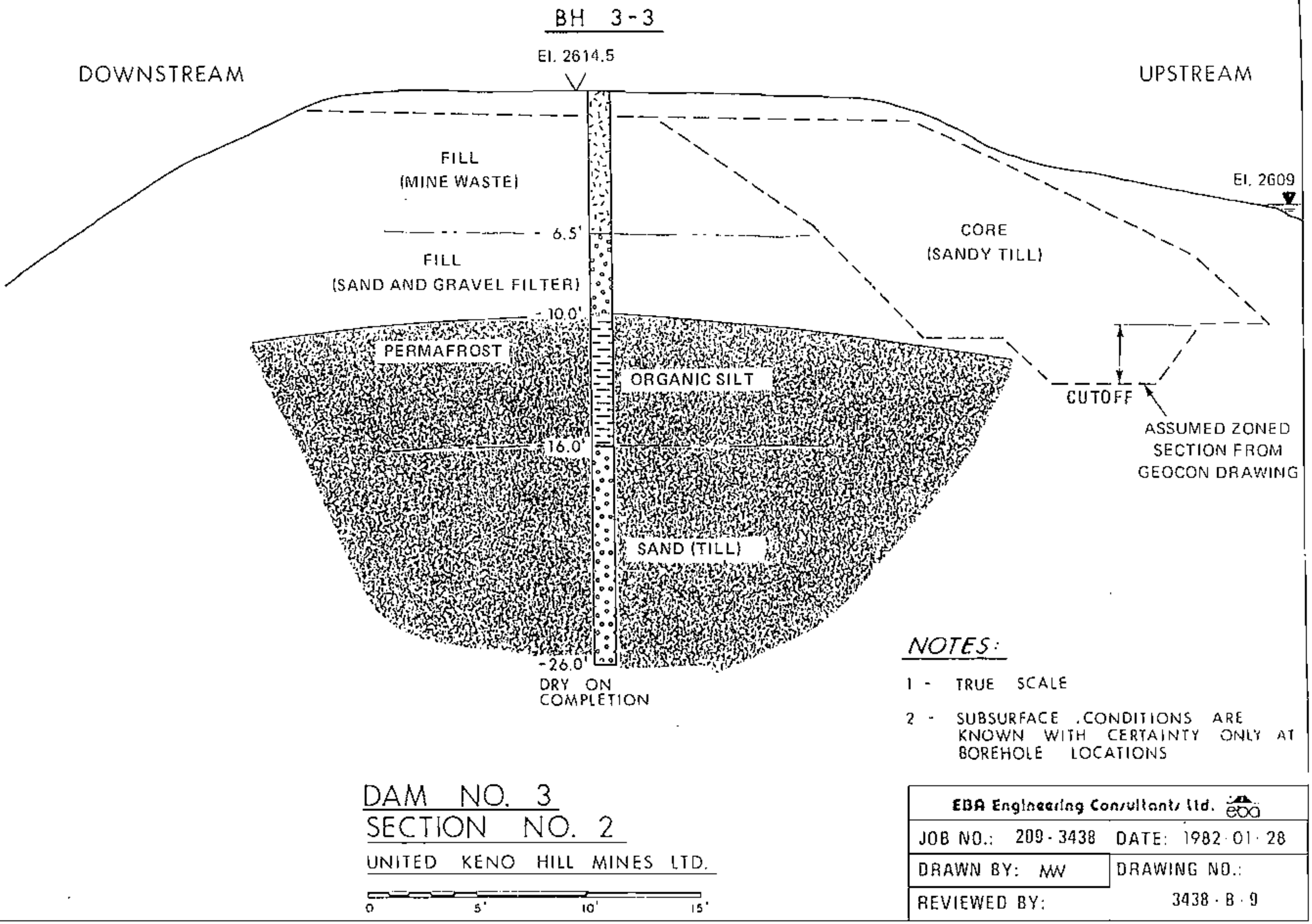

BH 2-2
El. 2621.5
DOWNSTREAM
UPSTREAM
El. 2618
FILL (MINE WASTE)
3.5'
MEASURED WATER
LEVEL (1981/11/19)
FILL (SILT TILL)
-13.0'
PEAT
-15.0'
SILT (TILL)
-34.5'
PERMAFROST
NOT
ENCOUNTERED
NOTES.
1 - TRUE SCALE
2 - SUBSURFACE CONDITIONS ARE KNOWN WITH CERTAINTY ONLY AT BOREHOLE LOCATIONS
DAM NO. 2
SECTION NO. 2
UNITED KENO HILL MINES LTD.
0
5'
10'
15'
EBA Engineering Consultants Ltd.
JOB NO.: 209 - 3438
DATE: 1982 - 01 - 28
DRAWN BY: MW
DRAWING NO.:
REVIEWED BY:
3438 - B - 7

Figure 5-21



NOTES:

1 - TRUE SCALE

2 - SUBSURFACE CONDITIONS ARE KNOWN WITH CERTAINTY ONLY AT BOREHOLE LOCATIONS

DAM NO. 3
SECTION NO. 2
UNITED KENO HILL MINES LTD.

EBA Engineering Consultants Ltd.	
JOB NO.: 209-3438	DATE: 1982-01-28
DRAWN BY: MW	DRAWING NO.:
REVIEWED BY:	3438-B-9

5.2.5 Galkeno

Development: Table 5-5-a and 5-5-b

Figures: Figure 5-22 Site Plan

Figure 5-23 Site Plan

Figure 5-24 Galkeno Mine, Cross-section showing McLeod, Sime Workings and 900 Level Adit, Looking Northeast

Figure 5-25 Galkeno Mine, Vertical Longitudinal Section, Looking Azimuth 330°

Figure 5-26 Galkeno McLeod Vein, Vertical Longitudinal Section, Looking West

Figure 5-27 Jock, Hector, Calumet and Galkeno Mines Composite Plan

Galkeno mine is primarily an underground mining area, mining two veins; the McLeod Vein and the Sime Vein. The area was mined in the 1950's and 60's. UKHM did not mine from any of the McLeod workings, but did development work on the Sime 400 and 500 levels.

The McLeod Vein was mined from underground, with workings from the 100 to 500 levels, and an adit at the 900 level. The 900 level adit was driven to dewater the McLeod Vein workings below the 500 level, but apparently was not used for production.

The adits at the 100 and 200 levels have both caved, preventing access to the underground.

The adit at the 300 level is open, blocked by a wooden door but not locked. The 300 level adit connects the McLeod and Sime workings. There was also a shaft on the McLeod vein connecting surface with the 100 level. It is reported that this shaft has caved, which will be confirmed.

In the fall of 1993, an hydraulic plug was installed by UKHM in the Galkeno 900 level adit, in response to concerns from Environment Canada that this adit was a major source of contaminant loading to the receiving environment. This installation is summarized in Section 5.2.6, and discussed in detail in the "UKHM Galkeno 900

Hydraulic Plug As-Built Report" (Klohn Crippen, 1995). The objective of the installation was to cause flooding of the underground workings which would limit oxidation and dissolution of metals into the drainage water.

It has been recognised, given the geology of the hillside and extent of development above the 900 level, that :

- the workings would not entirely flood and the source of soluble metals could continue; and,
- as water accumulated behind the plug, the increasing hydraulic head would force the water to seep from the rock mass beyond the plug and surrounding grout curtain, and to daylight elsewhere in the hillside.

Therefore, a temporary active water treatment system has been established at the Galkeno 900 adit, comprising lime addition and two settling ponds. Investigations into passive treatment systems are in progress, based on observations of *in-situ* sulphate reduction downstream of the Galkeno 900 adit drainage. This work is described in more detail in Technical Appendix II.

The Sime Vein was mined both from a series of three open pits, and from underground. Access to underground was through two adits at the 200 and 300 levels, with an internal shaft connecting the 300 level to the 400 and 500 levels. The 300 level is partly caved, and connects to the Hector-Calumet 775 level. The status of the 200 level adit must be checked. It is assumed that some closure measures will be required.

The Sime open pits have some waste rock associated with them, but appear to have been mined in sequence, with waste deposited in and around the open pits. While no shafts are located within the pits, it appears that some stopes broke through to the pit floor, keeping the pits drained. The floors and lower benches of the upper two pits, called Sime 6 and Sime 4, are covered with broken rock.

The McLeod and Sime underground workings are also connected by a cross-cut at the 500 level. Prior to the development of this cross-cut, there was no hydraulic connection between the workings below the 400 level, as evidenced by the water level recorded in March 1965. This is shown on Figure 5-24.

Also associated with the Galkeno area is the former Galkeno mill and tailings. This mill was operated by Mackeno Mines in the 1950's, with some custom milling. UKHM did not use this mill, or the tailings facilities. All of the buildings were removed from the area, and some contouring done. While anecdotal evidence indicates that the tailings were deposited in the lake, at least during winter months, old air photos show what appears to be a tailings impoundment adjacent to the mill and upstream of the mouth of Christal Lake. It is likely that the custom milling operations resulted in tailings deposition in different areas, that is, both on-land and underwater disposal.

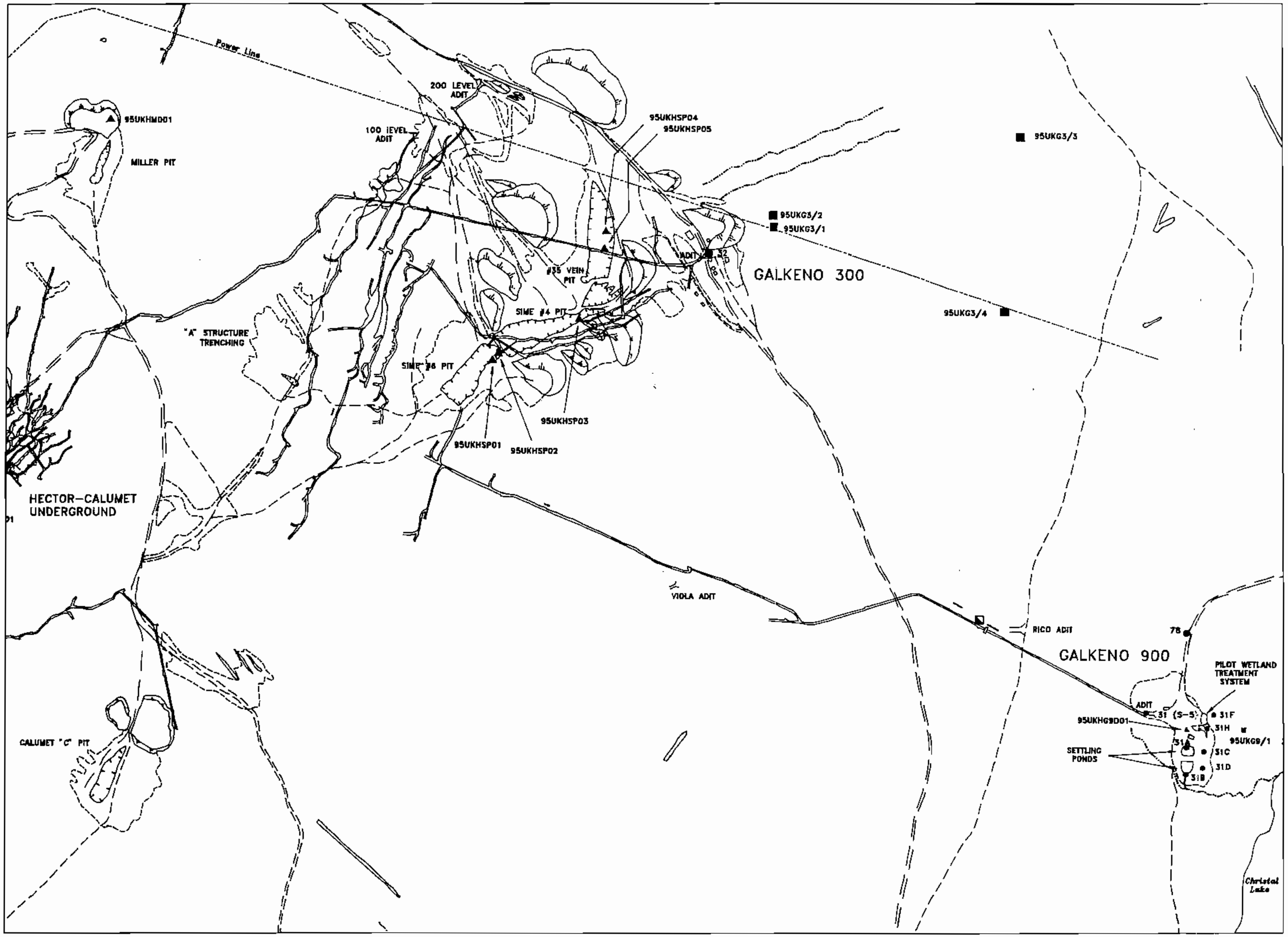
TABLE 4-5a

Mine Development								
Mine:	Galkeno including McLeod and Sime veins							
Location:								
Period of Development:		100 Adit	200 Adit	300 Adit	500	900 Adit		
Developed by:		Mackeno	Mackeno	Mackeno+UKHM	UKHM	Mackeno		
Monitoring at:	S-5							
Development at Galkeno								
	Underground	**Shafts, Raises**	**Bldgs**	**Rock Piles**				**Other**
		Portals, Adits	**& Equip.**	**@ 100**	**@ 200**	**@ 300**	**@ 900**	
Period of	5 levels							
Development	100: 1953 to 1957	1953		1953 to 1957	1953 to 1957	1953 to 1957	1957 to	1994 to present
	200: 1953 to 1957	1953				1958 to1965	1965	Treatment plant
	300: 1953 to 1957	1953		UKHM did not	UKHM did not			for discharge
	and 1958 to 1965			use adit	use adit			from bulkhead
	500: as for 300							
	900: 1957 to 1965	1957						
Production or				11,600 tons	4,000 tons	135,000 tons	20,800 tons	
Tonnage	167,063 tons =							
	UKHM production							
Features				1.57 oz Ag/t		1.77 oz Ag/t		Two settling
	100:	collapse, overgrown		0.37% Pb		0.40% Pb		ponds plus
	200:	timbered, overgrown		0.42% Zn		0.33% Zn		test wetland
	300:	timbered, doors		quartzite and	quartzite and	quartzite and		
	900:	bulkhead (1994)		schist	schist	schist		
Geometry		100 adit 2300'		road to Sime	road to Sime		slopes 35^o	
		200 adit 450'		6 pit crosses	6 pit crosses			
		300 adit 2400'		dump	dump			
		900 adit 4950'						
Drainage						Fe stain		
						dead veg.		
Remarks	Hydraulic bulkhead			1978 UKHM processed			Revegetation	
	installed at Galkeno			1,041 tons of waste rock from			Fireweed and	
	900 level, Oct. 1994			either or both 100 and 200 level			alder/willow	
				Limited revegetation				

TABLE 4-5b

Mine Development						
Mine:	Galkeno - old area					
Location:	Galena Hill (?) at Christal Lake					
Period of Development:		1953 to 1959?				
Developed by:		Mackeno Mines				
Monitoring:	S-18, S-19					
Development at Galkeno						
	Bldgs and Equip.	**Rock Piles waste, ore**	**Tailings**	**Mill or Plant**	**Other**	**Townsite**
Period of Development			1953 to 1957	1953 to Sept. 1957		
Production or Tonnage			~70,000 tons	846,747 tons of ore		
Features			EBA reports two small tailings ponds but no dams No comment on tailings in Lake.	Removed and burned Looks like waste rock used for site		
Geometry						
Drainage			Christal Creek and Lake Unconfirmed reports of tailings dumped in lake	Christal Creek and Lake		
Remarks				Custom milling; milled early Bellekeno production as well as Galkeno, Mackeno		

27/05/2004



LEGEND

- Soil test pit with piezometer
- Waste rock sample
- Water quality sample site
- Disturbed area
- Building
- Power Line
- Tramway Line
- Highway #11
- Road
- Trail
- Stream or River
- Underground Workings
- Open pit, trench
- Waste rock dump
- Tailings area
- Adit entrance
- Shaft location

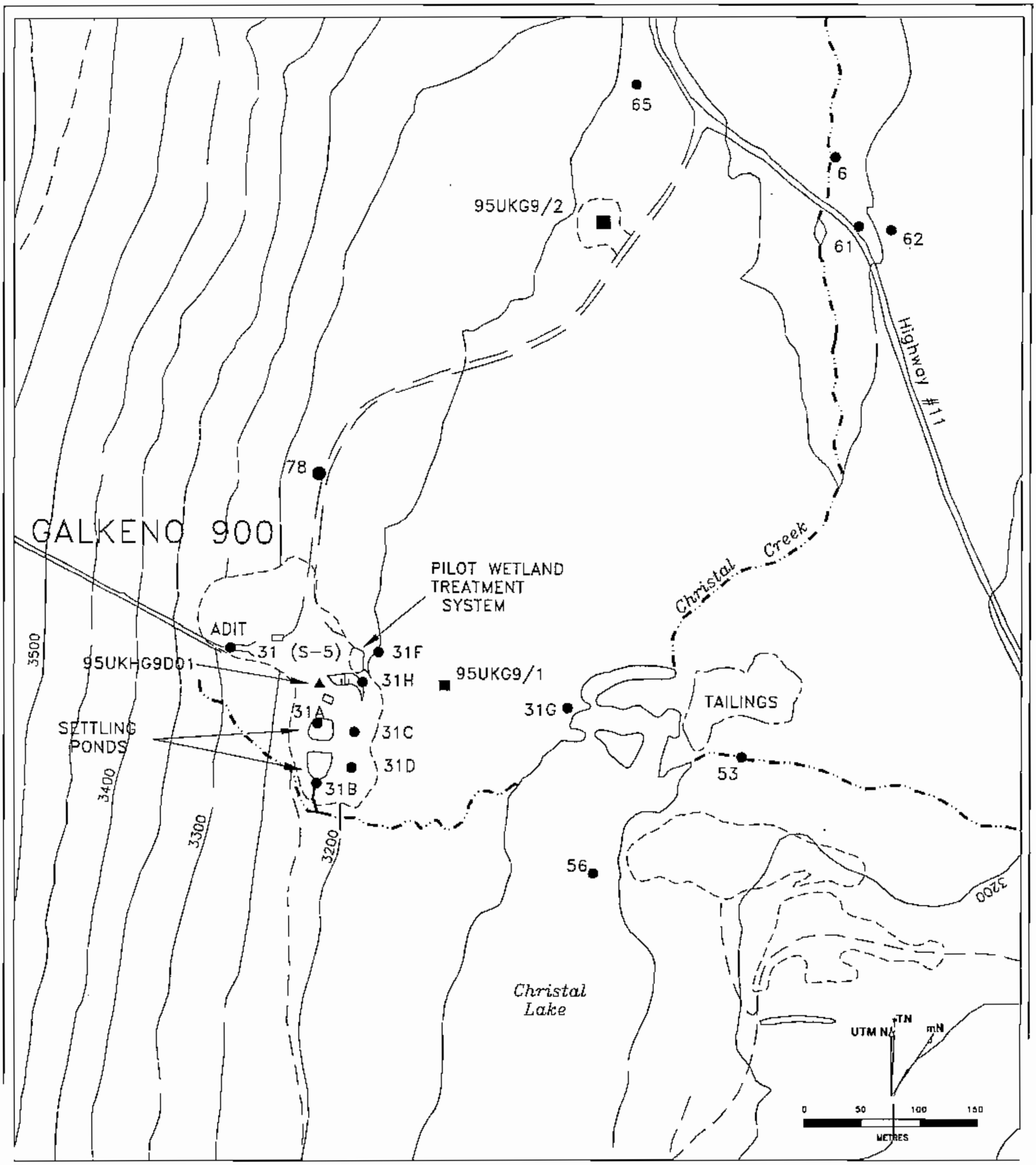
UNITED KENO HILL MINES LIMITED

GALKENO

SITE PLAN

Access Mining Consultants Ltd.

SCALE: 1 : 7,500	FILE: FGALKENO.DWG	DATE: 29/06/96
DRAWN: LCP Consult	DWG: 95UK18	FIGURE 5-22



LEGEND

- ■ Soil test pit with piezometer
- ▲ Waste rock sample
- ● Water quality sample site
- Disturbed area
- Building
- Power Line
- Telephone Line
- Highway #11
- Road
- Trail
- Stream or River
- Underground Workings
- Open pit, trench
- Waste rock dump
- Tailings area
- Adit entrance
- Shaft location

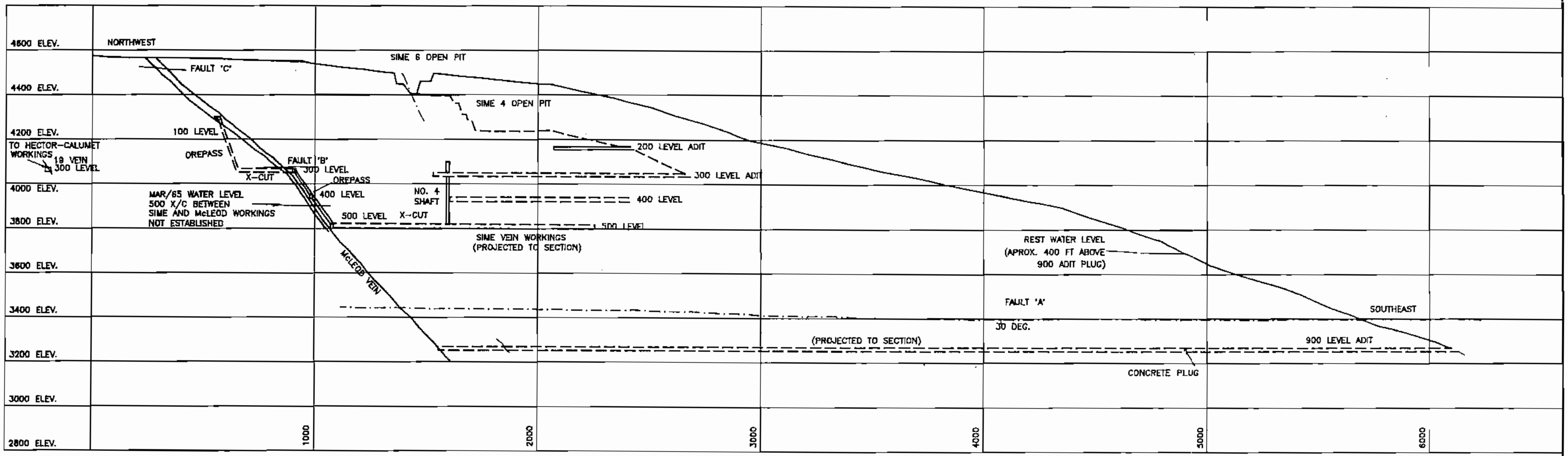
UNITED KENO HILL MINES LIMITED

GALKENO 900

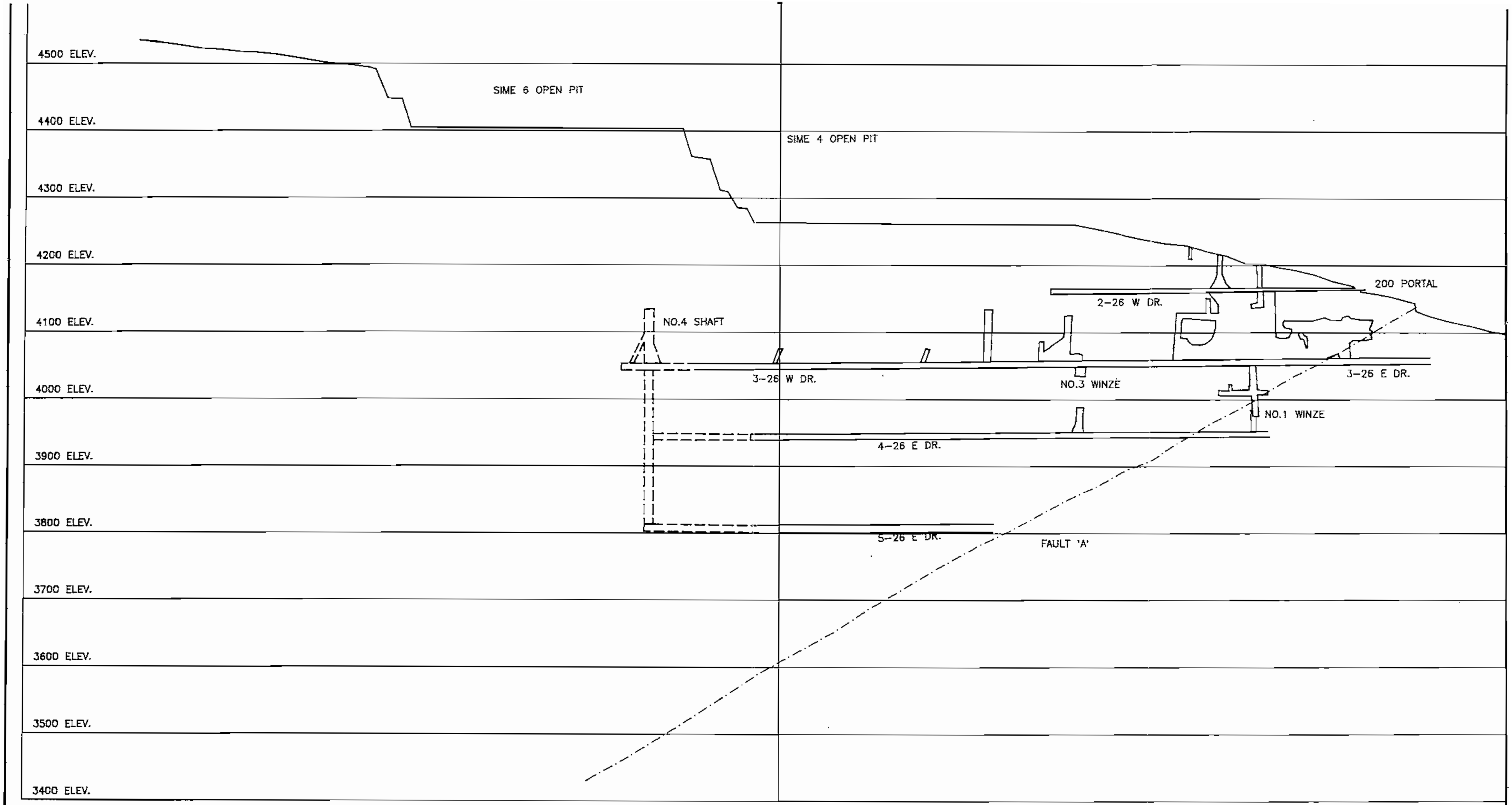
SITE PLAN

Access Mining Consultants Inc.

SCALE: 1 : 5,000	FILE: FGKNO900.DWG	DATE: 29/05/96
DRAWN: LCP Consult	DWG: 95UK1D	FIGURE 5-23



UNITED KENO HILL MINES LIMITED		
MINE WORKINGS		
X-SECTION SHOWING McCLEOD, SIME WORKINGS & 900 LEVEL ADIT (Looking Northeast)		
ACCESS MINING CONSULTANTS LTD.		
SCALE: NONE	FILE: GALSIME_DWG	DATE: 28/05/96
PLOTTED:	DWG: 95UK33	FIGURE: 5-24



UNITED KENO HILL MINES LIMITED

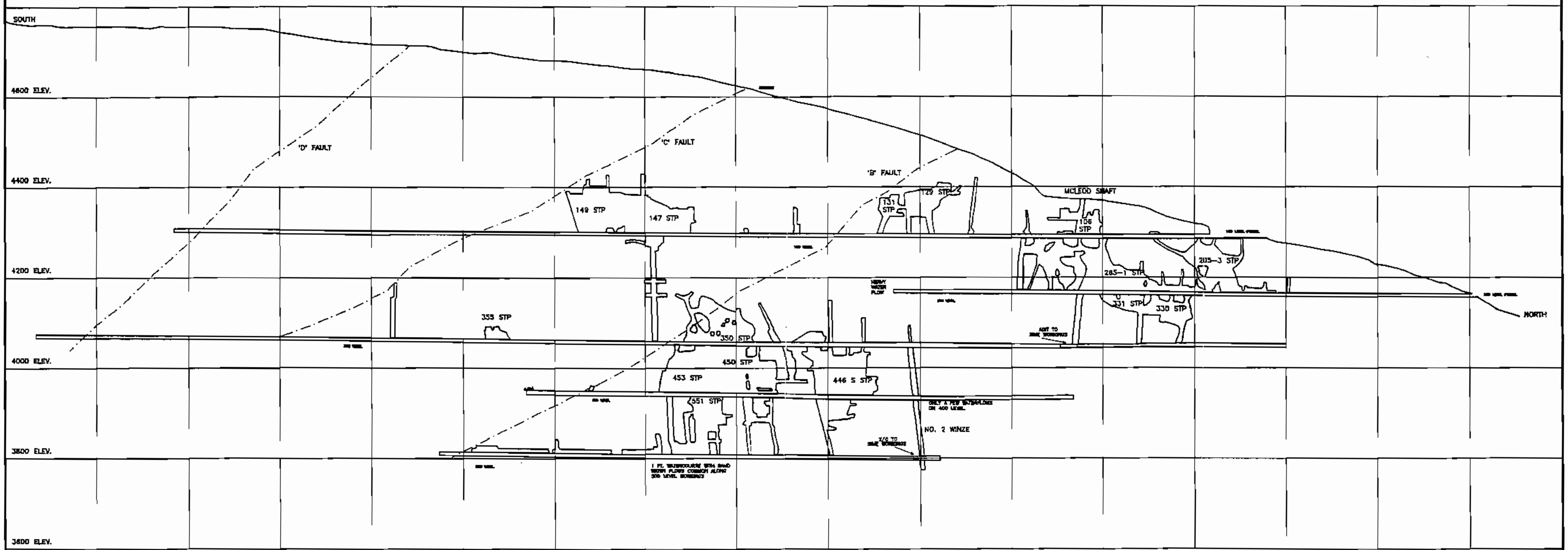
MINE WORKINGS

GALKENO MINE

VERTICAL LONGITUDINAL SECTION (Looking Azimuth 330°)

ACCESS MINING CONSULTANTS LTD.

SCALE: NONE	FILE: GALVERT.DWG	DATE: 28/05/96
PLOTTED:	DWG: 95UK34	FIGURE: 5-25



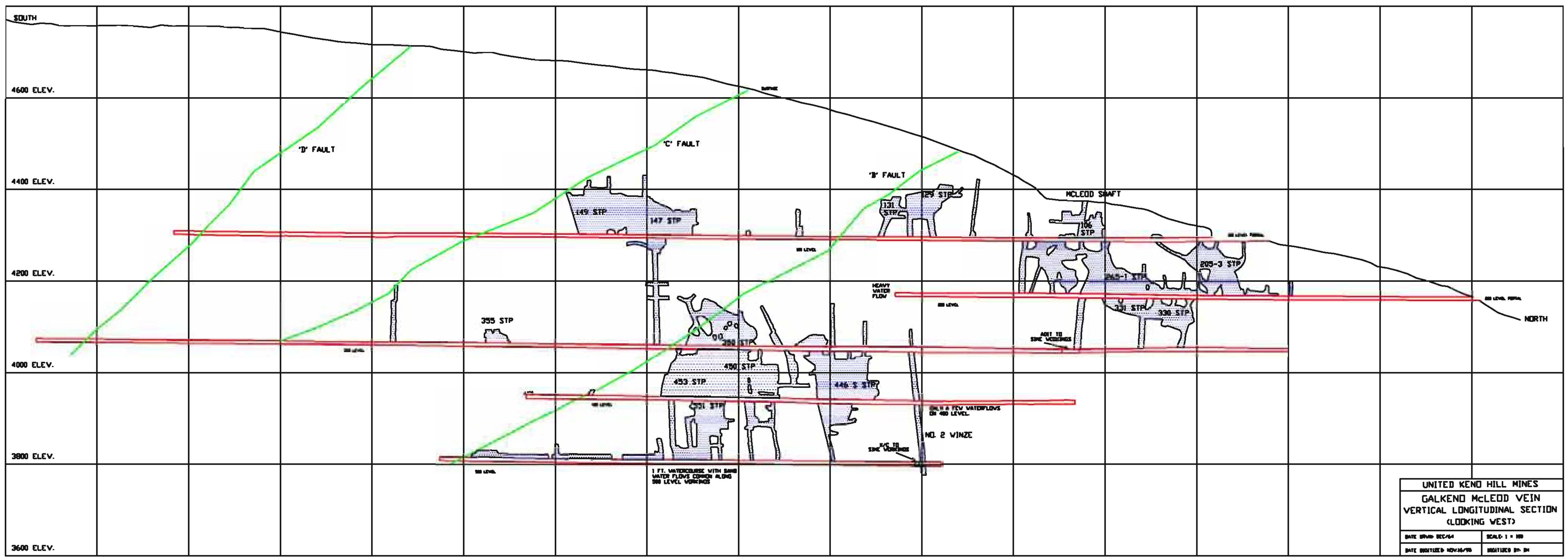
UNITED KENO HILL MINES LIMITED

MINE WORKINGS

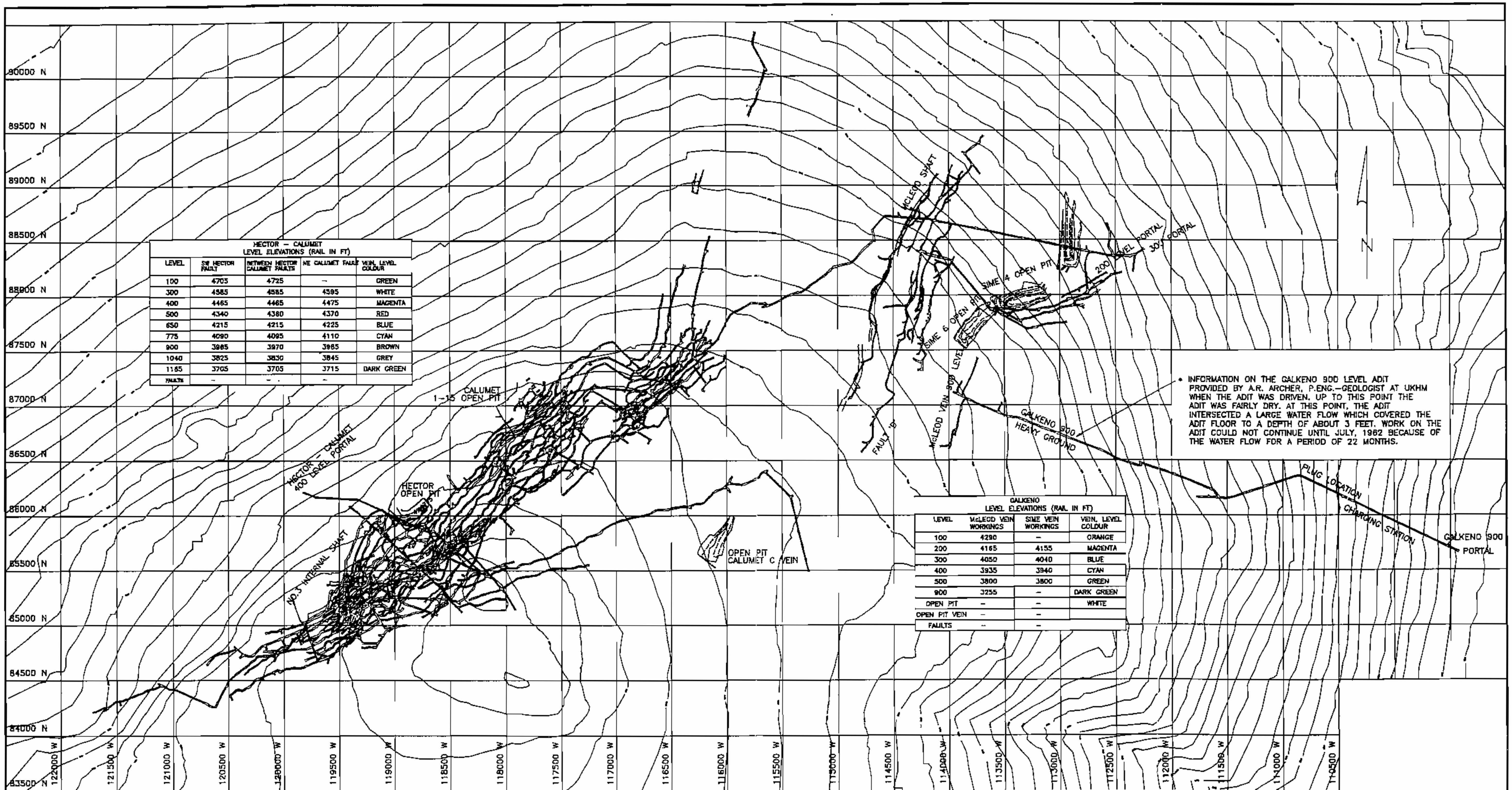
GALKENO McCLEOD VEIN
VERTICAL LONGITUDINAL SECTION (Looking West)

ACCESS MINING CONSULTANTS LTD.

SCALE: NONE	FILE: GLONGSEC.DWG	DATE: 28/05/96
PLOTTED:	DWG: 95UK60	FIGURE: 5-26



SOUTH
4600 ELEV.
4400 ELEV.
4200 ELEV.
4000 ELEV.
3800 ELEV.
3600 ELEV.
'D' FAULT
'C' FAULT
'B' FAULT
149 STP
147 STP
131 STP
129 STP
MCLEOD SHAFT
106 STP
205-3 STP
331 STP
330 STP
HEAVY WATER FLOW
355 STP
450 STP
453 STP
446 S STP
ADIT TO
NO. 2 WINZE
NORTH
UNITED KENO HILL MINES
GALKENO McLEOD VEIN
VERTICAL LONGITUDINAL SECTION
(LOOKING WEST)



HECTOR – CALUMET
LEVEL ELEVATIONS (RAIL IN FT)

LEVEL	SW HECTOR FAULT	BETWEEN HECTOR CALUMET FAULTS	NE CALUMET FAULT	VEIN, LEVEL COLOUR
100	4705	4725	–	GREEN
300	4585	4585	4595	WHITE
400	4465	4465	4475	MAGENTA
500	4340	4360	4370	RED
650	4215	4215	4225	BLUE
775	4090	4095	4110	CYAN
900	3985	3970	3985	BROWN
1040	3825	3830	3845	GREY
1165	3705	3705	3715	DARK GREEN
FAULTS	–	–	–	

GALKENO
LEVEL ELEVATIONS (RAIL IN FT)

LEVEL	McLEOD VEIN WORKINGS	SIME VEIN WORKINGS	VEIN, LEVEL COLOUR
100	4290	–	ORANGE
200	4165	4155	MAGENTA
300	4050	4040	BLUE
400	3935	3940	CYAN
500	3800	3800	GREEN
900	3255	–	DARK GREEN
OPEN PIT	–	–	WHITE
OPEN PIT VEIN	–	–	
FAULTS	–	–	

UNITED KENO HILL MINES LIMITED

MINE WORKINGS

JOCK, HECTOR, CALUMET & GALKENO MINES COMPOSITE PLAN

ACCESS MINING CONSULTANTS LTD.

SCALE: NONE	FILE: HCCOMP.DWG	DATE: 28/05/96
PLOTTED:	DWG: 95UK59	FIGURE: 5–27

5.2.6 Galkeno 900 Hydraulic Plug

Location and Background

The Galkeno 900 adit is located on the East side of Galena Hill near Keno City, Yukon. The adit was developed in the late 1950's to explore for the down-dip extensions of the upper Galkeno workings and to ultimately provide a means of transporting ore by gravity to a mill originally located on Christal Lake. Total development extended approximately 6000 feet at a gradient of roughly 0.25 to 0.5 %, such that the workings are 'free' draining.

During development the adit intersected a series of sub-vertical faults extending from surface to depth. Each of these fault intersections resulted in significant inflow of water as the rock mass drained. The combination of water inflow and generally poorer rock conditions in the fault zones resulted in difficult mining conditions. Several such intersections were abandoned in favour of detours around the areas of poor ground. The resulting adit development depicted on level plans shows long straight sections of adit bisected by areas of caved ground and awkward detours. Each of these locations was heavily timbered in an attempt to stabilize the excavation. With time these fault zones drained sufficiently to significantly improve the 'apparent' ground condition.

In the early 1960's development of the 900 adit was ceased. Local memory of that period recounts that work was halted because of the poor ground conditions. The adit has therefore remained essentially unused since its original excavation, and never entered production. Timber sets and original rail remained in place to present.

In 1991, concern about high concentrations of dissolved zinc in the adit discharge prompted United Keno Hill Mines to attempt minor remediation of the portal site. In December of 1991, the site was inspected to assess the conditions at that time and the report, "Galkeno 900 Adit - Portal Assessment", (Klohn-Leonoff, April 1992), provides a conceptual discussion of the alternatives for remediation. One of the proposed alternatives was the removal of the portal obstruction and construction of an "engineered bulkhead".

In May of 1992, small diameter percussive holes were drilled from the upper hillside to the adit level to define the target and to determine the depth of water impounded behind the portal obstruction. At that time it was observed that water was impounded up to 22 feet above the invert elevation in the drill hole. Excavation of the portal obstruction was not feasible given the amount of impounded water and the risk of an uncontrolled release. Therefore, a larger Schram drill was mobilized to drill and case a 6 inch diameter hole suitable for a submersible pump which facilitated dewatering of the adit.

All water pumped from the adit was treated at a small treatment plant where, with the addition of slaked lime, the pH of the water was modified to precipitate zinc. Ponds were created to allow the precipitate to settle prior to being discharged from the system. Once the adit water level was drawn down sufficiently excavation at the portal commenced. After the bulk of the portal debris was removed it became apparent that a block of frozen soil and rock had effectively sealed the opening, much like a guillotine gate. The principle conduit for water flow through this failed mass had been an existing and partially restricted 6” air-line.

Portal rehabilitation work was undertaken by UKHM, including excavation of the failed material and construction of timber protection around the portal area. Once this was completed, the crew continued work into the adit, rehabilitating the adit back through caved areas and up to the plug target area. The target area was roughly 1200 feet from the portal. This work also included refurbishing rail and resetting timber where required.

Klohn Leonoff report “Galkeno 900: Plug Construction Specification and Drawings”, June 1993 was provided to contractors for their preparation of competitive bids to carry out the work. In addition, the latter report was reviewed by regulators in Whitehorse and Ottawa including; Environment Canada, CANMET, and the Mining Engineering Unit of the Occupational Health and Safety Branch (WCB-Yukon). The latter organization provided approval of the construction specification and a work permit to proceed. All work was carried out in accordance with this permit and in compliance of the Occupational Health and Safety Handbook and Mine Safety Regulations of the Yukon Territorial Government.

Design

The purpose of the plug was to provide a permanent structure which would impound water within the upstream mine workings. Since those workings did not apparently connect to other mine workings (including mined out stopes) on levels at higher elevations, the impounded water was expected to partially restore the groundwater regime within the hillside. Since the historic groundwater table was unknown prior to mining, the final flooded level and extent of flooding to workings was difficult to predict. The assumption was made however, that flooding workings (and drained mineralised geologic structures in the rock mass) to an elevated groundwater profile would have a beneficial effect by minimizing the possibility of acid rock drainage and associated metal loading from those areas.

The design philosophy was therefore to safely impound water within the 900 workings by installing a plug at a location which would provide the required factor of safety against a maximum potential static head equivalent to the elevation difference to the next level. In addition, the length of the plug would help to minimise the potential seepage flows by increasing the flow path around the structure. The flow path was further lengthened by the installation of a grout curtain.

Since UKHM did not intend to reopen this part of the mine, the plug was also designed as a permanent structure with no provision for future access past the structure. Instrumentation was installed to monitor the upstream pressure at the face of the plug. This pressure can be directly related to the equivalent static head and thus the elevation of impounded water.

The plug was constructed as specified over the period August 1993 to November 1994.

Instrumentation

The construction specification called for the installation of a pressure monitoring system to record the upstream pressure on the plug. The system includes a .25” stainless steel tube which was anchored to the diversion pipe. The tube was fitted with an upstream filter to minimize sediment impeding the recorded pressure, and porous stone to prevent the transfer of upstream pressure for sustained flows should the gauge or pipework fail.

The instrumentation box is secure and has posted warning signs. The box contains a shutoff valve before the gauge, and a pressure gauge calibrated in psi and MPa. The gauge can be accurately read to the nearest 5 psi.

Performance

The performance of the plug installation, including the grout curtain, concrete mass, and post construction grouting phases is assessed on the basis of visual observation of seeps, and monitoring of upstream pressure readings and seepage flows at measurement stations.

In effect, the installation becomes an integral part of a new (or semi-restored) hydrogeologic regime, which will take time to achieve an ‘equilibrium’ condition. The term equilibrium is intended to describe the condition where upstream pressure stabilizes due to an effective balance between new inflows (upstream) and seepage occurring downstream. Generally, increased seepage rates are expected with an increase in upstream pressure. At the equilibrium point inflows are balanced with a rate of total seepage observed at a specific pressure.

Hydraulic plug installations are directly analogous to very high dams. During construction of both types of structures efforts are made to minimize seepage at the contact between the concrete mass and the foundation (rock), through the mass, and through the foundation (rock). All such structures have some amount of seepage due to flows through fractured rock mass foundation and the concrete/rock contact areas. At dam sites seepage is often difficult to observe due to the general requirement for dams to maintain a downstream flow or ‘spill’ condition which prevents observation of seepage points. Hydraulic plugs display seepage readily due to the lack of other downstream water flow. The amount of seepage which occurs is a function of the conductivity of the rock mass and the effectiveness of grouting to prevent direct migration of flow. Grout curtains are designed to increase the effective length of the flow path, thus reducing the hydraulic gradient and the amount of seepage which would otherwise flow parallel to the structure.

Observed Pressure and Seepage to Date

The installation was inspected by mine personnel on a daily basis for approximately ten days after closure of the diversion. As the pressure began to rise, small flows were observed and measured in three of the downstream drains. Specifically, drains located in the lower left (looking upstream) quadrant of both rings were characterized by continuous flows. These flows increased as expected with increases in upstream pressure, and continued to be monitored. At no time were the flows in drains observed to be cloudy or to have any sediment which may indicate an erosion or 'void enlarging' phenomenon.

As the upstream pressure increased over time seepage at specific locations near the concrete/rock contact and at downstream locations in rock joints were observed and monitored.

As familiarity with the plug's performance was achieved, inspection of the plug and pressure/seepage recording was carried out on a twice-weekly, weekly, and subsequently monthly basis by mine personnel. Records of pressure and total flow measured at a downstream weir were sent to Klohn Crippen for review.

Observed pressure and flow data collected to date is illustrated on Figure 5-28. After an upstream pressure of 25 psi was recorded flows from rock joints and the concrete/rock contact area were also observed but could not be directly measured. As the pressure continued to rise total seepage flows were recorded at the portal weir site and measurement of individual flows from drains was ceased.

Immediately after closure of the diversion valve assembly total flows discharging from the adit were negligible. Once the upstream pressure had reached 50 psi however, continuous flows of 0.5 L/s were recorded. This 'total' flow was observed to be consistent with the flows discharging from all drains and seepage points downstream of the plug.

The latest pressure and seepage condition readings were recorded at the end of August 1995. At that time the recorded upstream pressure was 168 psi (equivalent to 360 feet head of water) with an observed total flow at the portal weir of approximately 4.5 L/s. Figure 5-28 provides the observed pressure and seepage data. The general trend of the data is essentially convex, indicating that an equilibrium condition may be approaching.

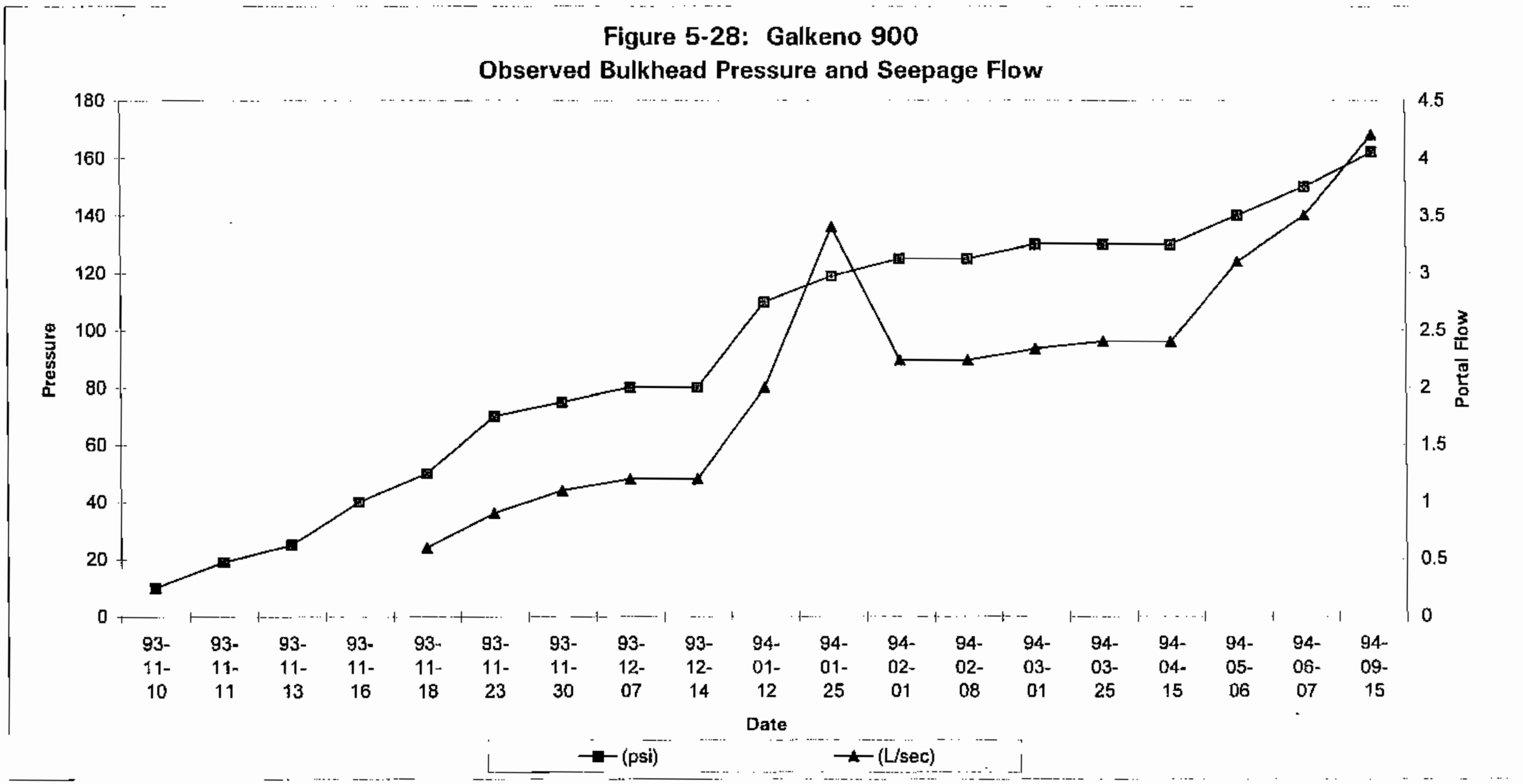


Figure 5-28: Galkeno 900
Observed Bulkhead Pressure and Seepage Flow
180
160
140
120
100
80
60
40
20
0
Pressure
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Portal Flow
93-11-10
93-11-11
93-11-13
93-11-16
93-11-18
93-11-23
93-11-30
93-12-07
93-12-14
94-01-12
94-01-25
94-02-01
94-02-08
94-03-01
94-03-25
94-04-15
94-05-06
94-06-07
94-09-15
Date
(psi)
(L/sec)

5.2.7 Hector-Calumet

Development: Table 5-6-a and 5-6-b

Figures: Figure 5-29 Site Plan
Figure 5-30 Site Plan
Figure 5-27 Jock, Hector, Calumet and Galkeno Composite
Figure 5-31 Hector-Calumet Mine, Vertical Long Section, No.5 Vein, Looking Northwest
Figure 5-32 Hector-Calumet Mine, Cross Section, Looking Northwest

The Hector-Calumet mine workings are probably the most extensive workings on Galena Hill, and include three open pits mined in the mid 1980's and the older Hector-Calumet underground workings. Just over half of the Company's total silver production has come from the Hector-Calumet mine.

The composite plan, Figure 5-27, shows the Calumet workings and their relation to the Galkeno Mine. Sections through the Hector-Calumet underground workings, and the related surface openings, are shown in Figures 5-31 and 5-32. While these workings are clearly very extensive and close to surface, it is reported that there was considerable backfilling, using waste rock generated underground, and thus subsidence to surface is not a concern.

There is one portal, at the 400 level, which remains open. The portal is supported by timber and concrete and appears stable. Access is limited by doors at the portal.

There is a significant amount of waste rock at the 400 portal; estimated at about 200,000 tons. Some of this was used as fill and road construction around Calumet, and for foundations for the aerial tramway terminus. The remainder is deposited at the portal. The tramway was used to transport ore from Hector-Calumet to the mill. Most of the Calumet tramway station has been demolished or burned, although some wood and debris remains, as does the cribbing for the foundations.

There are two shafts at the Calumet workings. Both are reported collapsed, but this must be confirmed. It appears from old drawings and plans that there may be additional shafts and raises to surface associated with the older workings, which will be investigated.

The locations of the open pits are shown on the composite plan, Figure 5-27 and Figure 5-29. The Calumet 1-15 is the second largest pit mined by UKHM, and was mined to recover the crown pillars of the No.1 and No.15 veins. There are two waste dumps associated with the open pit, comprising about 1,000,000 tons of waste rock. The Hector Pit (also called the No. 1 Vein pit) and the 4-11 pit are smaller, with the 4-11 "pit" being a large stripped area and a series of trenches adjacent to the Hector pit, about 600 feet to the west south-west. The 4-11 area was stripped to sample veins, and then a backhoe was used to mine a short, narrow section of ore material. The open pits are connected to the underground workings through either old raises or fault structures and thus are not expected to flood.

The composite plan also shows the very small Calumet "C" pit which was mined in 1981. The pit is, in fact, a small shallow slot which is filled with water.

There was a significant amount of infrastructure at the Hector-Calumet during the peak years of operation, that is, from 1948 through to 1972. A townsite was built, although all of the buildings and structures have since been removed. There was also a steam power plant operating at the 400 level, which explains the residual coal and ash evident in the lower section of the waste dump.

During operation, the mine was dewatered from the 400 level adit. The water discharged on to the hillside downslope from the adit, flooding the area with water and silt, and resulting in the dead trees still evident today. There has been no drainage from the Hector 400 adit since mining ceased in October of 1972. It is understood that the underground water reports to the Galkeno workings. Review of the operations reports from the shaft development period (1953/54) shows that the Hector shaft was essentially dry with the exception of two areas:

- at about 940 ft. depth, the Hector fault was encountered resulting in ". . . water problems";

- between the 1165 and 1300 levels heavy water inflows were encountered (Aug. 2, 1954), with recorded flows of up to 100 gpm.

Development was finished in October of 1954 and it was reported that ". . . water flow continues undiminished." It is expected that, after the mining of the Hector underground was finished in 1972, the drainage from underground may have reported ultimately to the Galkeno 900 Adit.

TABLE 5-6a

Mine Development

Mine:	Calumet which includes the Hector Calumet underground, two open pits, 1 trenching
Location:	Galena Hill
Period of Development:	from 1930's to 1985
Developed by:	

Development at Calumet

	Open Pit	Underground	Shafts, Raises Portals, Adits	Bldgs & Equip.	Rock Piles @ Hector 400	@ Hector O/P	Calumet 1-15 pit	Hector 1 Vein pillar pit
Period of	1984	1935 to 1972			Hector 400			
Development	1985				1937 to 1941?	1984	1984-85	1985
					1947 to 1972			
Production or	Total = 2,721,273 tons						1,000,000 t	10,000 t
Tonnage	Calu 1-15=87,922	UG =			198,000 tons	100,000 t	in 2 dumps	
	Hect = 18,233 t	2,612,726 t					700,000 and	
	Calu 3&4=2,392t						300,000 tons	
Features						pit for recovery	2nd largest	mined small
		timbered	internal shaft		16,000 t was	of crown pillars	pit by UKHM	crown pillar
		ice at portal	from 400 to 1200		milled in 1970's	from #1, #2 Vein	recovery of	from
			level		4 oz/t Ag, .55% Pb	& ore in Hector	pillars on #1	Hector-
					1% Zn	fault	and #15 Vein	Calumet 1 vein
Geometry							tension cracks	
			adit 1200' long		39° slopes	40° slopes	slumping	
			shaft 1000' deep					
Drainage								
Remarks		extensively			head of aerial	quartizite,graph	primarily	quartizite,graph
		backfilled			tramway	sch.&greenstn	quartizite,	sch.&greenstn
		w/ development				country rock	graph. schist	country rock
		muck				is majority	country rock	is majority
	* includes Calumet 1-2 and Calumet 4-11 pits					of dump		of dump

TABLE 5-6b

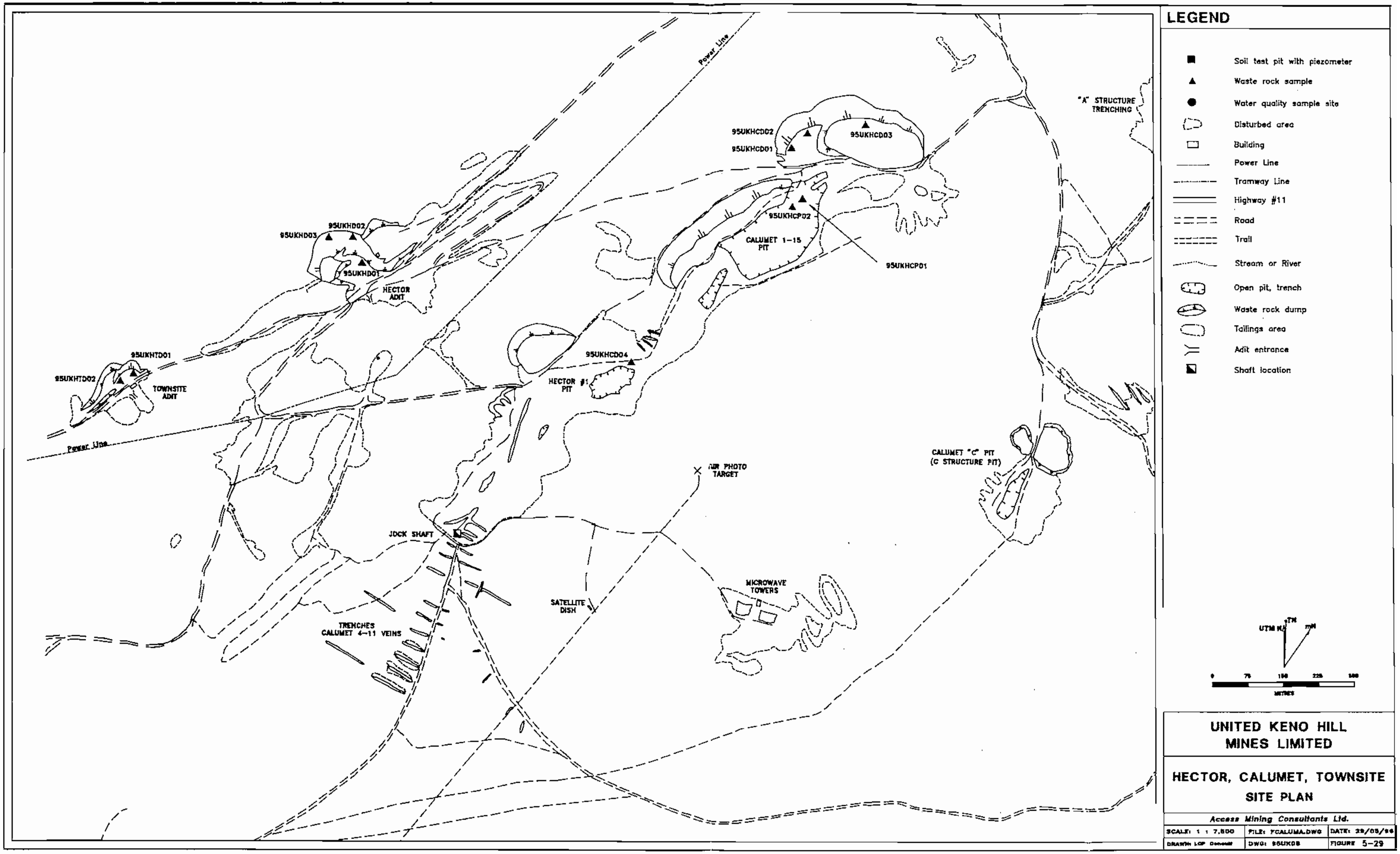
Mine Development

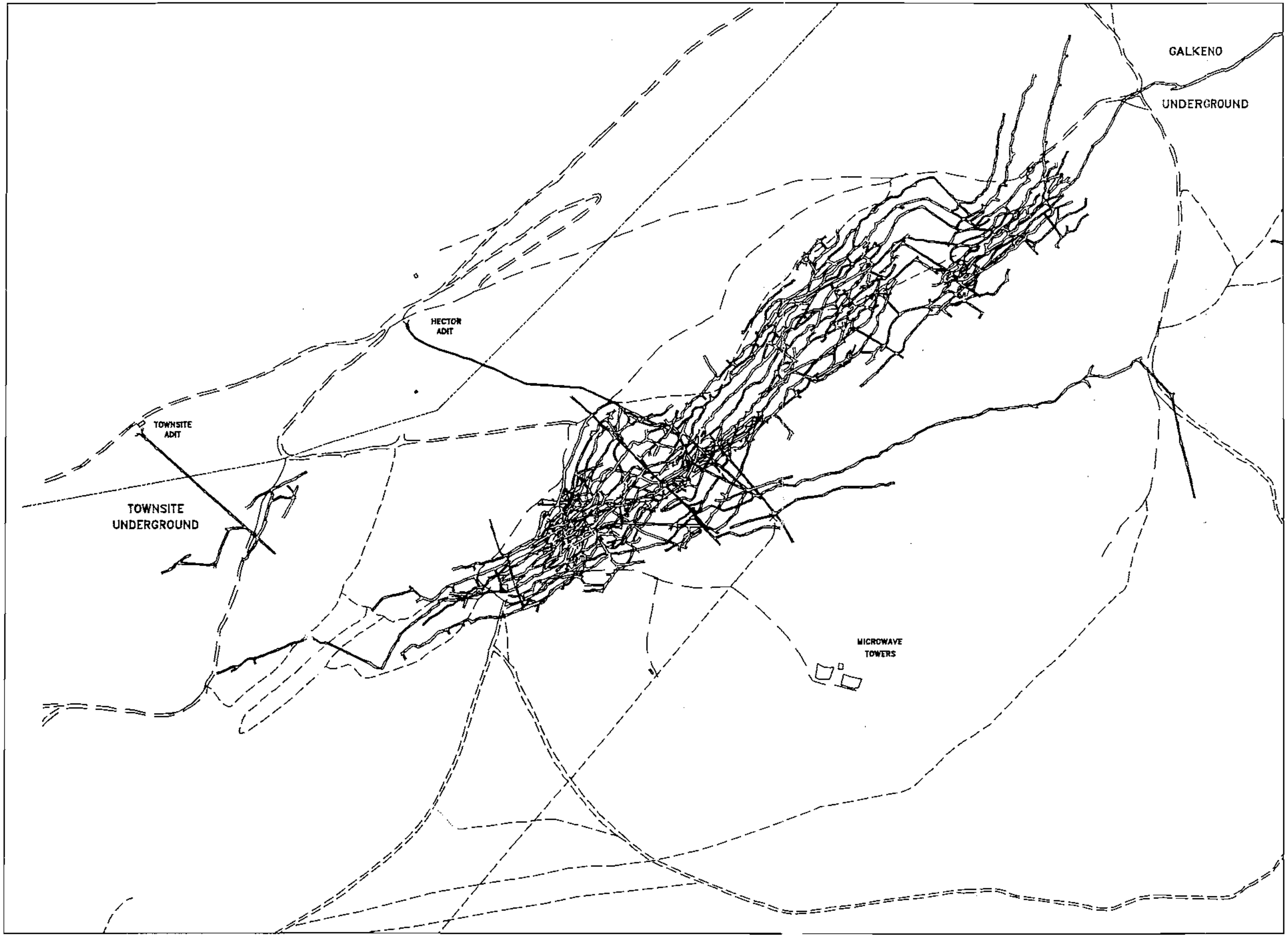
Mine:	C Structure
Location:	Galena Hill
Period of Development:	1981
Developed by:	

Development at C Structure

	Open Pit	Underground	Shafts, Raises Portals, Adits	Bldgs and Equip.	Rock Piles waste, ore	Tailings	Mill or Plant	Other	Townsite
Period of Development	1981				1981				
Production or Tonnage	2,392 tons				25,000 tons				
Features	small shallow slot								
Geometry									
Drainage	retains water - no surface discharge								
Remarks					revegetation				

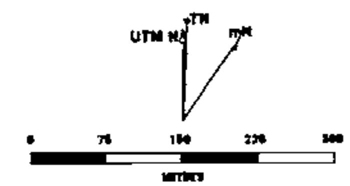
96-06-01


LEGEND
Soil test pit with piezometer
Waste rock sample
Water quality sample site
Disturbed area
Building
Power Line
Tramway Line
Highway #11
Road
Trail
Stream or River
Open pit, trench
Waste rock dump
Tailings area
Adit entrance
Shaft location
Power Line
Power Line
95UKHD02
95UKHD03
95UKHD01
HECTOR ADIT
95UKHTD01
95UKHTD02
TOWNSITE ADIT
95UKHCD02
95UKHCD01
95UKHCD03
95UKHCP02
95UKHCP01
CALUMET 1-15 PIT
"A" STRUCTURE TRENCHING
95UKHCD04
HECTOR #1 PIT
AIR PHOTO TARGET
CALUMET "C" PIT
(C STRUCTURE PIT)
JOCK SHAFT
SATELLITE DISH
MICROWAVE TOWERS
TRENCHES
CALUMET 4-11 VEINS
METRES
UNITED KENO HILL
MINES LIMITED
HECTOR, CALUMET, TOWNSITE
SITE PLAN
Access Mining Consultants Ltd.
SCALE: 1 : 7,500
FILE: FCALUMA.DWG
FIGURE 5-29



LEGEND

- Soil test pit with piezometer
- Waste rock sample
- Water quality sample site
- Disturbed area
- Building
- Power Line
- Tramway Line
- Highway #11
- Road
- Trail
- Stream or River
- Open pit, trench
- Waste rock dump
- Tailings area
- Adit entrance
- Shaft location



UNITED KENO HILL MINES LIMITED

HECTOR, CALUMET, TOWNSITE UNDERGROUND

Access Mining Consultants Ltd.

SCALE: 1 : 7,500	FILE: FCALUMB.DWG	DATE: 29/05/96
DRAWN: LCP	DWG: 95UK09	FIGURE 5-30

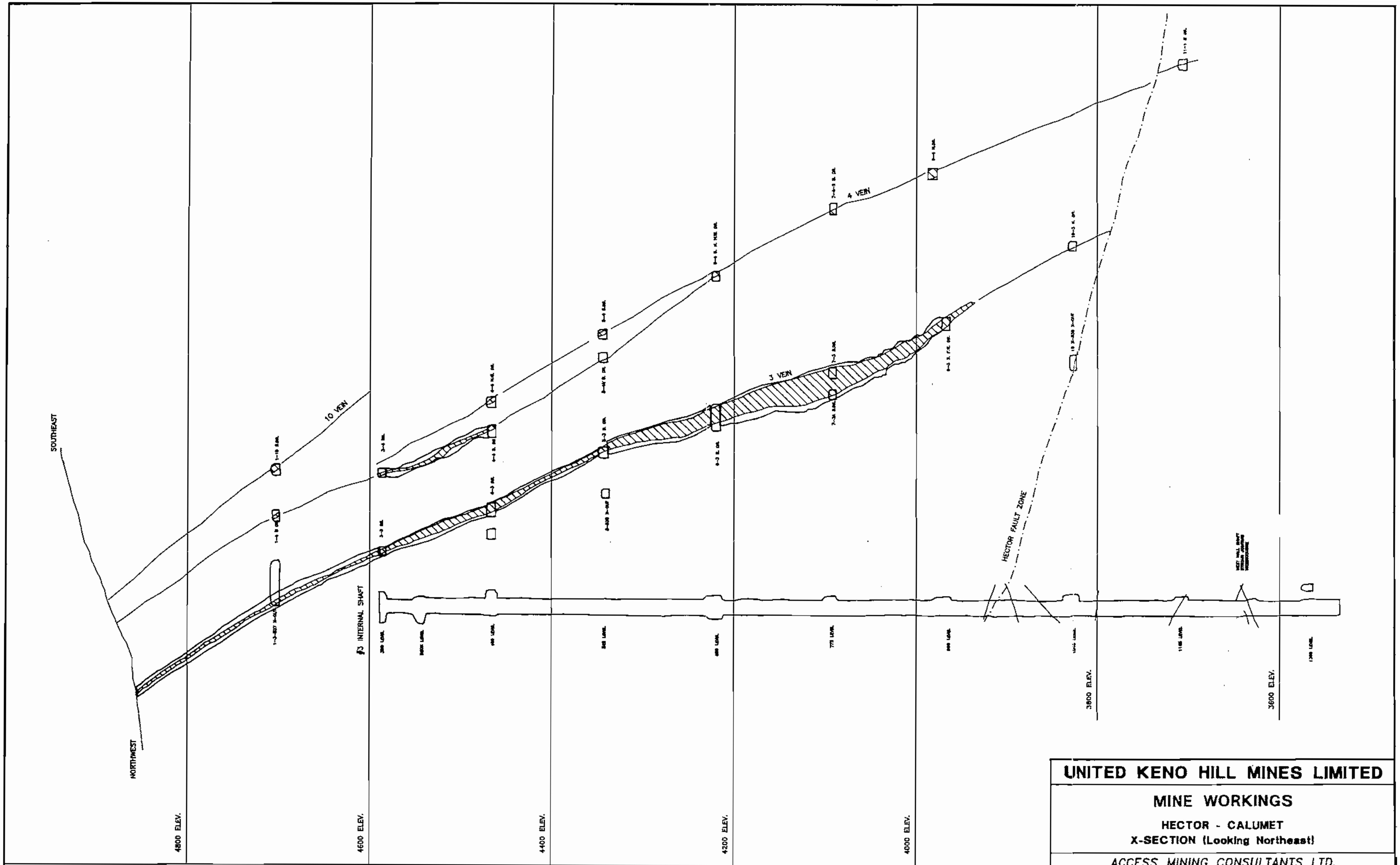
UNITED KENO HILL MINES LIMITED

MINE WORKINGS

HECTOR - CALUMET
VERTICAL LONGITUDINAL SECTION

ACCESS MINING CONSULTANTS LTD.

SCALE: NONE	FILE: HCLONG.DWG	DATE: 28/05/96
PLOTTED:	DWG: 95UK35	FIGURE: 5-31



UNITED KENO HILL MINES LIMITED		
MINE WORKINGS HECTOR - CALUMET X-SECTION (Looking Northeast)		
ACCESS MINING CONSULTANTS LTD.		
SCALE: NONE	FILE: HCSECT.DWG	DATE: 28/05/96
PLOTTED:	DWG: 95UK36	FIGURE: 5-32

5.2.8 Husky

Development: Table 5-7-a

Figures: Figure 5-33 Site Plan

Figure 5-34 Husky and Husky S.W. Mines, Composite Plan

Figure 5-35 Husky Mine, No.2 Vein, Vertical Longitudinal Section, Looking Northwest

Figure 5-36 Husky Mine, Cross Section 122, Looking Northeast

The Husky underground mine was developed over a 20 year period from 1968. All mine development extends below the shaft, which is at about 2800 ft elevation.

The shaft is flooded and partially frozen. During sinking of the shaft heavy water flows were encountered between the 100 and 200 levels. Shaft sinking stopped for about a year to dry out the shaft. The primary conduit for recharge is believed to be from the groundwater and the Elsa mine through the Tick Fault and Brefalt Fault. Since all buildings remain in place, access to the shaft is limited by locked doors and gates.

There were four main mining levels underground; the 125, 250, 375 and 450 level. The 250 level drift connects to the Husky SW workings at the same level. There are two raises to surface.

The shaft buildings and shops, headframe, hoist, and some equipment remain in place. There is a small waste rock pile at the shaft, although the majority of the waste was used for foundation fill, road construction in the area, and also the No. 3 tailing dam.

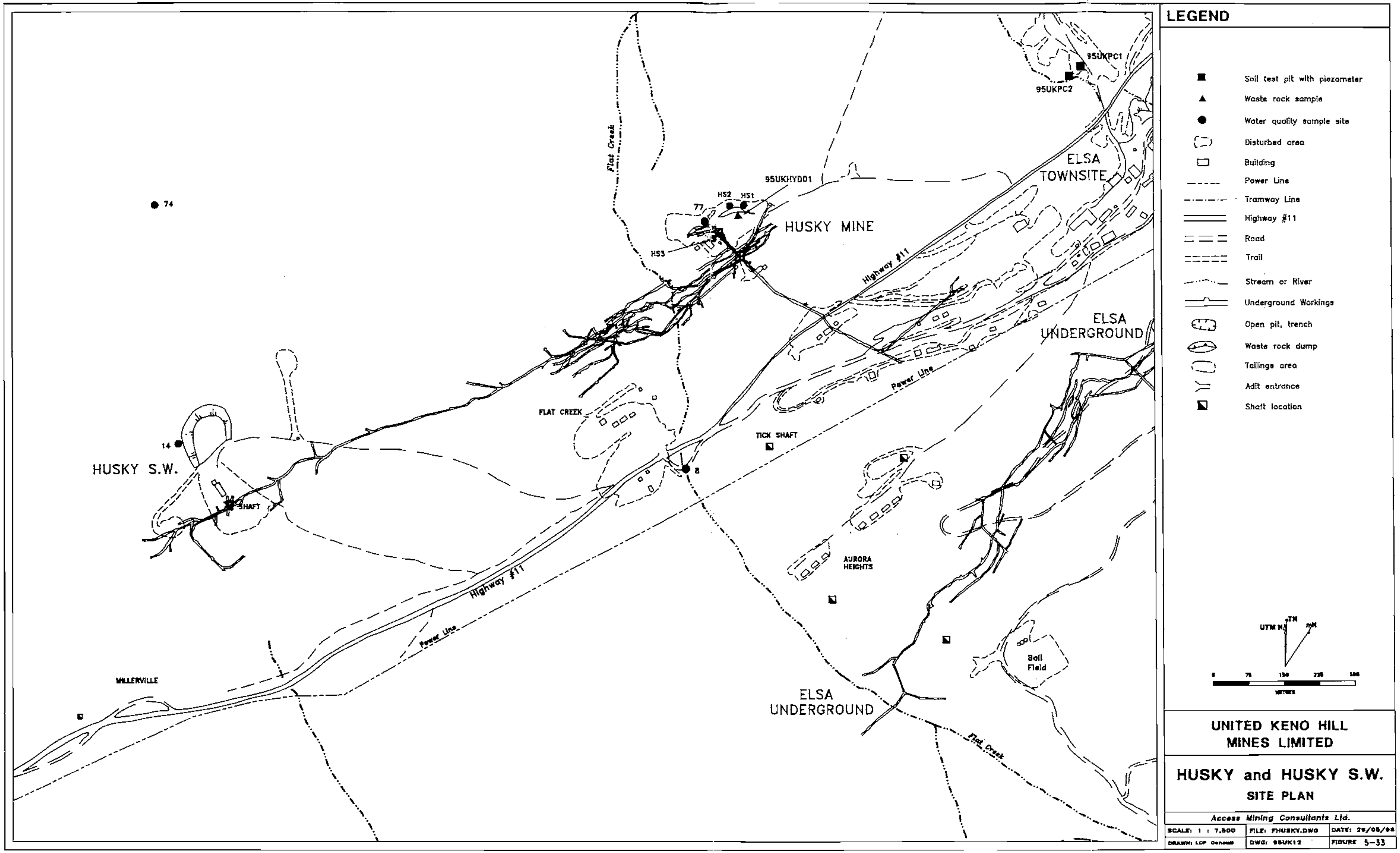
TABLE 5-7a

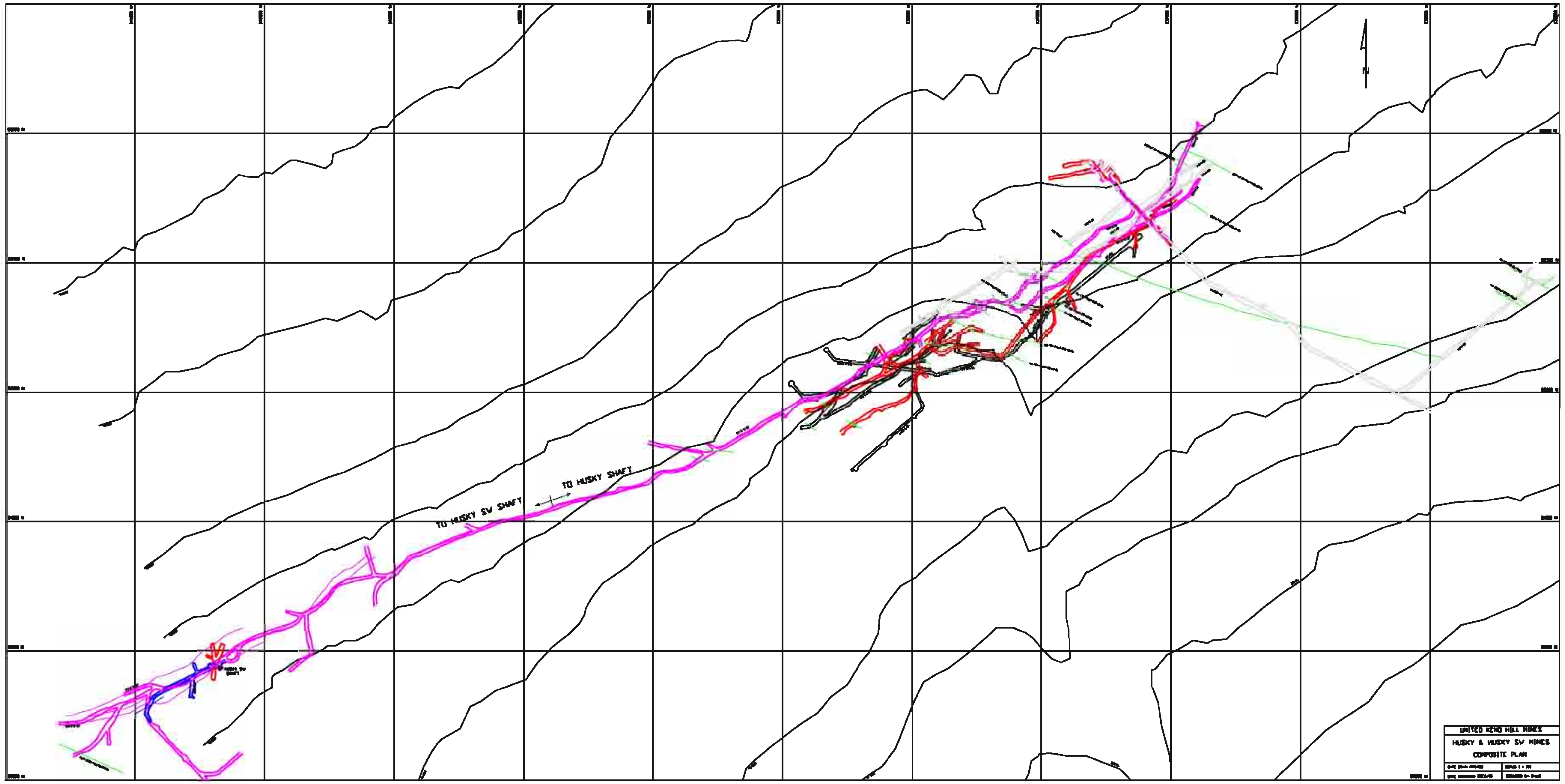
Mine Development

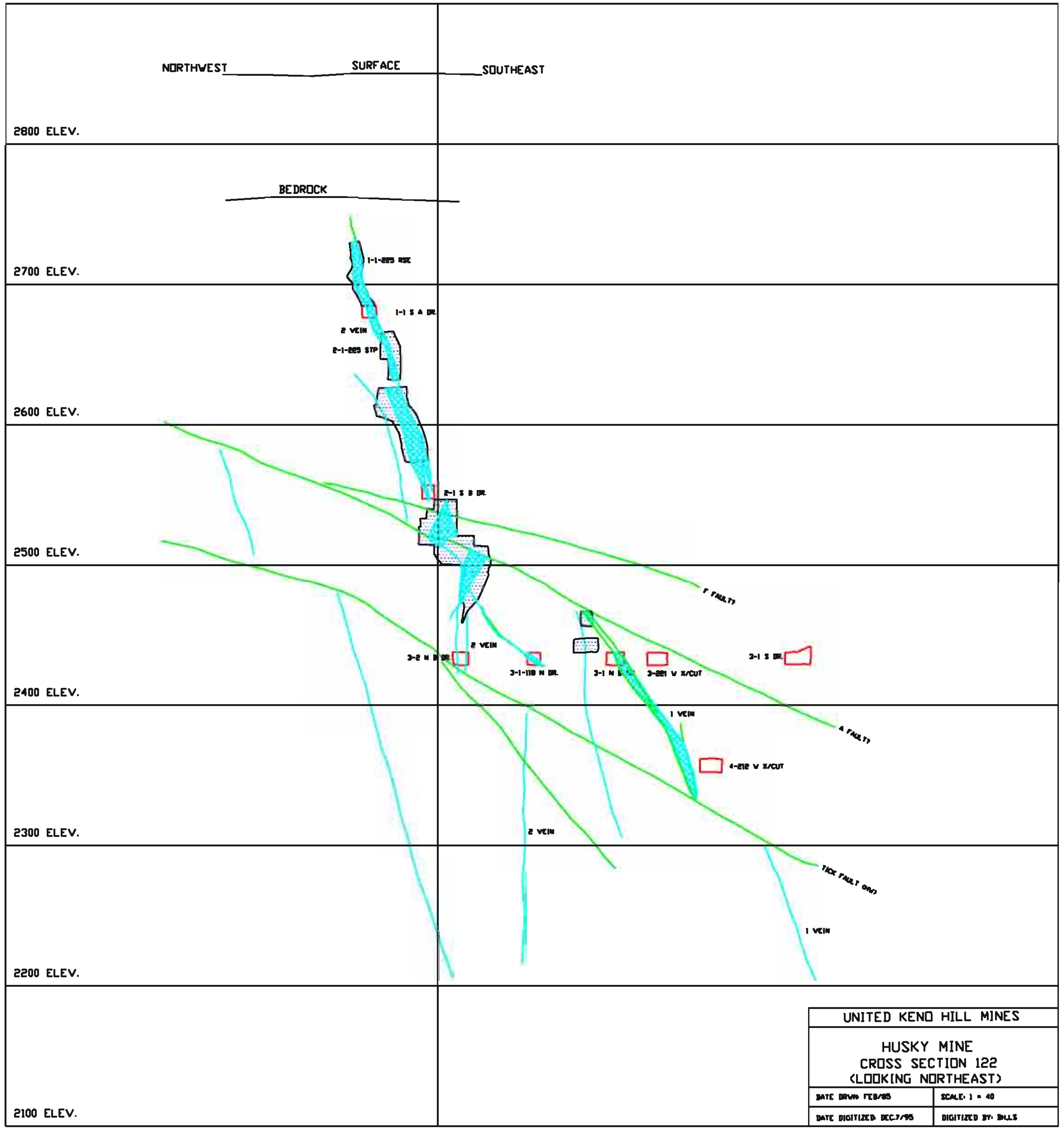
Mine:	Husky
Location:	Galena Hill
Period of Development:	1970's and 1980's
Developed by:	

Development at Husky

	Underground	Shafts, Raises Portals, Adits	Bldgs and Equip.	Rock Piles waste, ore	Other
Period of Development	1968 to 1988	shaft collared in 1968, levels developed 1970	1960's and 1970's	1968 to 1988	
Production or Tonnage	429,367 tons			4,600 tons	
Features	4 levels @ 125, 250, 375, 450		headframe, vent. shops, power?	may have some galena - no sphalerite at Husky	pad constructed from dump material
Geometry		shaft 400' deep decline from 375 to 450 level			
Drainage					Fe- stained drainage
Remarks		shaft flooded and ice in shaft		Rock used for construction around site.	


LEGEND
Soil test pit with piezometer
Waste rock sample
Water quality sample site
Disturbed area
Building
Power Line
Tramway Line
Highway #11
Road
Trail
Stream or River
Underground Workings
Open pit, trench
Waste rock dump
Tailings area
Adit entrance
Shaft location
95UKPC1
95UKPC2
ELSA TOWNSITE
95UKHYDD01
HS2
HS1
77
HS3
HUSKY MINE
74
Flat Creek
Highway #11
ELSA UNDERGROUND
Power Line
FLAT CREEK
TICK SHAFT
14
HUSKY S.W.
SHAFT
8
AURORA HEIGHTS
Highway #11
Power Line
MILLERVILLE
Ball Field
ELSA UNDERGROUND
Flat Creek
UTM N
TN
mN
UNITED KENO HILL MINES LIMITED
HUSKY and HUSKY S.W.
SITE PLAN
Access Mining Consultants Ltd.
SCALE: 1 : 7,500
FILE: FHUSKY.DWG
DWG: 95UK12
FIGURE 5-33


TO HUSKY SW SHAFT
TO HUSKY SHAFT
UNITED KENO HILL MINES
HUSKY & HUSKY SW MINES
COMPOSITE PLAN


NORTHWEST
SURFACE
SOUTHEAST
2800 ELEV.
BEDROCK
2700 ELEV.
1-1 S A DR.
2 VEIN
2600 ELEV.
2-1 S B DR.
2500 ELEV.
F FAULT?
2 VEIN
3-1-110 N DR.
3-201 V X/CUT
3-1 S DR.
2400 ELEV.
1 VEIN
A FAULT?
4-212 V X/CUT
2300 ELEV.
2 VEIN
1 VEIN
2200 ELEV.
2100 ELEV.
UNITED KENO HILL MINES
HUSKY MINE
CROSS SECTION 122
(LOOKING NORTHEAST)
SCALE: 1 = 40
DATE DIGITIZED: DEC.7/95

5.2.9 Husky Southwest

Development: Table 5-7-b

Figures: Figure 5-33 Site Plan
Figure 5-34 Husky & Husky SW Mines, Composite Plan
Figure 5-37 Husky SW Mine, Vertical Longitudinal Section, No.1 Vein

The Husky SW underground workings were developed in the two years following mining of the Husky underground. Contract miners were used, and all equipment removed at the end of mining. Significant ore (60,000 tons) remains at Husky SW and the plan is to mine it out in the near future.

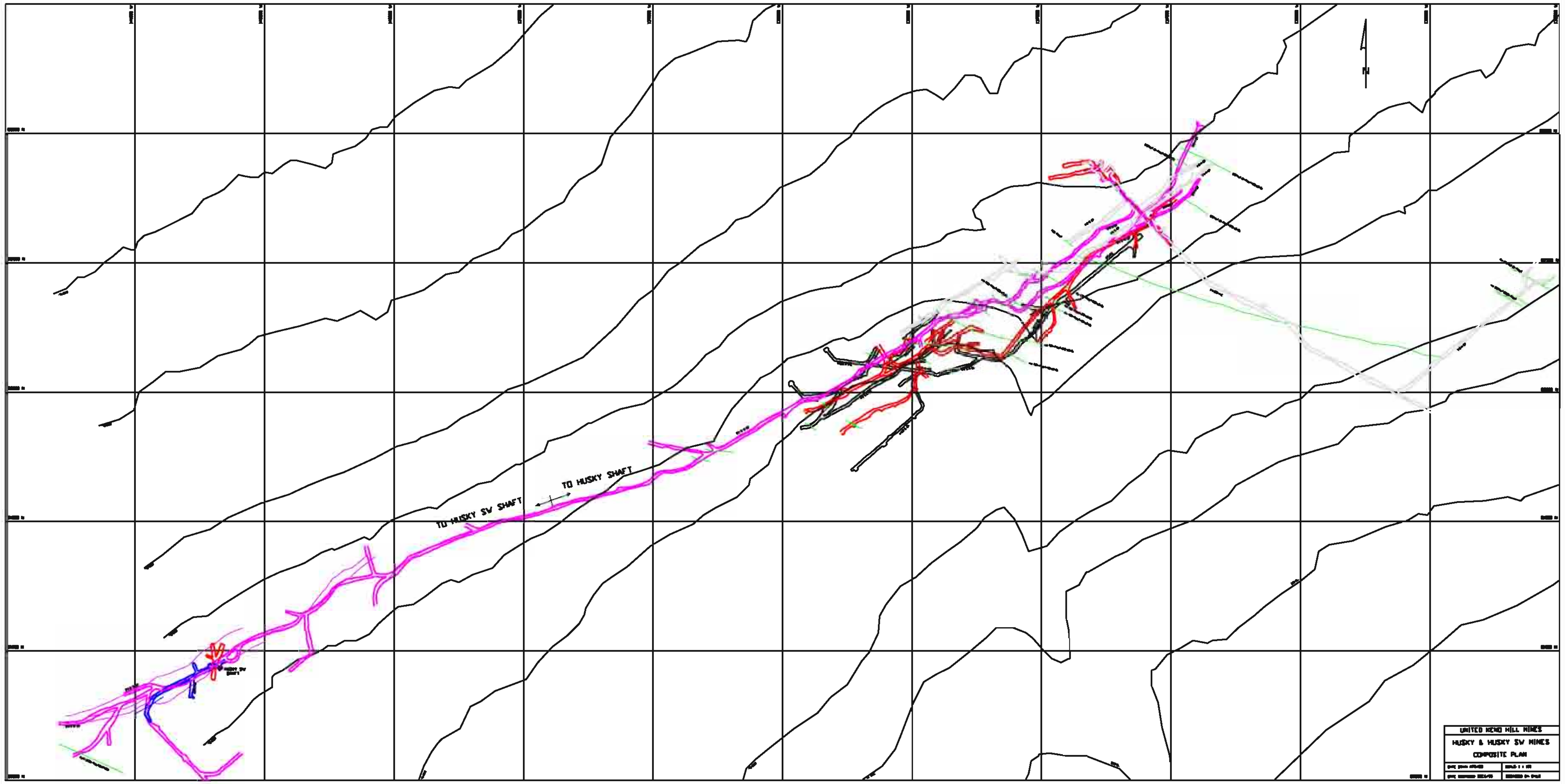
Access to underground was via the shaft and there are no other openings to surface from the underground. The headframe and a shop buildings are still in place.

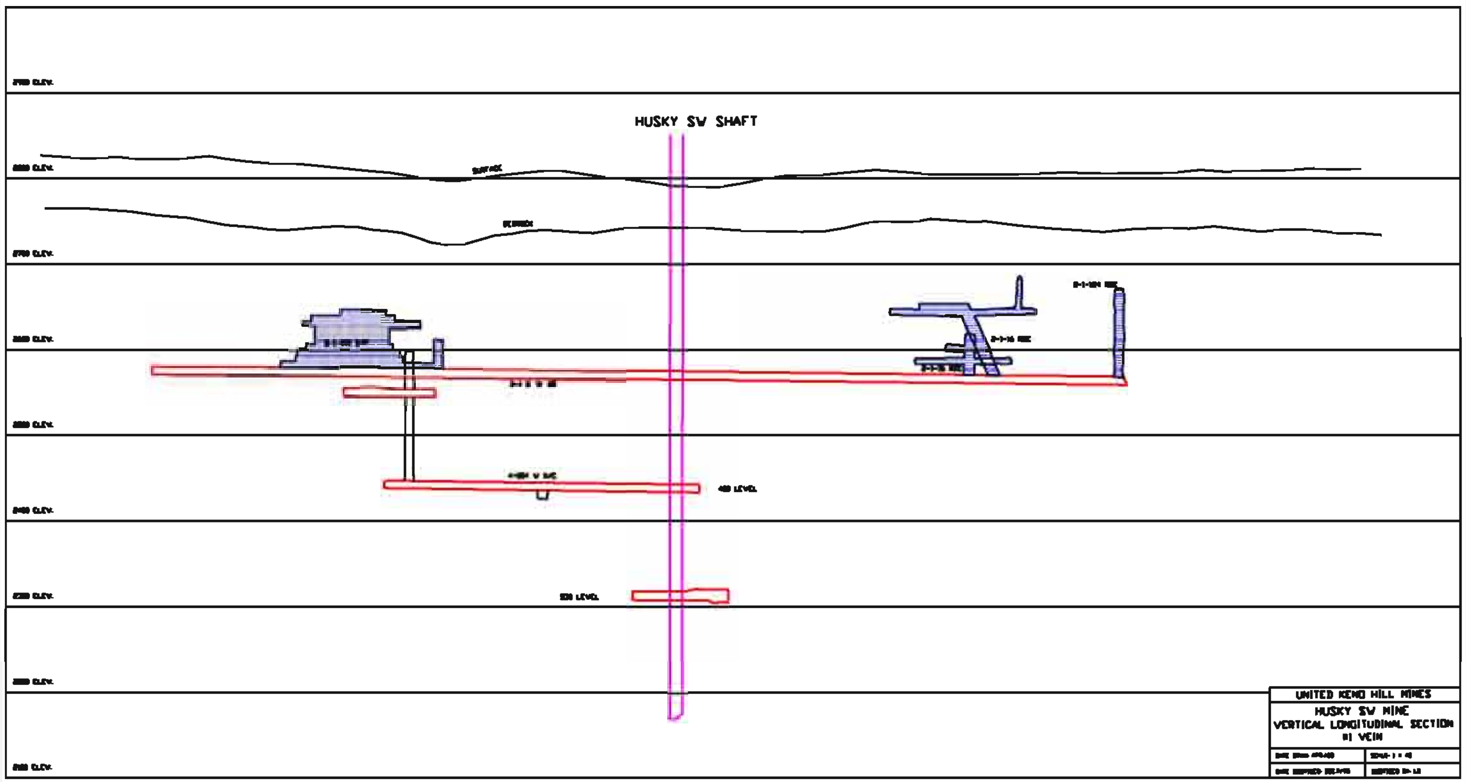
The Husky SW workings are connected (hydraulically) to the Husky underground at the 250 level. As with the Husky, the Husky SW workings are also flooded. Most of the recharge to these workings is through the water bearing Flat Creek Cross Fault and through the Tick - Brefalt Fault from the Elsa and/or Husky Mines. Some of the underground water is discharged from the shaft via a pipe and culvert, to maintain the water level in the shaft.

There are waste rock piles and some low grade ore around the Husky SW shaft. Waste rock was used for local road construction and fill in this area. On the road to Husky SW from the main road, there is also a small waste rock pad and building. This was reported to be an explosives magazine, although all explosives have been removed.

TABLE 5-7

Mine Development						
Mine:	Husky Southwest					
Location:	Galena Hill					
Period of Development:		1980's				
Developed by:		UKHM				
Monitoring at:	S-17					
Development at Husky Southwest						
	Underground	**Shafts, Raises**	**Bldgs**	**Rock Piles**	**Other**	**Townsite**
		Portals, Adits	**and Equip.**	**waste, ore**		
Period of	1987 to 1988	1987		1987 to 1988		
Development						
Production or						
Tonnage	10,461 tons			17,000		
Features				Primarily quartzite		
				and schist with some		
				barren or low grade		
				vein.		
Geometry				Overburden base		
		shaft 620' deep				
Drainage	discharge via			Fe staining		
	culvert from			surface water diverted		
	underground			in a ditch around dumps		
Remarks	shaft flooded	250 level connects		Husky schaft excavated		
	and partially	to Husky		in qtzite & graph schist		
	frozen			country rock, 1-10% py		
				rock dump is on till base		


TO HUSKY SW SHAFT
TO HUSKY SHAFT
UNITED KENO HILL MINES
HUSKY & HUSKY SW MINES
COMPOSITE PLAN


HUSKY SW SHAFT
UNITED KENO HILL MINES
HUSKY SW MINE
VERTICAL LONGITUDINAL SECTION
#1 VEIN

5.2.10 Miller

Development: Table 5-8

Figures: Figure 5-38 Site Plan

Figure 5-27 Hector, Calumet, Galkeno Composite

The Miller pit is a relatively small development. Initially mined from a 35' shaft and 135' of drifting, it was subsequently mined by open pit. The open pit mined to the bottom of the old underground workings. All that remains in the area is the shallow open pit, and some associated waste rock within the pit. The pit has not accumulated water.

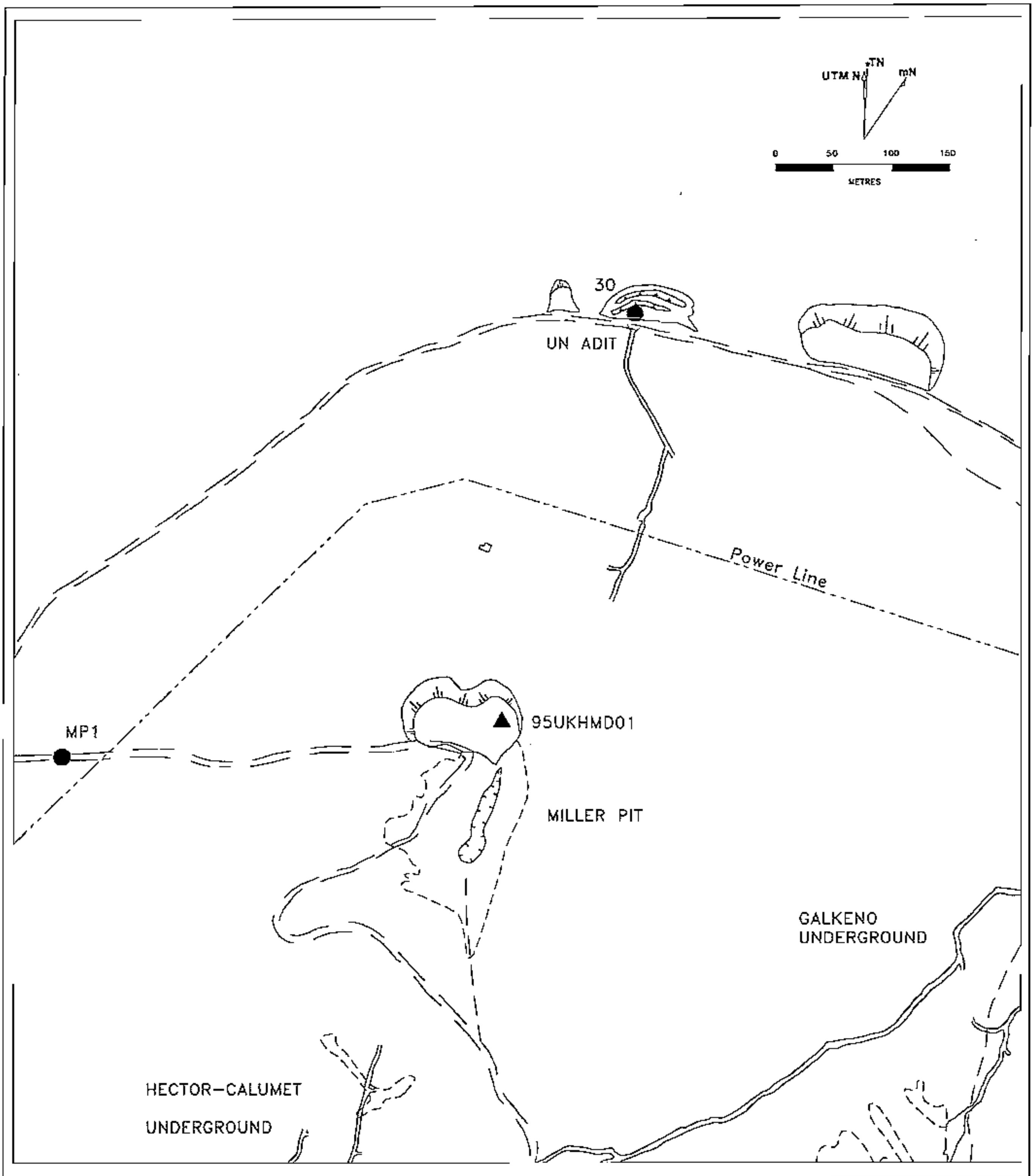
TABLE 5-8

Mine Development

Mine:	Miller						
Location:	Galena Hill						
Period of Development:		Open pit in 1981, 1985 by UKHM					
		Small underground in 1920's and 1930's					

Development at Miller

	Open Pit	**Underground**	**Shafts, Raises Portals, Adits**	**Bldgs and Equip.**	**Rock Piles waste, ore**	**Other**	**Townsite**
Period of Development	1981, 1985	1920's or 30's	1 old shaft				
Production or Tonnage	pit = 9,263 t 9390 tons = total production includes UN and Dragon				63,000 tons		
Features	mined out undeground workings		shaft in pit		primarily of quartzite		
Geometry					stable at 36^o		
Drainage							
Remarks	vegetation growth				vegetation regrowth		



LEGEND

- Soil test pit with piezometer
- Waste rock sample
- Water quality sample site
- Disturbed area
- Building
- Power Line
- Telephone Line
- Highway #11
- Road
- Trail
- Stream or River
- Underground Workings
- Open pit, trench
- Waste rock dump
- Tailings area
- Adit entrance
- Shaft location

UNITED KENO HILL MINES LIMITED

UN and MILLER

SITE PLAN

Access Mining Consultants Inc.

SCALE: 1 : 5,000	FILE: FUNMILL.DWG	DATE: 28/05/96
DRAWN: LCP Consult	DWG: 95UK01	FIGURE 5-38

5.2.11 No Cash

Development: Table 5-9-a and 5-9-b

Figures: Figure 5-39 (No Cash 500) Site Plan

Figure 5-40 No Cash Mine Composite Plan, 63, 66 & 67 Veins

Figure 5-41 No Cash Mine, Vertical Longitudinal Section, Looking Northwest 66 Vein

Figure 5-42 No Cash Mine, Section 111, Looking Northeast 66 & 67 Veins

The No Cash underground mine was mined from two levels; initially from the 100 level, and then from the 500 level. The development at the 100 level included the Brefalt shaft and the 100 adit. The shaft is covered by a building but it is in poor condition and some subsidence is visible. The portal is blocked by metal doors, but the doors are not locked. There is also one Butler metal building which was used to house the compressor. Around both the shaft and building are wide deep trenches, excavated to locate the No Cash veins at bedrock.

There are also the remnants of the aerial tramway transfer station at this level. The tramway ran from the Calumet workings to the mill. The structure is of timber and steel construction and is partially collapsed.

Access to the mine at the 500 level was via the 500 level adit. The portal is blocked by metal doors. The only other opening to surface from the No Cash Mine is a raise near the Brefalt shaft. There are no records of closure of this raise, and it is assumed that some reclamation will be required.

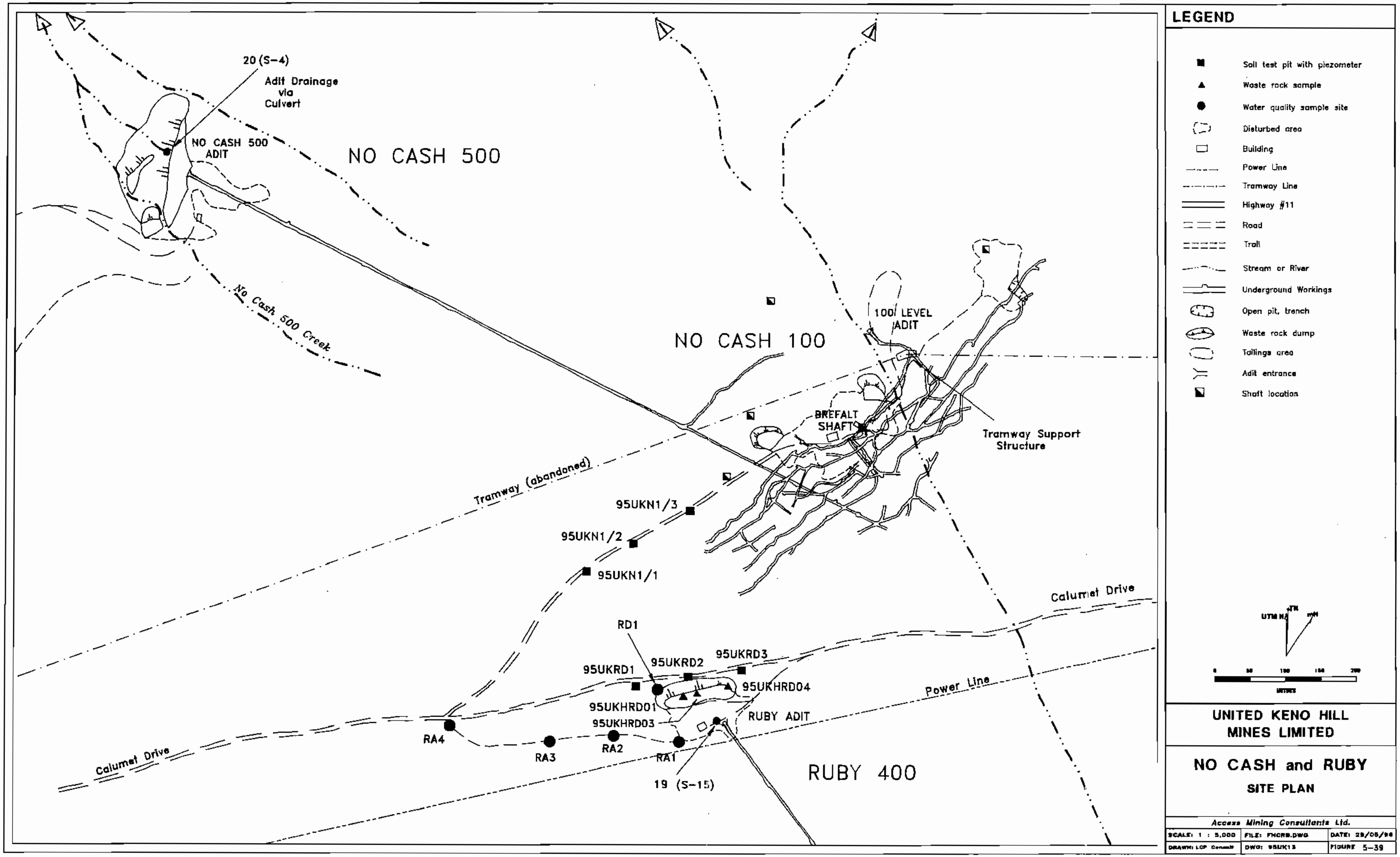
The No Cash Mine is drained at the 500 level. Water from the adit is discharged to No Cash Creek via a culvert through the waste dump at the portal. Recharge to the No Cash Mine is primarily from groundwater, enhanced by connections to other underground workings. It is understood that there is an hydraulic connection to the Calumet Mine via the Jock Fault.

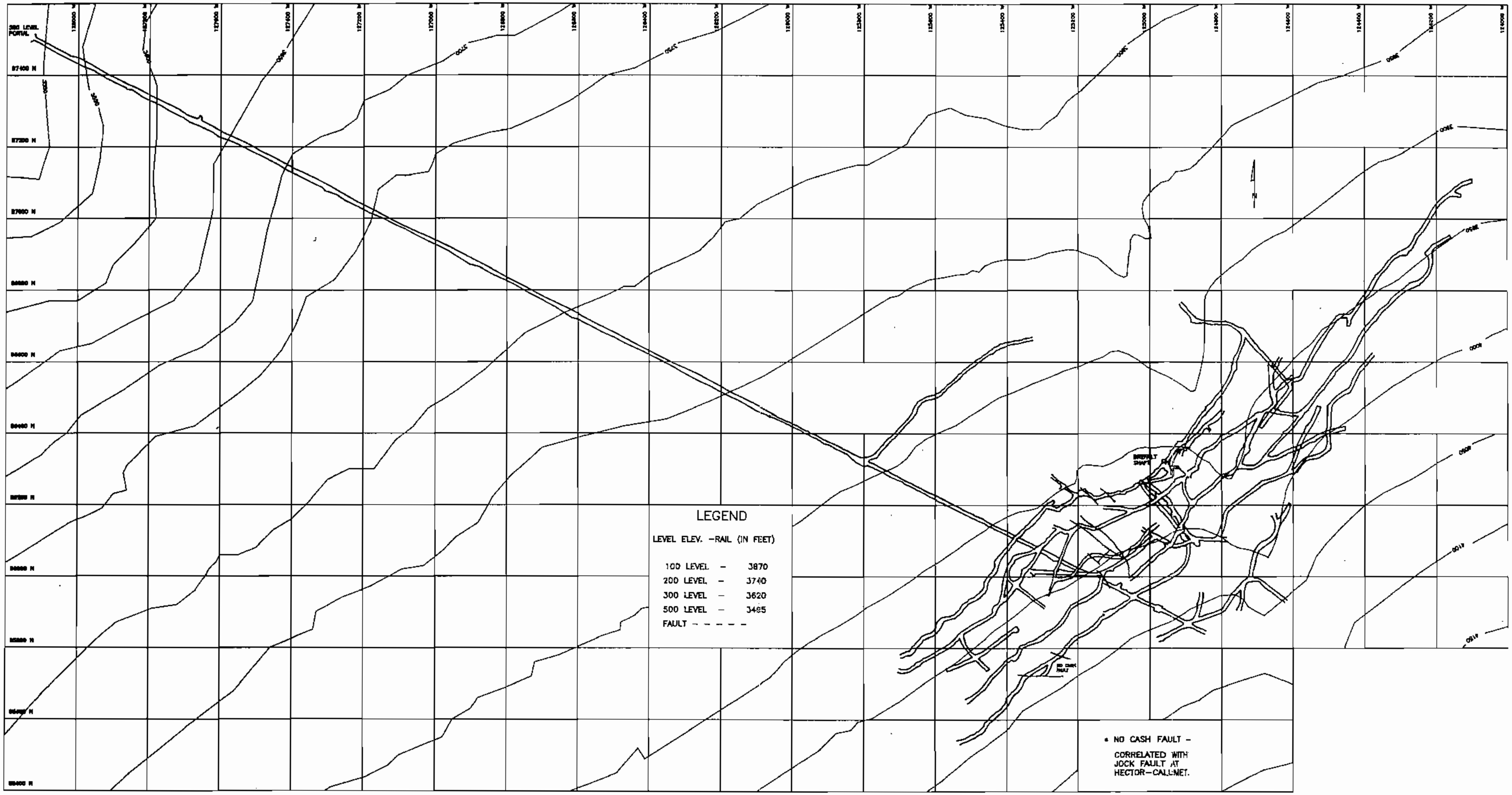
TABLE 5-9

Mine Development						
Mine:	No Cash 100					
Location:	Galena Hill					
Period of Development:		1928 to 1938 & 1948 to 1988				
Developed by:						
Monitoring at:	S-04					
Development at No Cash 100						
	Underground	**Shafts, Raises**	**Bldgs**	**Rock Piles**	**Other**	**Townsite**
		Portals, Adits	**and Equip.**	**waste @100L**		
Period of			1 near shaft		Equipment and	
Development	1948 to 1975	1966	Tramway station	1948 to 1970's	cribbing at tram	
			1 @adit 100, 500		station.	
Production or	See					
Tonnage	No Cash			6,500 tons		
	500					
Features		Rails from u/g.		Quartzite and		
		Door at portal.		schist country rock.		
				4.75 oz Ag/t		
				0.6 % Pb,		
				0.12 % Zn		
Geometry		100L adit 400' long				
		shaft 240' deep				
		500L = 3660'				
Drainage						
Remarks	Primarily used					
	for access as					
	most haulage					
	from 500 level.					

TABLE 5-9

Mine Development						
Mine:	No Cash 500					
Location:	Galena Hill					
Period of Development:		1960's and 1980's				
Developed by:						
Monitoring at:	S-04					
Development at No Cash 500						
	Underground	**Shafts, Raises**	**Bldgs**	**Rock Piles**	**Other**	**Townsite**
		Portals, Adits	**and Equip.**	**waste, ore**		
Period of					cribbed	
Development	1948 to 1988	1966	1 small bldg	1966 to 1982	platform on	
				1986 to 1988	dump	
Production or						
Tonnage	Total for No Cash			138,100 tons		
	166,530 tons					
Features		Culvert through				
		dump drains		lower schist		
		adit.				
		In lower schist				
Geometry						
		adit 3650' long				
Drainage				No Cash		
				Creek		
Remarks		Primary ore		Some reveg.		
		and waste		fireweed and		
		haulage way.		alder/willow		


LEGEND
Soil test pit with piezometer
Waste rock sample
Water quality sample site
Disturbed area
Building
Power Line
Tramway Line
Highway #11
Road
Trail
Stream or River
Underground Workings
Open pit, trench
Waste rock dump
Tailings area
Adit entrance
Shaft location
20 (S-4)
Adit Drainage via Culvert
NO CASH 500 ADIT
NO CASH 500
No Cash 500 Creek
NO CASH 100
100 LEVEL ADIT
BREFALT SHAFT
Tramway Support Structure
Tramway (abandoned)
95UKN1/3
95UKN1/2
95UKN1/1
Calumet Drive
RD1
95UKRD1
95UKRD2
95UKRD3
95UKHRD04
95UKHRD01
95UKHRD03
RUBY ADIT
Power Line
RA4
RA3
RA2
RA1
19 (S-15)
RUBY 400
Calumet Drive
UNITED KENO HILL MINES LIMITED
NO CASH and RUBY
SITE PLAN
Access Mining Consultants Ltd.
SCALE: 1 : 5,000
FIGURE 5-39



UNITED KENO HILL MINES LIMITED

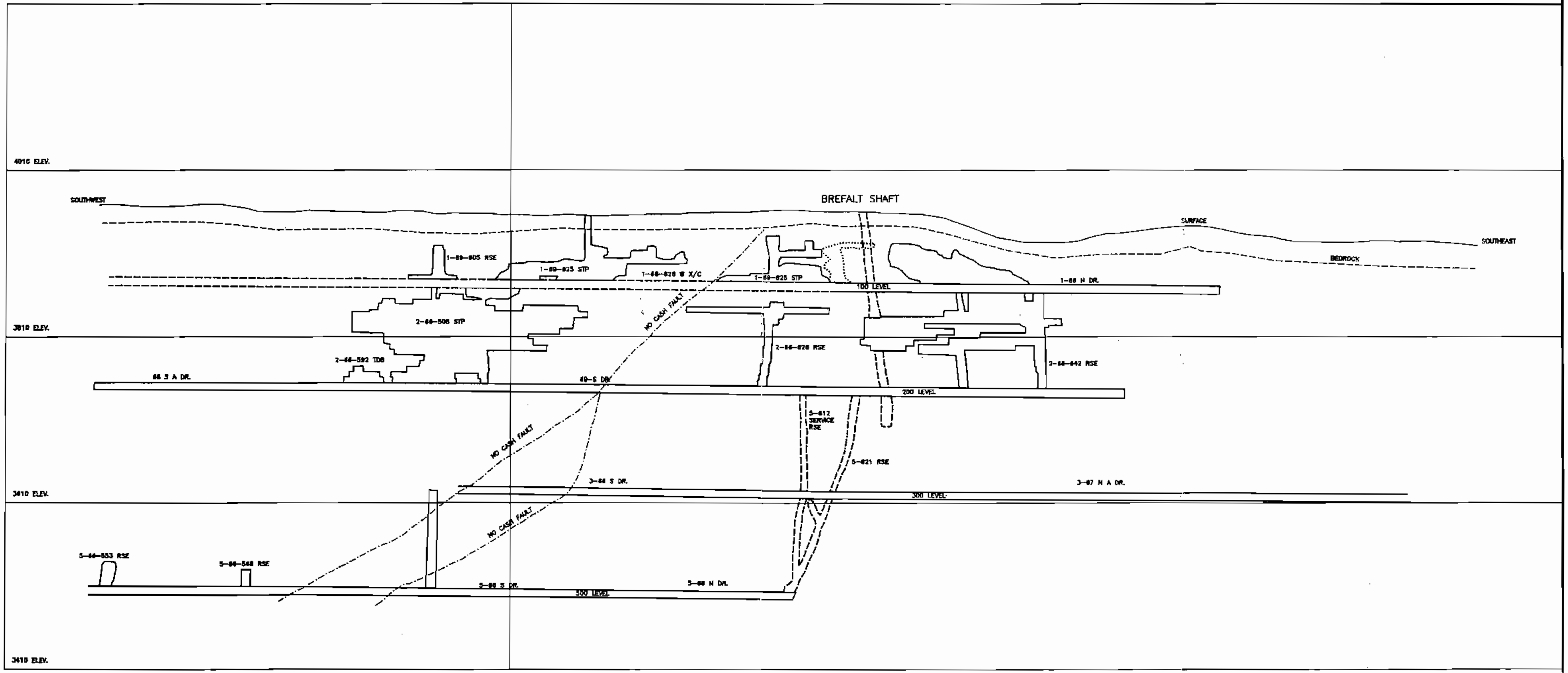
MINE WORKINGS

NO CASH MINE

COMPOSITE PLAN - 63, 68 & 67 VEINS

ACCESS MINING CONSULTANTS LTD.

SCALE: NONE	FILE: NCCOMP.DWG	DATE: 28/05/96
PLOTTED:	DWG: 95UK45	FIGURE: 5-40



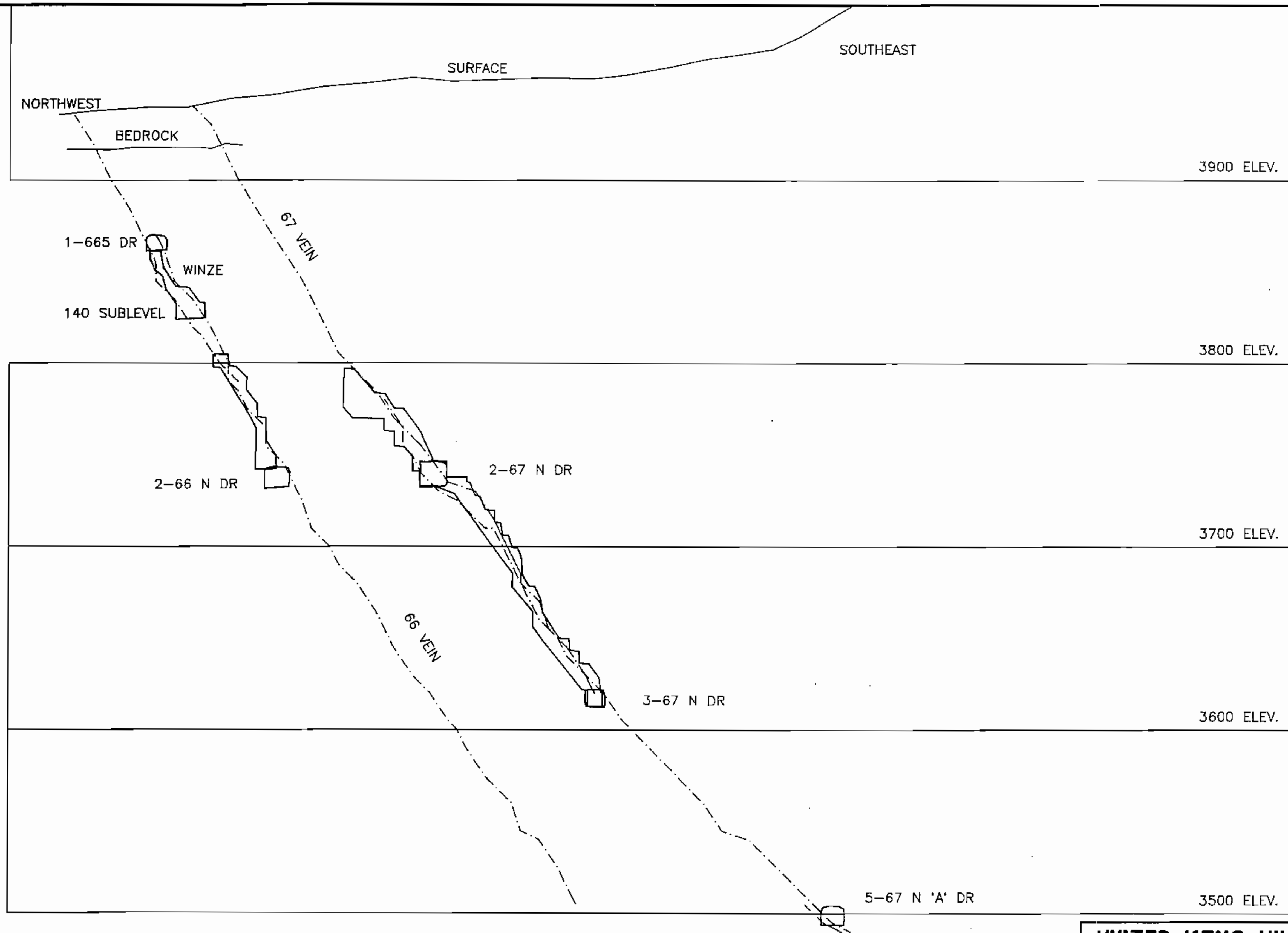
UNITED KENO HILL MINES LIMITED

MINE WORKINGS

NO CASH MINE - 66 VEIN
VERTICAL LONGITUDINAL SECTION (Looking Northwest)

ACCESS MINING CONSULTANTS LTD.

SCALE: NONE	FILE: NC66LONG.DWG	DATE: 28/05/96
PLOTTED:	DWG: 95UK44	FIGURE: 5-41



UNITED KENO HILL MINES LIMITED

MINE WORKINGS

NO CASH MINE, 66 & 67 VEINS
SECTION 111 (Looking Northeast)

ACCESS MINING CONSULTANTS LTD.

SCALE: NONE	FILE: NCXSECT.DWG	DATE: 28/05/96
PLOTTED:	DWG: 95UK46	FIGURE: 5-42

5.2.12 Ruby

Development: Table 5-10

Figures: Figure 5-4 (in Section 5.2, Bermingham)
Figure 5-5 Ruby - Bermingham Composite Plan

The Ruby mine was an underground mine with access via a portal at the 400 level, and ventilation raise which connects with the bottom of the Ruby shaft. There are metal doors at the 400 portal (not locked) to block access. Ice is evident within the adit year-round. The vent raise is also currently covered with a building.

The Ruby headframe building is still in place at the Ruby shaft, although most of the equipment has been removed. Some collapse is evident around the shaft probably due to the failure of ground support. There is also a wooden building remaining near the shaft which was the powder magazine but is now empty.

At the portal, there remains a loadout, several buildings, and a water supply line. The waste rock from development of the Ruby adit is located immediately downslope from the portal.

TABLE 5-10

Mine Development						
Mine:	Ruby 400					
Location:	Galena Hill					
Period of Development:		1940's, 1978				
Developed by:						
Monitoring:	S-15					
Development at Ruby						
	Underground	**Shafts, Raises**	**Bldgs**	**Rock Piles**	**Other**	**Townsite**
		Portals, Adits	**and Equip.**	**waste**		
Period of					Cribbed	
Development		1978	several 1980's		platform for	
			rails		loadout.	
Production or						
Tonnage	40,652 tons			28,900 tons		
Features	iced	Door at portal		Quartzite and		
		considerablw		greenstone		
		ice buildup at		minimal sulphides		
		portal				
Geometry		adit 2350' long		slope 38^o		
Drainage		adit drains to				
		dithh S of dump				
		then acsoss road				
		in culvert				
Remarks						

5.2.13 Silver King

Development: Table 5-11

Figures: Figure 5-43 Site Plan
Figure 5-44 Site Plan
Figure 5-45 Silver King Mine, Composite Plan
Figure 5-46 Silver King Mine, Vertical and Longitudinal Section

The first discovery in the Elsa silver camp was in Galena Creek in 1906; the area of the current Silver King mine. Hand mining began in the area in 1912.

The area comprises both the open pit, which was mined from 1983 to 1984, and the underground workings.

Underground mining began in 1912 with the development of the Aitken shaft and the 50 and 75 adits. The shaft was located in the Galena Creek Canyon and extended to the 300 level. Mining from this shaft continued until 1918.

In 1928 underground workings were established on the No. 1 & 2 Veins, to the northeast of Galena Creek. Mining continued until 1939 from shafts, shallow adits and lateral development on the 100, 200 and 300 levels.

In the 1980's, access to underground was from the 100 level (1140 ft) adit. The Silver King open pit was also mined during this period, primarily for crown pillar recovery from the No. 3 shaft located in the open pit. Some timbering is still evident at surface but the surrounding rock has caved into the shaft..

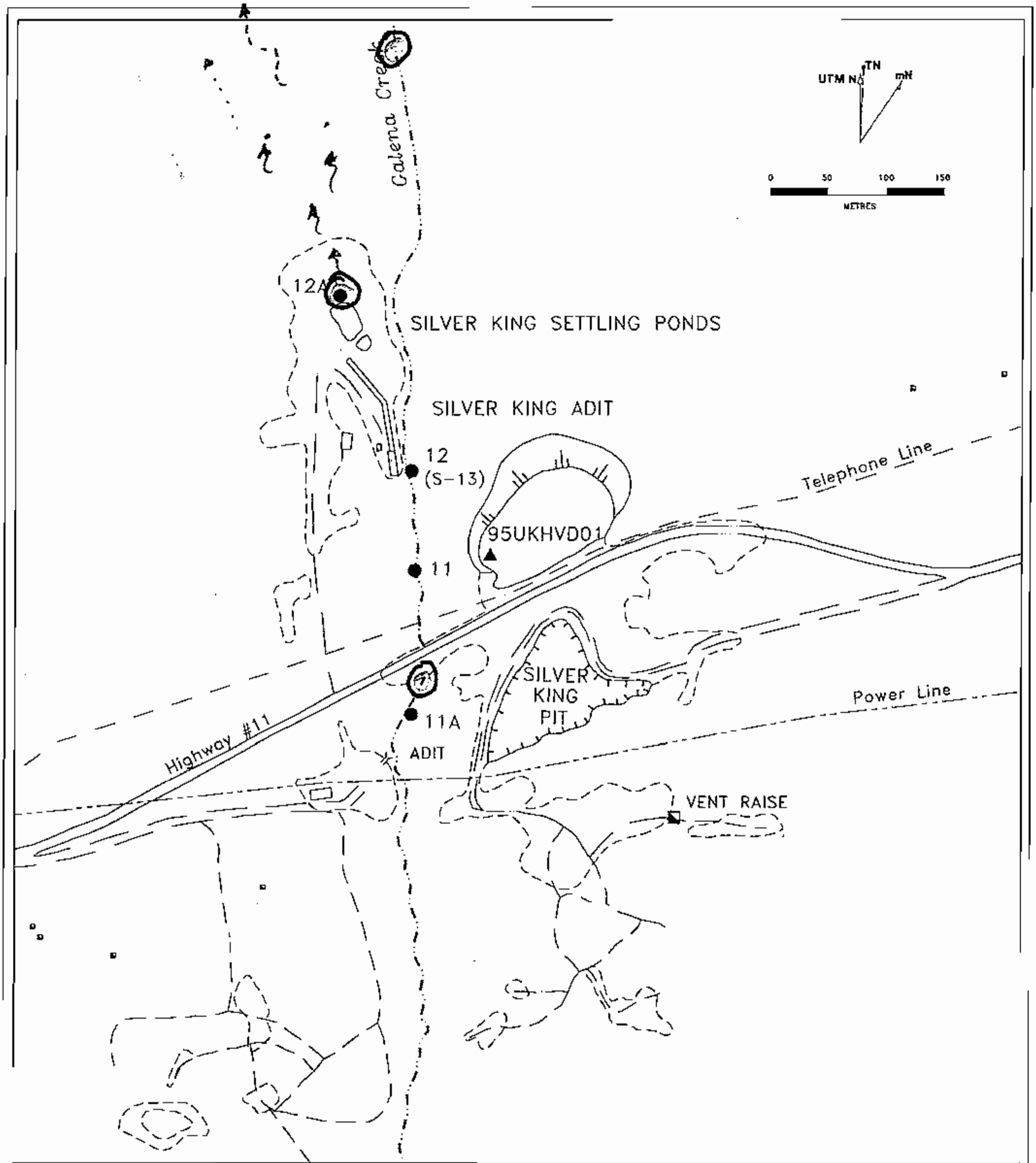
The third stage of development was begun in 1994; primarily exploration and associated development of a decline from the 300 to 400 levels. Two raises were driven to surface. One collapsed, and the other is now used as an escapeway (1-5-735 Raise). The 75 level adit, located in Galena Creek Canyon, is connected to the 100 level adit and is now used for ventilation. The portal was re-timbered recently and mesh screening placed across the entrance.

Rehabilitation of the underground workings prior to the recent exploration program included establishment of a simple water treatment system to remove dissolved metals from the water pumped from underground at the 100 level adit. Lime slurry is added to the water as it is pumped from underground. Two settling ponds, constructed at the portal, allow the sludge to settle prior to discharge of the treated water. The treated discharge ultimately reports to Galena Creek and then to Flat Creek.

Old site plans and reports indicate that there may be up to seven additional raises and nine shafts to surface from the No.1 and 2 Veins, associated with the early years of mining (1928 to 1939). Most of these are reported to have caved and are no longer readily evident from surface, however this will be confirmed.

TABLE 5-11

Mine Development								
Mine:	Silver King adit and open pit							
Location:	Galena Hill							
Period of Development:		1980's						
Developed by	UKHM							
Monitoring at:	S-13							
Development at Silver King								
	Open Pit	**Underground**	**Shafts, Raises**	**Bldgs**	**Rock Piles**	**Pit dump**	**Ore**	**Other**
			Portals, Adits	**& Equip**	**adit dump**			
Period of		pre-1945	pre-1945					
Development	1983	1984 to 1988	Adit 1984		1984 to 1988	1983	1994-1995	1994 to present
			Ramp 1987					Treatment plant
Production or								
Tonnage	Total = 207,613 tons				43,000 tons	120,000 tons		
	Pit = 6,631 tons	UG=						
		200,982 tons						
Features		E&W	Adit 100' long		Primarily country	Overburden		2 settling ponds
		100L	Adit 1040' long		rock - quartzite	at base with		
			Current?		and graphitic	quartzite		
			Shaft 300' deep		schist			
Geometry			Ramp from 100					
			level to 300 level		40^o slope	38^o slope		
			1995 decline					
			from 300L to					
			400L					
Drainage								To Galena Creek
Remarks	Crown pillar		most adit dump is		Natural reveg.			
	recovery at		country rock graph					
	#3 shaft		schist / qtzite					
			few % py					



LEGEND

- ■ Soil test pit with piezometer
- ▲ Waste rock sample
- ● Water quality sample site
- Disturbed area
- Building
- Power Line
- Telephone Line
- Highway #11
- Road
- Trail
- Stream or River
- Open pit, trench
- Waste rock dump
- Tailings area
- Adit entrance
- Shaft location

UNITED KENO HILL MINES LIMITED

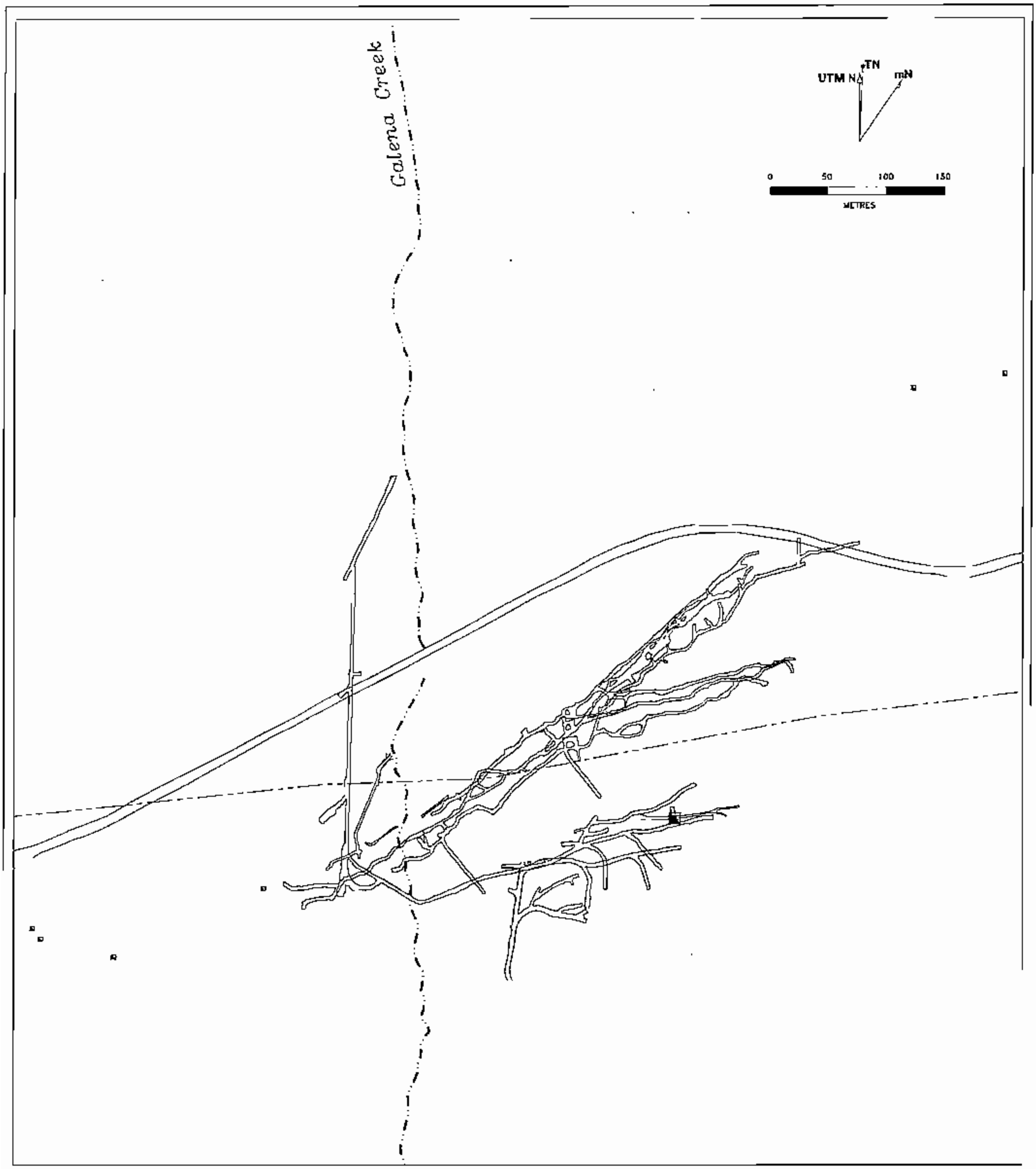
SILVER KING

SITE PLAN

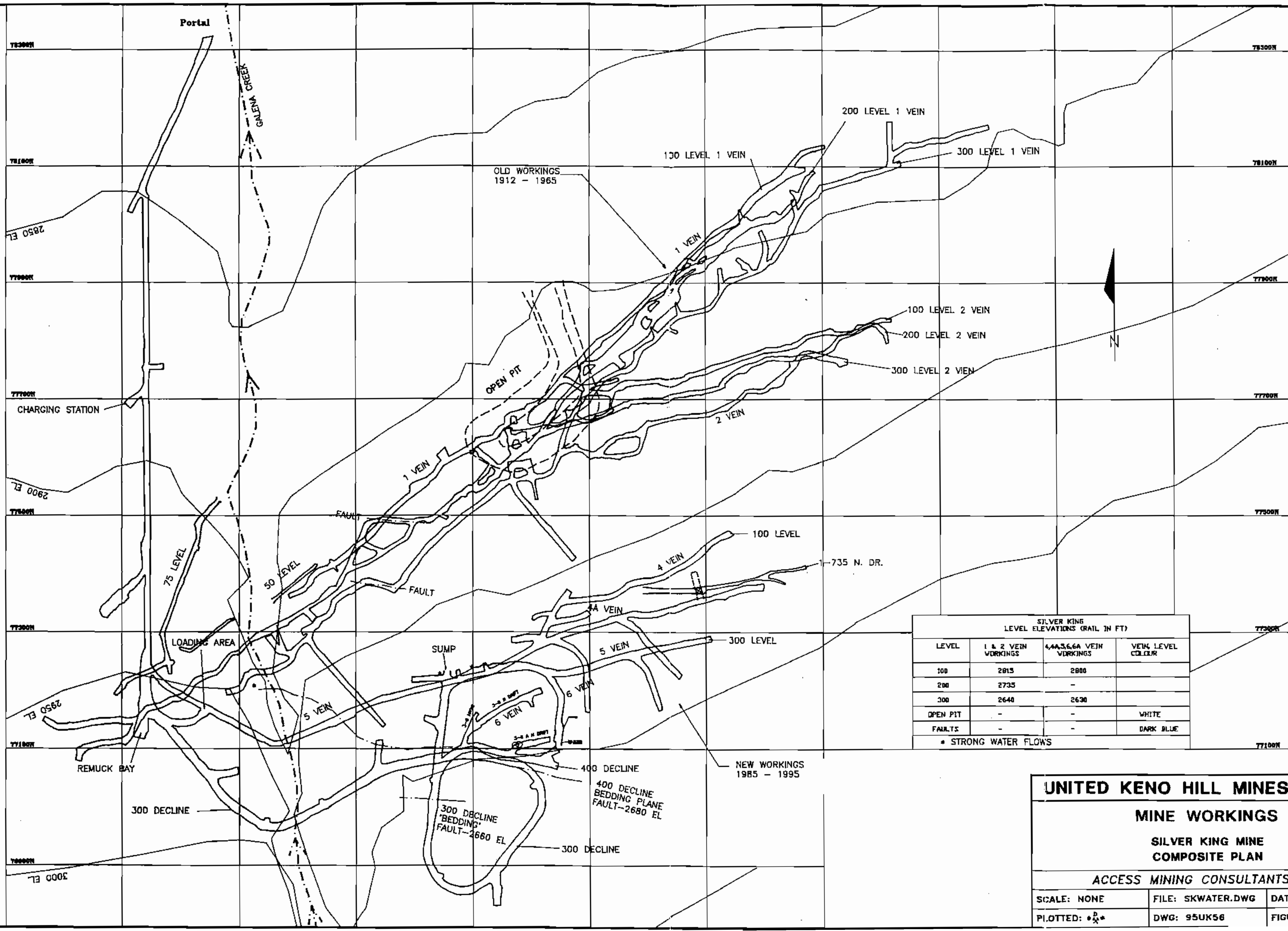
Access Mining Consultants Inc.

SCALE: 1 : 5,000	FILE: FACKINGA.DWG	DATE: 28/05/98
DRAWN: LCP Consult	DWG: 95UK06	FIGURE 5-43

◎ 2001 AMT SAMPLE LOC'N.



LEGEND			UNITED KENO HILL MINES LIMITED
Soil test pit with piezometer	Telephone Line	Open pit, trench	SILVER KING
Waste rock sample	Highway #11	Waste rock dump	UNDERGROUND
Water quality sample site	Road	Tailings area	Access Mining Consultants Inc.
Disturbed area	Trail	Adit entrance	SCALE: 1 : 5,000 — FILE: FAGKINGB.DWG — DATE: 29/05/96
Building		Shaft location	DRAWN: LCP Consult — DWG: 95UK07 — FIGURE 5-44
Power Line	Stream or River		



SILVER KING
LEVEL ELEVATIONS (RAIL IN FT)

LEVEL	1 & 2 VEIN WORKINGS	4,4A,5,6,6A VEIN WORKINGS	VEIN LEVEL COLOUR
100	2815	2800	
200	2735	-	
300	2640	2630	
OPEN PIT	-	-	WHITE
FAULTS	-	-	DARK BLUE

* STRONG WATER FLOWS

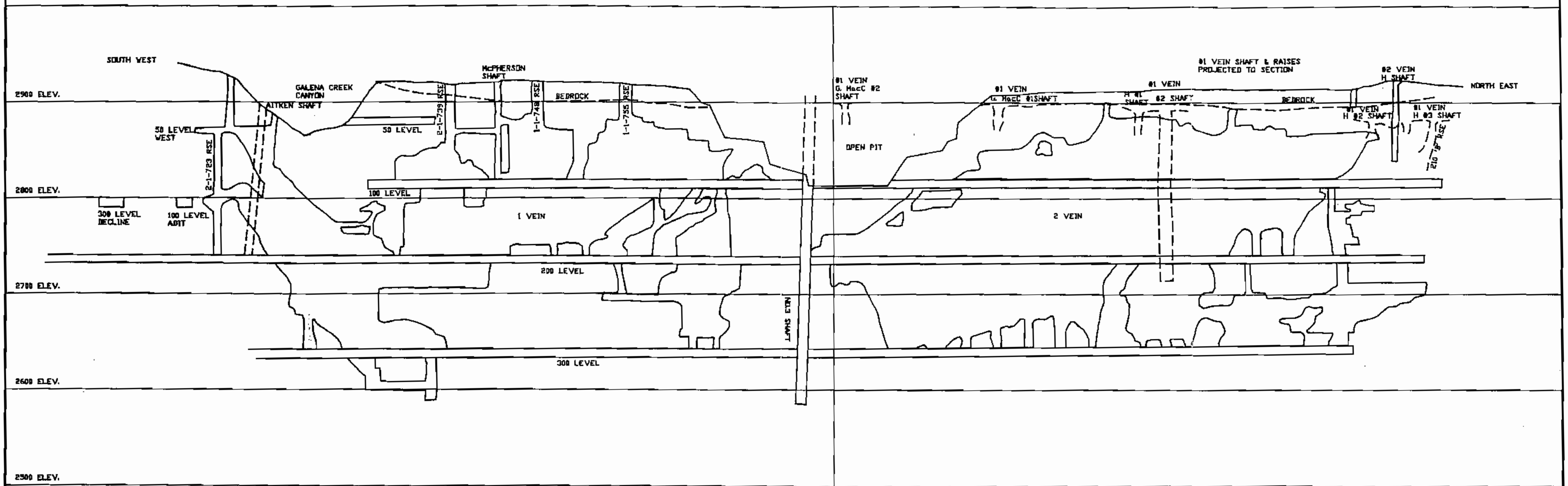
UNITED KENO HILL MINES LIMITED

MINE WORKINGS

SILVER KING MINE
COMPOSITE PLAN

ACCESS MINING CONSULTANTS LTD.

SCALE: NONE	FILE: SKWATER.DWG	DATE: 28/05/96
PLOTTED:	DWG: 95UK56	FIGURE: 5-45



UNITED KENO HILL MINES LIMITED

MINE WORKINGS

SILVER KING MINE, VERTICAL AND LONGITUDINAL SECTION 1 & 2 VEINS, (Looking Northwest)

ACCESS MINING CONSULTANTS LTD.

SCALE: NONE	FILE: SKLONG.DWG	DATE: 28/05/96

5.2.14 Sime Pits

Development: Table 5-12

Figures: Figure 5-47 Site Plan

Figure 5-24 Galkeno Mine, Cross Section showing McLeod, Sime Workings & 900 Level Adit, Looking Northeast

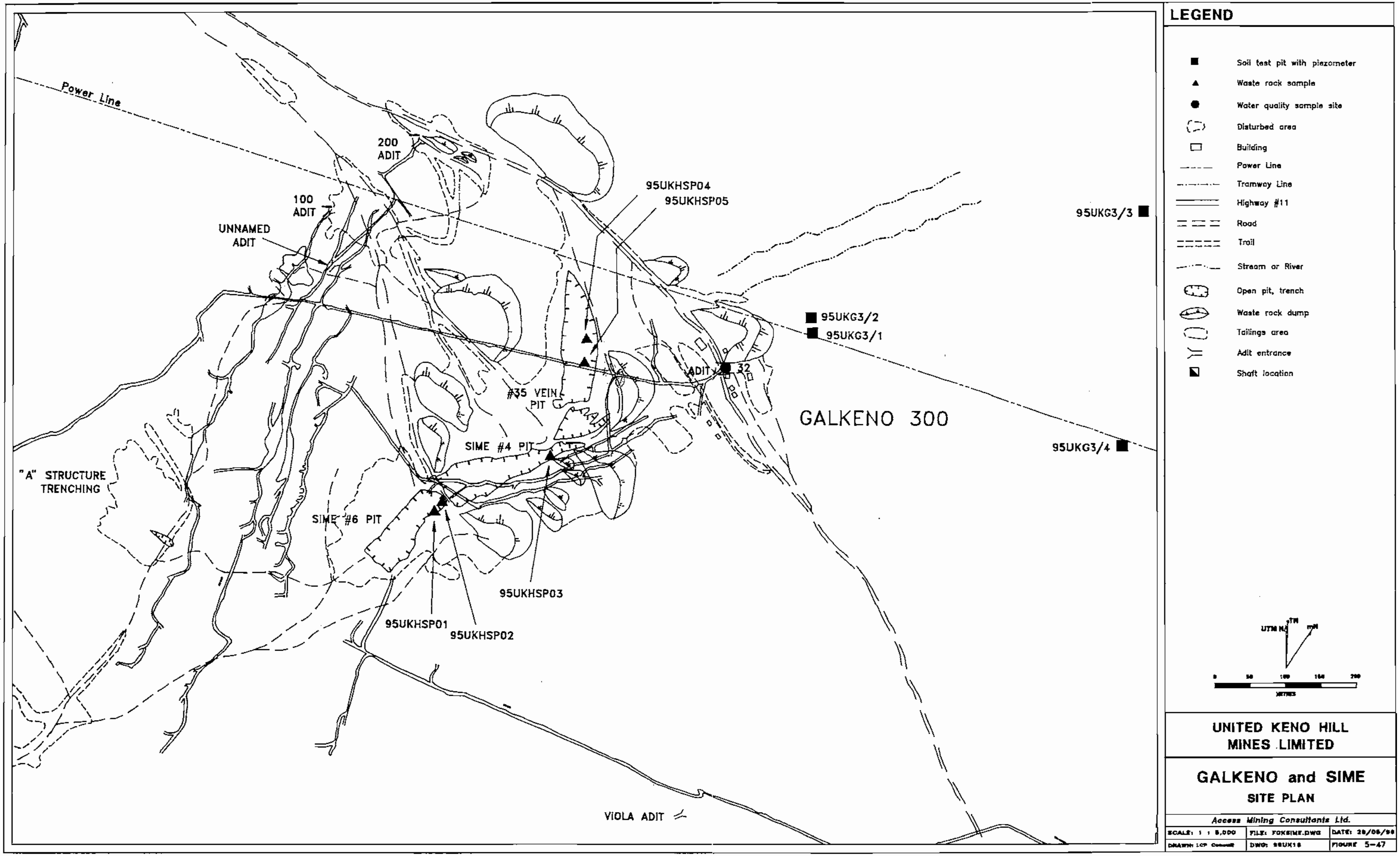
Figure 5-25 Galkeno Mine, Vertical Longitudinal Section, Looking Azimuth 330°

Figure 5-27 Jock, Hector, Calumet and Galkeno Composite Mine Plan

A series of three shallow open pits comprise the Sime workings. Mining was completed in the late 80's. While there is no record of a connection with underground workings for these pits, there is no net accumulation of water evident in the pits. In the lowest pit, the Sime 35 pit, water is seen in the spring but none in the summer. It is assumed to drain to the underground workings. The 300 level adit is relatively close to the bottom of the pit and there may be an hydraulic connection through faults and fractures.

TABLE 5-12

Mine Development							
Mine:	Sime 4, Sime 6, "35" Vein						
Location:							
Period of Development:		1980's					
Developed by:	UKHM						
Development at Sime							
	Open Pit	**Underground**	**Shafts, Raises Portals, Adits**	**Bldgs and Equip.**	**Rock Piles waste, ore**	**Other**	**Townsite**
Period of Development	1979-1981 1984						
Production or Tonnage	Sime 4&6 = 38,128 tons Sime 35= 9,176 tons		1S daylights in upper pit		total 450.000 t in series of small dumps		
Features					quartzite with some graphitic schist		
Geometry	3 small open pits, continuous down slope				slopes from 34 to 41^{o}		
Drainage					primarily to underground		
Remarks					some remnants of ore piles on top of rock dumps		


Power Line
200 ADIT
100 ADIT
UNNAMED ADIT
95UKHSP04
95UKHSP05
95UKG3/3
95UKG3/2
95UKG3/1
ADIT
32
#35 VEIN PIT
GALKENO 300
SIME #4 PIT
95UKG3/4
"A" STRUCTURE TRENCHING
SIME #6 PIT
95UKHSP03
95UKHSP01
95UKHSP02
VIOLA ADIT
LEGEND
Soil test pit with piezometer
Waste rock sample
Water quality sample site
Disturbed area
Building
Power Line
Tramway Line
Highway #11
Road
Trail
Stream or River
Open pit, trench
Waste rock dump
Tailings area
Adit entrance
Shaft location
UNITED KENO HILL MINES LIMITED
GALKENO and SIME
SITE PLAN
Access Mining Consultants Ltd.
FILE: FOXSIME.DWG
FIGURE 5-47

5.2.15 Townsite

Development: Table 5-13

Figures: Figure 5-29 Site Plan (in 5.2.7 - Hector Calumet)
Figure 5-30 Site Plan (in Section 5.2.7 - Hector Calumet)
Figure 5-48 Townsite Mine, Plan
Figure 5-49 Townsite Mine, 35 Vein, Vertical Longitudinal Section, Looking Northwest

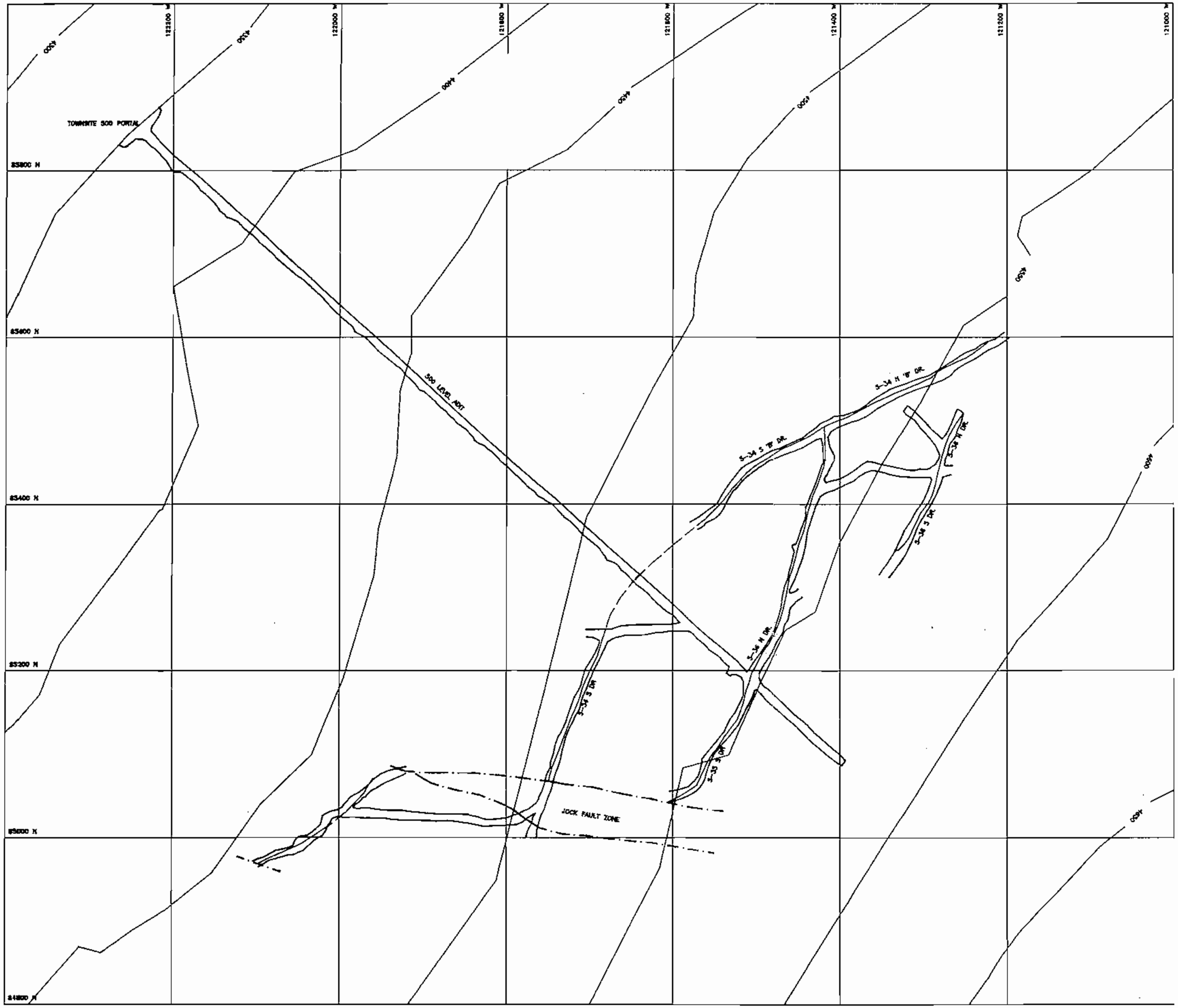
The Townsite Mine is primarily underground, although an open pit was proposed for the area. Some preliminary stripping was done.

The Townsite 500 adit is located on the road to Hector-Calumet. The portal is completely caved and covered by broken rock to seal it. The timber cribbing of the foundation for the loadout remains, located on the other side of the road from the adit. Some waste rock from the adit development was used to build the loadout area, with the remainder of the waste deposited adjacent to the loadout area.

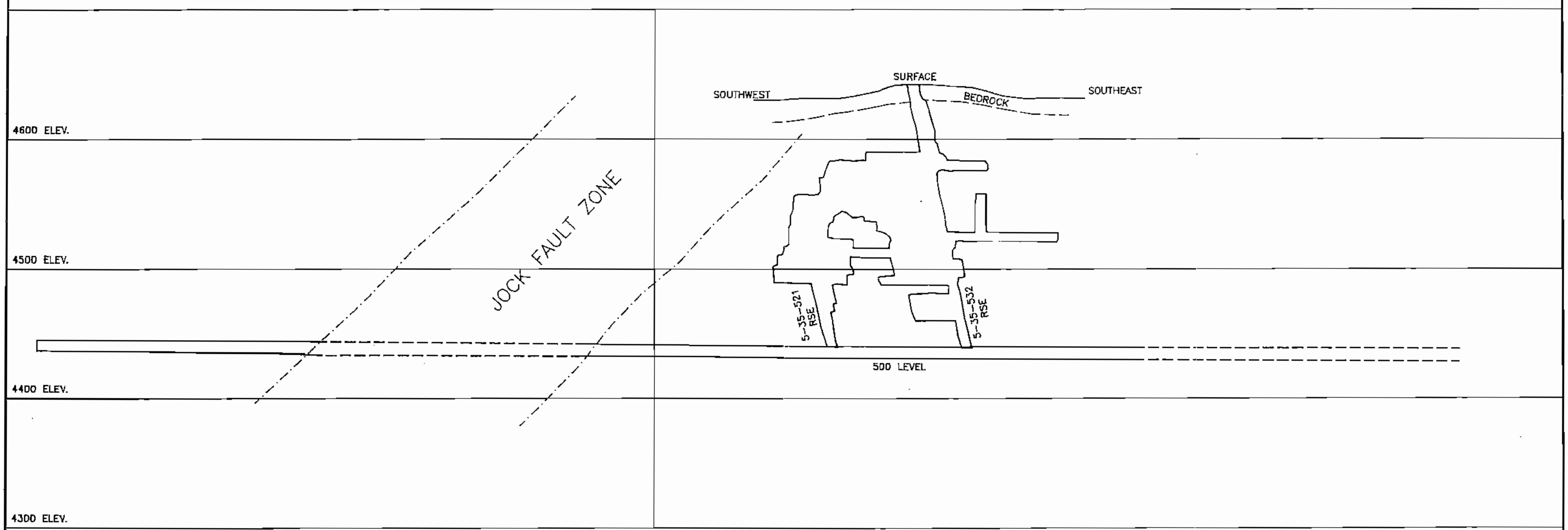
It is reported that there was also a raise from the adit to surface which was also caved and sealed.

TABLE 5-13

Mine Development						
Mine:	Townsite					
Location:	Galena Hill					
Period of Development:		1970's				
Developed by:						
Development at Townsite						
	Underground	**Shafts, Raises**	**Bldgs**	**Rock Piles**	**Other**	**Townsite**
		Portals, Adits	**and Equip.**	**waste, ore**		
Period of					Cribbed platform	1970's
Development	1970's	1972		1972 to 1975	for loadout?	
Production or						
Tonnage	18,570 tons			14,300 tons		
Features	iced	Covered by		Crosscut material		Removed
		rockfall		primarily quartzite		
				country rock distant		
				from the vein		
Geometry		Adit 1,150' long		Slope 42^{o}, stable		
Drainage		No drainage				
		visible at adit				
Remarks		No access to				
		adit				



UNITED KENO HILL MINES LIMITED		
MINE WORKINGS		
TOWNSITE MINE PLAN		
ACCESS MINING CONSULTANTS LTD.		
SCALE: NONE	FILE: TOWNPLAN.DWG	DATE: 28/05/96
PLOTTED:	DWG: 95UK58	FIGURE: 5-48



UNITED KENO HILL MINES LIMITED		
MINE WORKINGS TOWNSITE MINE - 35 VEIN VERTICAL LONGITUDINAL SECTION (Looking Northwest)		
ACCESS MINING CONSULTANTS LTD.		
SCALE: NONE	FILE: TOWNLONG.DWG	DATE: 28/05/96
PLOTTED:	DWG: 95UK57	FIGURE: 5-49

5.2.16 UN Adit

Development: Table 5-14

Figures: Figure 5-38 (in Section 5.2.10 - Miller) Site Plan

Figure 5-27 Jock, Hector, Calumet and Galkeno Composite

The UN adit and associated limited underground workings were developed in the 1950's but no ore was mined here. There is a small waste dump and an adit. The adit does drain, although flows are relatively low. The portal is timbered but not secured for closure. There are no remaining buildings or equipment.

TABLE 5-14

Mine Development						
Mine:	UN					
Location:	Galena Hill					
Period of Development:		early 1950's				
Developed by:						
Monitoring at:	S-02					
Development at UN						
	Underground	**Shafts, Raises Portals, Adits**	**Bldgs and Equip.**	**Rock Piles waste, ore**	**Other**	**Townsite**
Period of Development	1950's	1950's		1950's		
Production or Tonnage	included with Miller			3,200 tons		
Features	no ore was			1.06 oz Ag/t		
	mined from			0.40% Pb		
	here			0.12% Zn		
Geometry		Adit 400' long				
		Drift 500'				
Drainage						
Remarks		Revegetation		Limited revegetation		

5.2.17 Flame and Moth

Development: Table 5-15

Site Plan: There is no plan for Flame and Moth (see Figure 2-1 for location)

The Flame and Moth was originally a small underground development comprising a shaft and 75 foot level drift on vein. It was developed initially in 1923, but mined primarily in the 1950's. Only 1600 tons of ore are reported to have been extracted in total from this area.

In the late 1980's open pit mining to recover the crown pillar from the old underground was started by UKHM, and the site was still in production at closure. The open pit still contains ore reserves.

The mine is reported to be on the Onek vein, and more closely resembles the Keno Hill mineralogy with higher calcite content and higher, according to Lynch, pyrrhotite and arsenopyrite than is typical of Galena Hill.

There is a small waste dump associated with the open pit. The shaft is located within the open pit, but has been partially mined out.

There is no apparent discharge of water from the pit or dumps, however there may be shallow ground water flow from the area. Any drainage would ultimately report to Christal Lake.

TABLE 4-15

Mine Development						
Mine:	Flame and Moth					
Location:	Galena Hill					
Period of Development:		1950's & 1980's				
Developed by:						
Development at Bermingham						
	Open Pit	**Underground**	**Shafts, Raises**	**Bldgs**	**Rock Piles**	**Other**
			Portals, Adits	**and Equip.**	**pit dump**	
Period of						
Development	late 1980's	1950's	1950's		1980's	
Production or	1590					
Tonnage						
Features	Still contains	75 foot level	1 old shaft		1 small waste	
	ore reserves	drift on vein	located within		dump associated	
			open pit has been		with open pit	
			partially mined out			
Geometry			75 foot level			
			drift on vein			
			1500' lateral dev.			
Drainage	Drainage would				No apparant	
	ultimately report				discharge of	
	to Christal Lake				water from dump	
Remarks						

5.2.18 Sadie Ladue (Wernecke Camp)

Development: Table 5-16

Figures : Figure 5-50 Site Plan

Figure 5-51 Sadie - Ladue Mine, Composite Plan

The Sadie Ladue underground workings are some of the oldest workings in the Keno Hill area, mined in the 1920’s and 1930’s. There were four shafts, two on the Sadie portion of the vein to the 400 level and two on the Ladue portion to the 600 level. The Sadie vein was developed on five levels (100 level to 400 level) and the Ladue and six levels (50 level to 600 level). The Sadie 600 level adit was driven for dewatering and access of men and materiel. Some rehabilitation work was done at the 600 adit in the late 60’s and early 70’s to remove the ice and allow access to the upper old workings. Frozen ground was noted to extend below 260 feet depth (Wernecke quoted in McTaggart, K.C., 1960).

There is still a small, shallow open pit at the Wernecke Camp. The Sadie-Ladue 600 adit has partially collapsed since it was last used in the 1960’s, but does still drain water for some of the year.

The Sadie-Ladue surface disturbance was done by UKHM surface exploration trenching and Archer Cathro’s hand mining operation. Before their work, a thick cover of alder up to 5 feet high covered the area. It is reported that all the shafts, as well as the two stopes and raises to surface, were filled in as of the 1980’s.

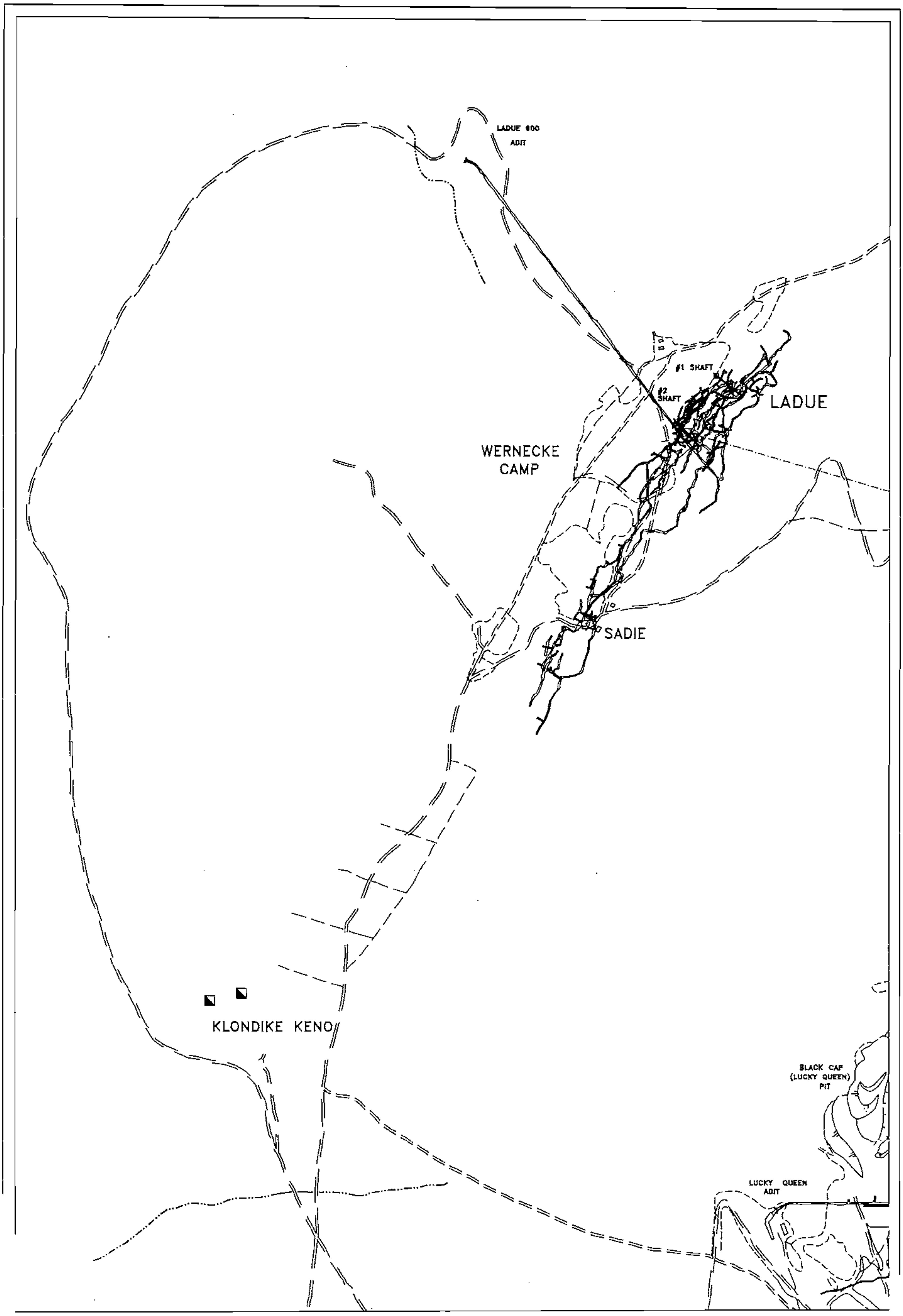
TABLE 5-16

Mine Development

Mine:	Sadie Ladue (Wernecke Camp) and Sadie 600 adit						
Location:	Keno Hill						
Period of Development:		1920's and 1980's, and 1960's at 600L					
Developed by:							

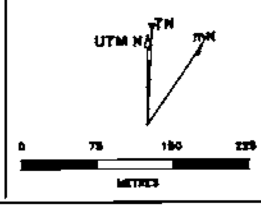
Development at Sadie Ladue

	Underground	Shafts, Raises Portals, Adits	Bldgs and Equip.	Rock Piles shaft dump	600 adit dump	Other	Mill and Tailings
Period of Development	1923 to 1932	1923 shaft	old mine manager's	1923 to 1932	1928 to 1932	cribbed platform	1925 to 1931
	1982 to 1989	1928 @600 adit	house		1968 to 1970	for loadout @600	
	hand cobbing	1968 rehab.					
Production or Tonnage	244,330 tons			24,500 tons	9,500 tons		125 ton/day
Features		600 adit is		waste vein	3.8 oz Ag/t		no dams
		partially collapsed		material	0.9% Pb		
				quartzite, schis	0.4% Zn		
				greenstone			
Geometry							
				30^{o} slopes			
Drainage							
Monitoring Stations					S-7		
Remarks	The 600 adit was originally driven to provide drainage for the shaft workings. Reactivated in 1960's to access upper old workings.			Limited reveg.	Limited reveg.		Mill and tailings location at the Wernecke Camp



LEGEND

- Soil test pit with piezometer
- Waste rock sample
- Water quality sample site
- Disturbed area
- Building
- Power Line
- Tramway
- Highway #11
- Road
- Trail
- Stream or River
- Underground Workings
- Open pit, trench
- Waste rock dump
- Tailings area
- Adit entrance
- Shaft location

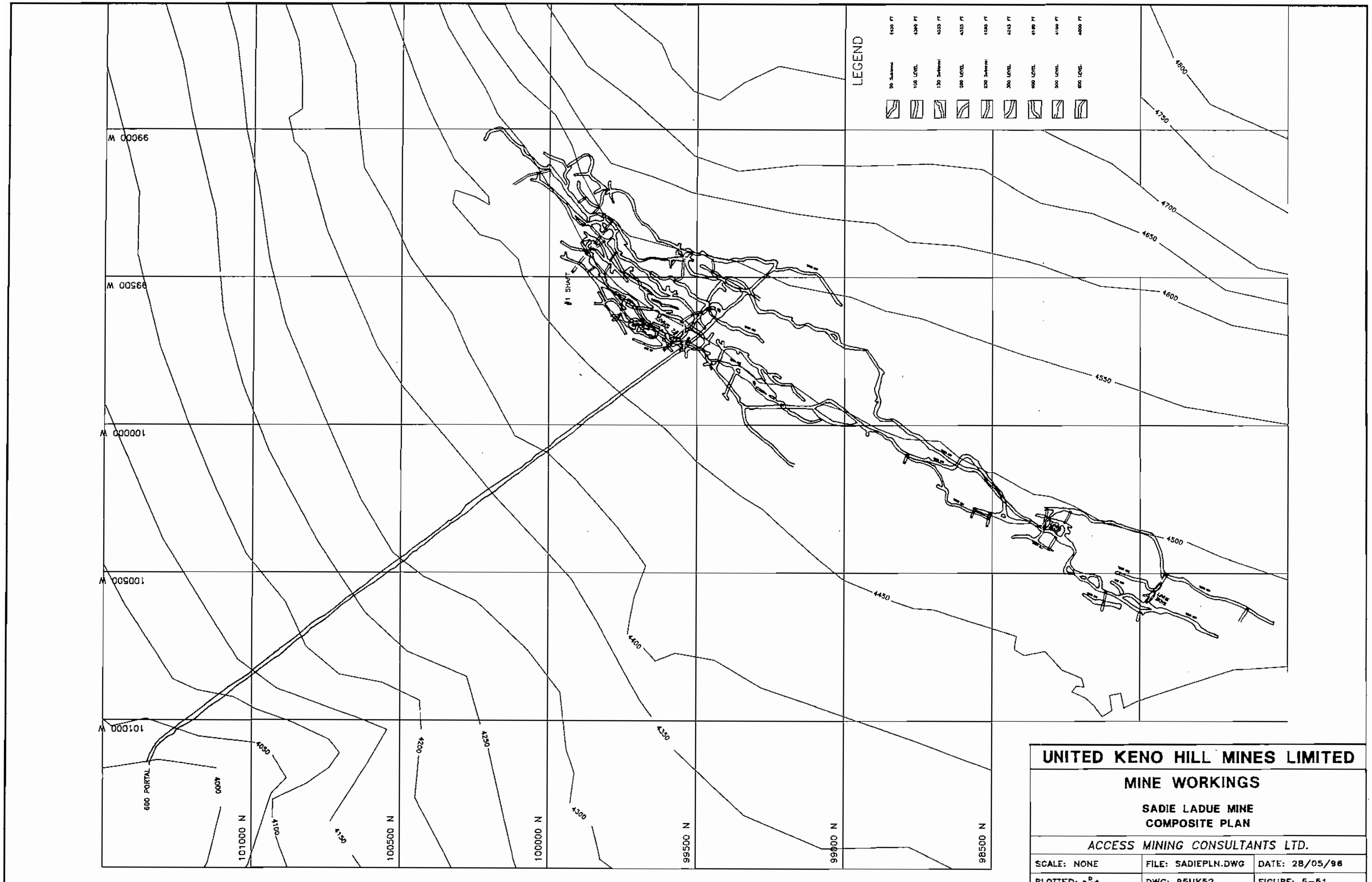


UNITED KENO HILL MINES LIMITED

WERNECKE, SADIE/LADUE KLONDIKE KENO SITE PLAN

Access Mining Consultants Ltd.

SCALE: 1 : 7,500	FILE: FWERNECK.DWG	DATE: 29/05/94
DRAWN: LCP Consult	DWG: 95UK21	FIGURE 5-50



UNITED KENO HILL MINES LIMITED

MINE WORKINGS

SADIE LADUE MINE
COMPOSITE PLAN

ACCESS MINING CONSULTANTS LTD.

SCALE: NONE	FILE: SADIEPLN.DWG	DATE: 28/05/96
PLOTTED:	DWG: 95UK52	FIGURE: 5-51

5.2.19 Lucky Queen

Development: Table 5-17

Figures : Figure 5-52 Site Plan

Figure 5-53 Lucky Queen Composite Plan

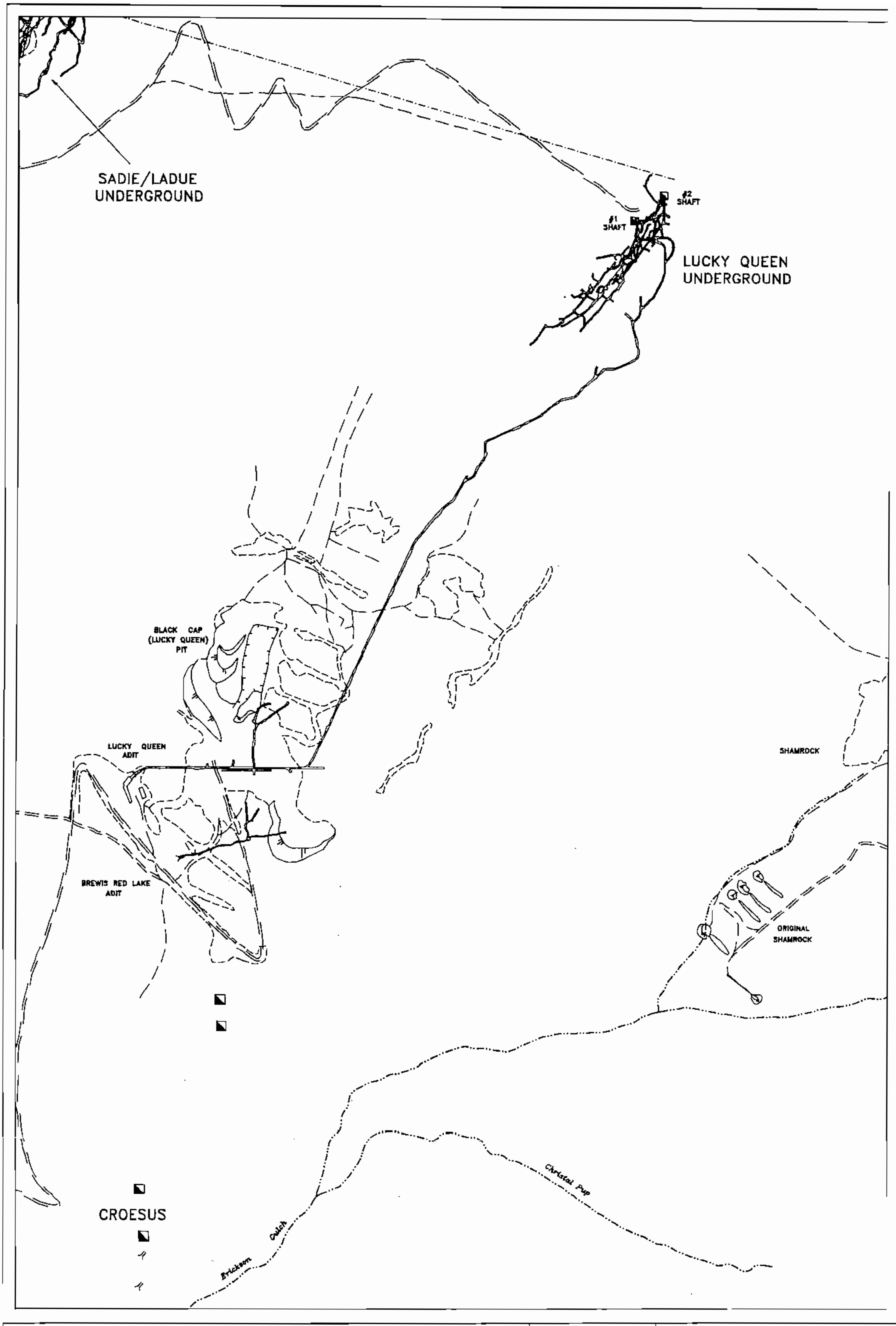
Lucky Queen was mined for a four year period, from 1928 to 1932, from an incline shaft and levels at the 50, 100, 200 and 300 levels and then again from 1984 to 1988. From 1984 to 1988 UKHM drove an adit on the 500 level to explore the Lucky Queen vein below the old 300 level workings. The adit, over 5,700 feet in length, was collared near the Black Cap open pit. The old incline shaft was de-iced to the bottom of the shaft and a raise from the 500 adit was driven to just above the 400 level. Archer Cathro also did some surface “hand mining” in the late 1980’s around the shaft.

The shaft is covered by a building, in good condition, but not locked. Subsidence has taken place in two areas above the old workings. The portal, which is near the Black Cap Open pit, is open but the road is blocked by a locked gate. There are reported to have been three short adits at Stone Claims, associated with Lucky Queen, but all three are caved.

Permafrost is reported to extend below the 300 level of the mine. The Lucky Queen was not reported to be a wet mine; the adit continues to drain during the summer only.

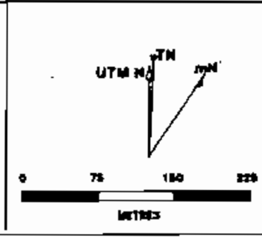
TABLE 5-17

Mine Development							
Mine:	Lucky Queen shaft and 500 adit						
Location:	Keno Hill						
Period of Development:		1920's and 1930's, 1980's					
Developed by:							
Monitoring at:	S-14						
Development at Lucky Queen							
	Open Pit	**Underground**	**Shafts, Raises**	**Bldgs**	**Rock Piles**	**500**	**Other**
			Portals, Adits	**and Equip.**	**shaft dump**	**adit dump**	
Period of		1928 to 1932	shaft				
Development		1984 to 1988	adit	1980's	1928 to 1932	1984-1988	
Production or		Total production=					
Tonnage		123,530 tons			5,000 tons	61,900 tons	
	small hand cob						
	open pit by A/C						
Features			500 adit collared	head frame	country rock and low	quartzite and schist	
			at Black Cap	Portal Bldg	grade vein material	plus barren vein	
			extends 5,000 ft	and train	7 oz Ag/t		
			to vein	dump at	0.8% Pb		
				500 adit	0.3% Zn		
Geometry							
		2 areas of			36^{o} slope, stable		
		subsidence					
		above old stopes					
Drainage							
Remarks		adit developed				some reveg.	
		below old shaft					
		workings					



LEGEND

- ■ Soil test pit with piezometer
- ▲ Waste rock sample
- ● Water quality sample site
- Disturbed area
- Building
- Power Line
- Tramway
- Highway #11
- Road
- Trail
- Stream or River
- Underground Workings
- Open pit, trench
- Waste rock dump
- Tailings area
- Adit entrance
- Shaft location

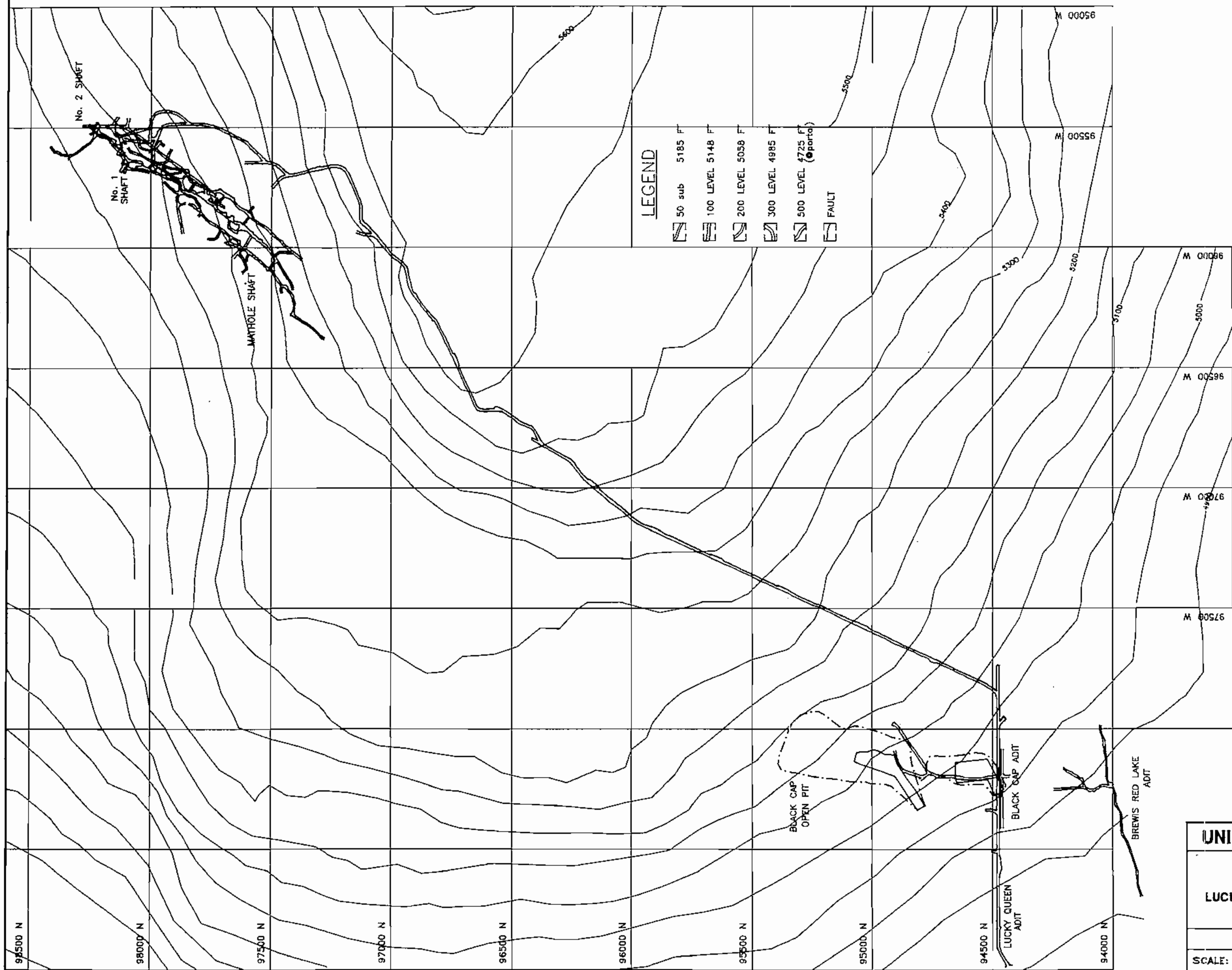


UNITED KENO HILL MINES LIMITED

LUCKY QUEEN
SITE PLAN

Access Mining Consultants Ltd.

SCALE: 1 : 7,500	FILE: FLQUEEN.DWG	DATE: [illegible]
DRAWN: LOP Consult	DWG: 95UK18	FIGURE 5-52



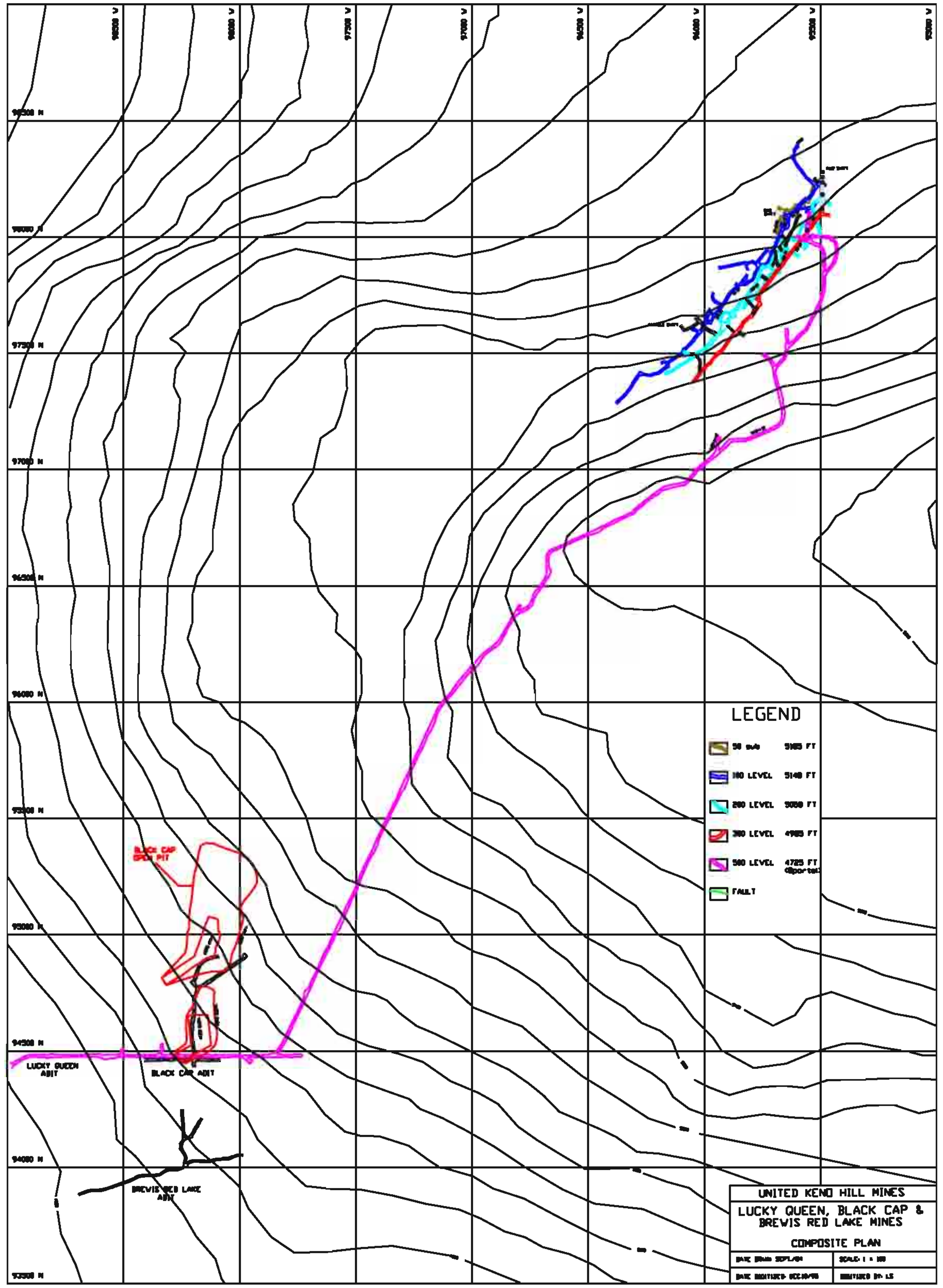
UNITED KENO HILL MINES LIMITED

MINE WORKINGS

LUCKY QUEEN, BLACK CAP & BREWIS LAKE MINES COMPOSITE PLAN

ACCESS MINING CONSULTANTS LTD.

SCALE: NONE	FILE: LQCOMPLN.DWG	DATE: 28/05/96
PLOTTED:	DWG: 95UK43	FIGURE: 5-53


LEGEND
100 LEVEL 5140 FT
200 LEVEL
300 LEVEL
500 LEVEL 4725 FT
FAULT
LUCKY QUEEN ADIT
BLACK CAP ADIT
BLACK CAP OPEN PIT
BREWIS RED LAKE ADIT
UNITED KENO HILL MINES
LUCKY QUEEN, BLACK CAP &
BREWIS RED LAKE MINES
COMPOSITE PLAN

5.2.20 Onek

Development: Table 5-18

Figures: Figure 5-54

Figure 5-55 Onek Mine Composite Plan

Figure 5-56 Onek Mine Vertical Longitudinal Section

Onek was mined originally from underground, and subsequently from the open pit. There is one adit, located at the 400 level, in Keno City. The Fisher shaft daylights within the Onek open pit (also called the Fisher Pit); the pit bottom being about 25 feet above the 100 level. The second shaft developed at Onek is located about 650 feet SW of the Fisher shaft.

There is clearly an hydraulic connection between the pit and the underground workings, primarily through the Fisher shaft. This hydraulic connection is of particular interest at Onek, due to the history of ice damming in the adit, and subsequent sudden release of stored water as the ice plug was displaced. This ceased to occur when the open pit was developed in the mid 1980's. However, the adit continues to drain water from the underground workings.

There are no remaining buildings or equipment remaining associated with the Onek development. The adit is open and, being located within Keno City, requires long-term control of access.

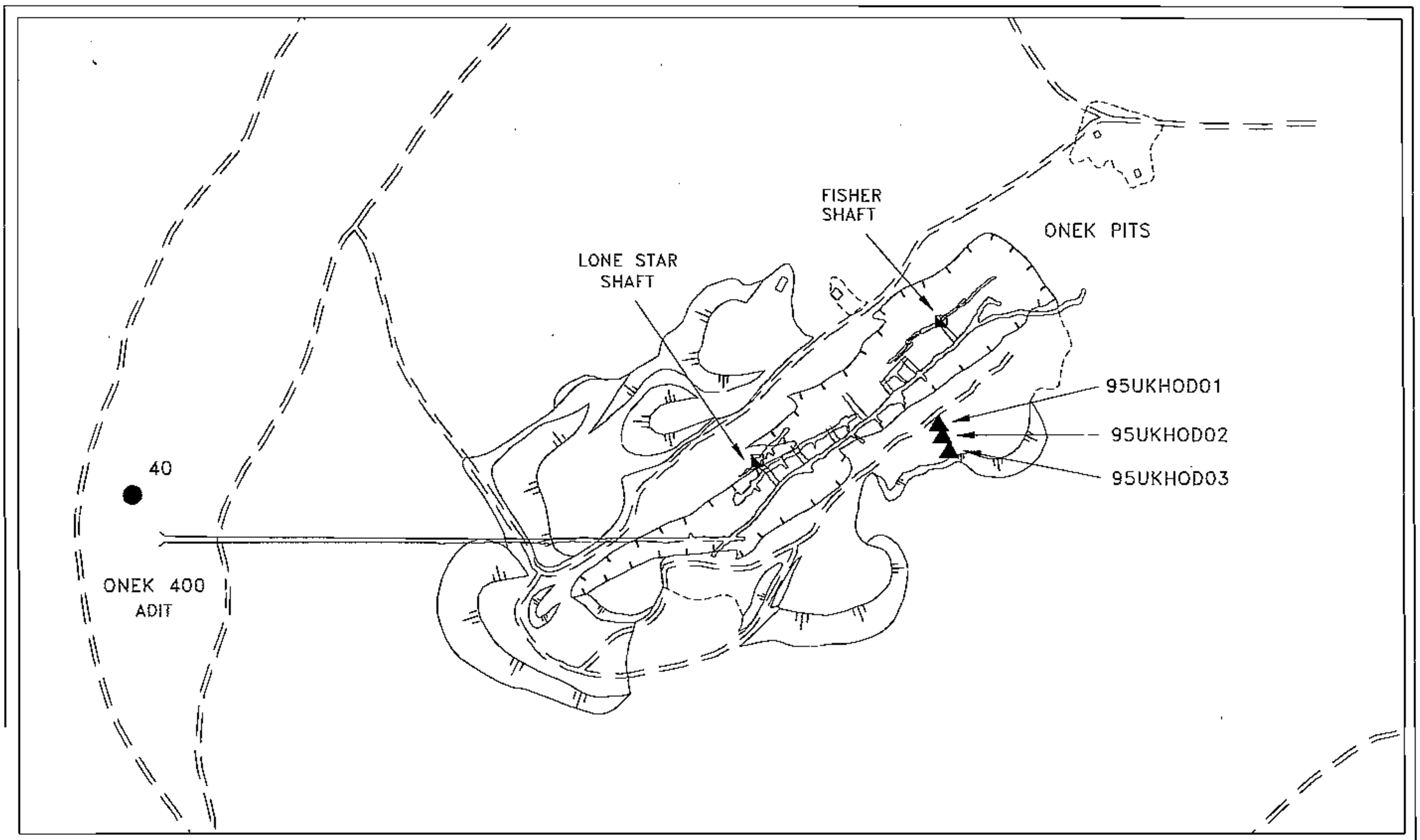
TABLE 5-18

Mine Development

Mine:	Onek	
Location:	Keno Hill	
Period of Development:		1980's and 1950's
Developed by:	others, UKHM	
Monitoring at:	S-08	

Development at Onek

	Open Pit	Underground	Shafts, Raises Portals, Adits	Bldgs and Equip.	Rock Piles pit dump	adit dump	Other	Townsite
Period of		1920's (schaft)	2 shafts, Fisher &					
Development	1987 to 1988	1952 (adit)	Lone Star		1987 to 1988	1952		
			1952 1 adit					
Production or								
Tonnage	Total production = 95,290 tons				600,000 tons	7500 tons		
	62,245 tons = pit	33,036 = UG				but used		
						locally		
Features		used to plug	Fisher shafts		quartzite and	1.05 oz Ag/t		
		with ice until	evident of pit		graphitic schist	0.3% Pb		
		open pit			(barren country rock)	0.8% Zn		
		developed	adit crosscut					
			into vein, drifted					
Geometry	deeper section				40^{o} slopes			
	of pit to northeast				old tension cracks up			
					to 75 m from crest			
					majority of waste to			
					north of pit			
Drainage								
Remarks	pit was mining			debris at adit	some reveg.			
	crown pillars							
	and ore from							
	Lone Star and Fisher							
	shafts (1920's)							



LEGEND

- ■ Soil test pit with piezometer
- ▲ Waste rock sample
- ● Water quality sample site
- Disturbed area
- Building
- Power Line
- Telephone Line
- Highway #11
- Road
- Trail
- Stream or River
- Underground Workings
- Open pit, trench
- Waste rock dump
- Tailings area
- Adit entrance
- Shaft location

UTM N TN mN

0 50 100 150 200

METRES

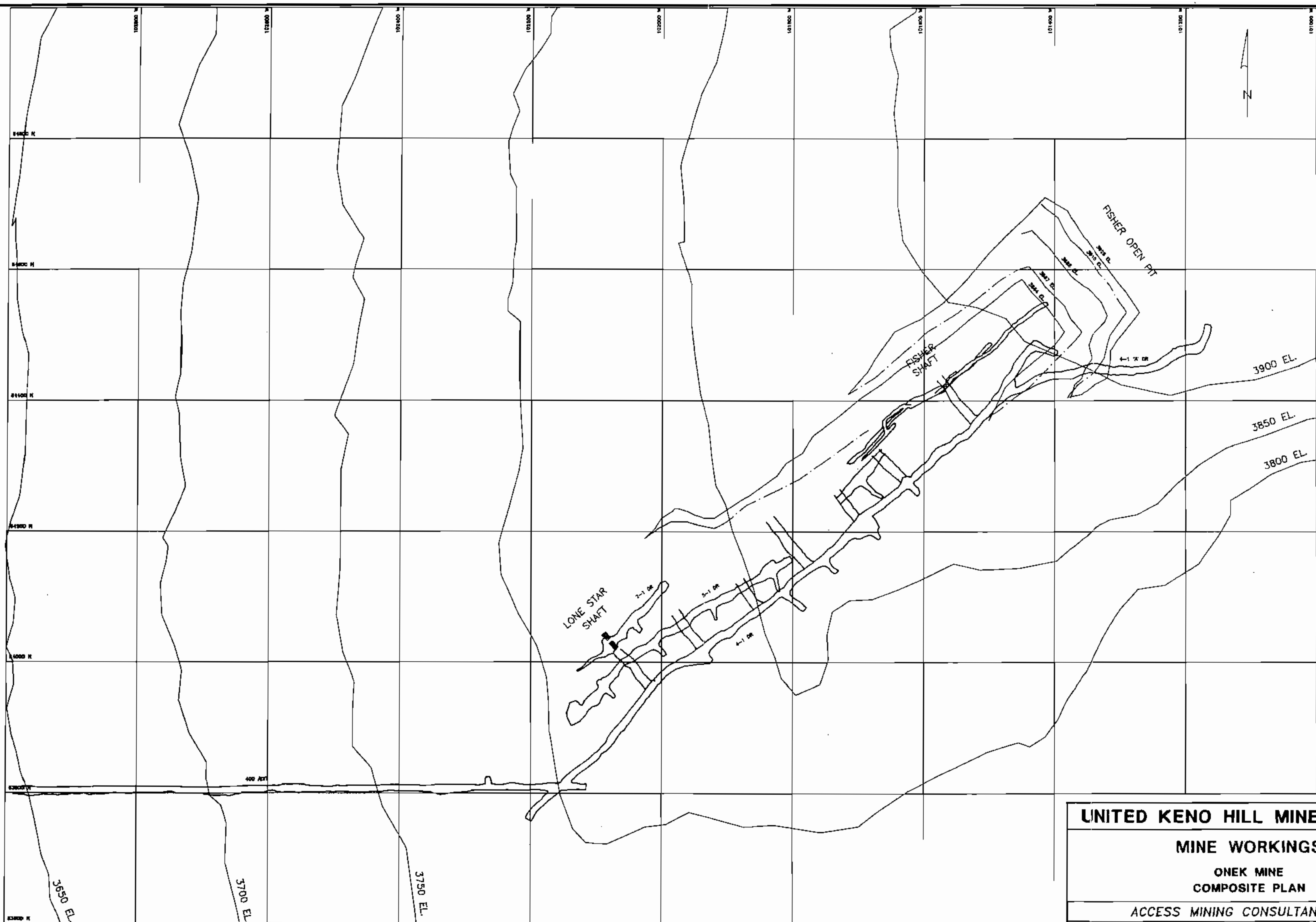
UNITED KENO HILL MINES LIMITED

ONEK

SITE PLAN

Access Mining Consultants Ltd.

SCALE: 1 : 5,000	FILE: FONEK.DWG	DATE: 28/05/96
DRAWN: LCP Consult	DWG: 95UK18	FIGURE 5-54



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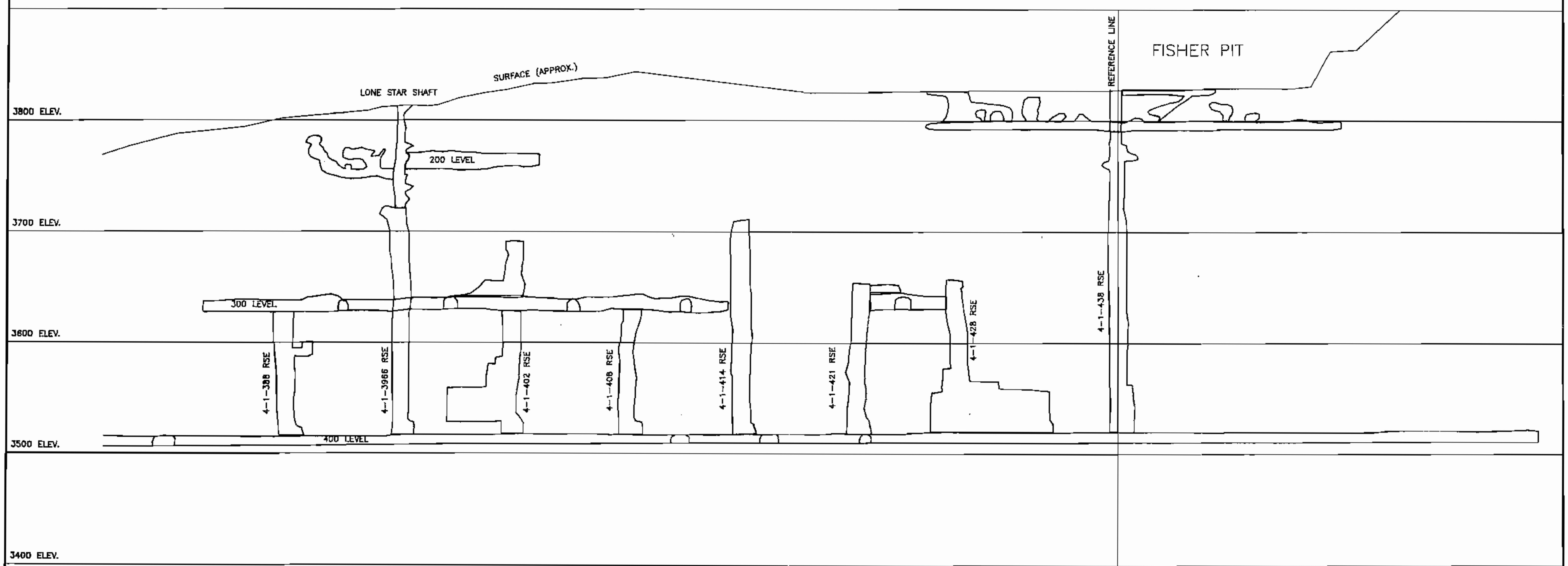
MINE WORKINGS

ONEK MINE
COMPOSITE PLAN

ACCESS MINING CONSULTANTS LTD.

SCALE: NONE	FILE: ONEKPLAN.DWG	DATE: 28/05/96
PLOTTED:	DWG: 95UK48	FIGURE: 5-55



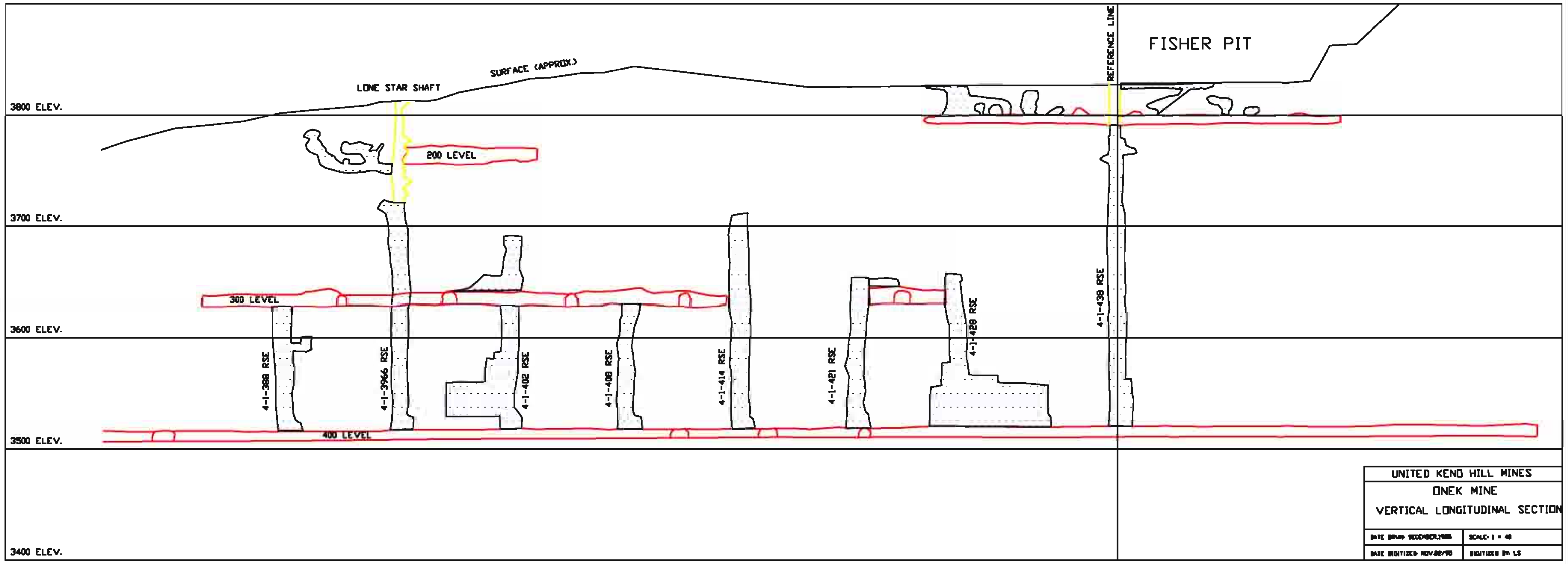
UNITED KENO HILL MINES LIMITED

MINE WORKINGS

ONEK MINE
VERTICAL LONGITUDINAL SECTION

ACCESS MINING CONSULTANTS LTD.

SCALE: NONE	FILE: ONEKSEC.DWG	DATE: 28/05/96
PLOTTED:	DWG: 95UK47	FIGURE: 5-56



FISHER PIT
REFERENCE LINE
SURFACE (APPROX.)
LONE STAR SHAFT
3800 ELEV.
3700 ELEV.
3600 ELEV.
3500 ELEV.
3400 ELEV.
200 LEVEL
300 LEVEL
400 LEVEL
4-1-388 RSE
4-1-3966 RSE
4-1-402 RSE
4-1-408 RSE
4-1-414 RSE
4-1-421 RSE
4-1-428 RSE
4-1-438 RSE
UNITED KENO HILL MINES
ONEK MINE
VERTICAL LONGITUDINAL SECTION
SCALE: 1 = 40

5.2.21 Keno 700 Mine

Development: Table 5-19

Figures: Figure 5-57 Site Plan
Figure 5-58 Keno Mine Composite Plan
Figure 5-59 Shamrock Mine Composite Plan, Keno No. 18 Vein
Figure 5-60 Shamrock Mine, Vertical Long Section, Looking Northwest

The Keno 700 adit accessed an underground mine, working the No. 9 Vein. The No. 9 vein was first mined in the 1920’s by Keno Hill Limited. The workings were in the upper part of the hill, with access via the 100 level adit (located in Faro Gulch) and from the shaft extending from surface to the 300 level. The 100 level adit is caved and iced in. An adit at the 200 level was also developed, in 1955, from Faro Gulch but is also caved and iced in.

UKHM worked No. 9 vein via the Keno 700 adit from 1958 to 1982. There was considerable further development, with an additional adit at the 200 level (on the south side of the hill), an incline from the 200 to 400 levels, and the No. 4 shaft developed from the 700 to 1075 levels. Overall, there are nine levels on the No. 9 vein from the 200 level to the 1075 level. Much of the ground in the No. 9 vein is frozen (to at least the 400 level).

The majority of the infrastructure was located at the 700 level and included the No. 4 shaft hoist (underground), and buildings, shops, power, offices and housing facilities located at the portal. Most of these buildings remain in place today. Development rock from the 700 adit was used for foundations for these buildings, with the remainder deposited downslope from the Keno 700 portal. The dump has failed locally and been eroded; some of the rock has been carried into the galley below the portal.

The only remaining facilities at the Keno 200 adit are the portal, which is blocked by doors, and a section of tracks from underground.

Two other adjoining veins were also worked as part of “Keno 700” Mine; the Shamrock J-18 vein (described below) and the Comstock - Keno - Porcupine (described in Section 5.2.23). The three mines are connected by workings at the 400 and 700 levels.

The Shamrock J18 vein was developed from the 400 level of the No. 9 vein with access from Keno 700 portal. There was a raise from the 400 level to surface for ventilation and for access of men and material to stopes. The raise is covered by a building which is collapsing.

Several other small veins were worked in conjunction with the No. 9 vein over the years. These include the No. 1 vein with two adits, one from Faro Gulch; the No. 3 vein, accessed by adit from Faro Gulch; the No. 12 vein accessed by 2 adits; the No. 5 vein also accessed by 2 adits at the northeast and southwest end of the vein, respectively; the No. 4 vein with an upper and lower adit; the No. 6 vein intersected by the Keno 200 adit with an old shaft from surface; and lastly, the No. 2 vein accessed by a shaft from surface. The condition of these various adits and shafts is not fully known but most pre-date the 1950’s and are likely to be caved.

Drainage from the underground workings, including the Keno 200 through 700, Comstock - Keno - Porcupine and Shamrock J-18, is collected at, and discharged from the 700 level to Hope Gulch, via a culvert through the waste rock. Hope Gulch reports to Lightning Creek.

TABLE 5-19

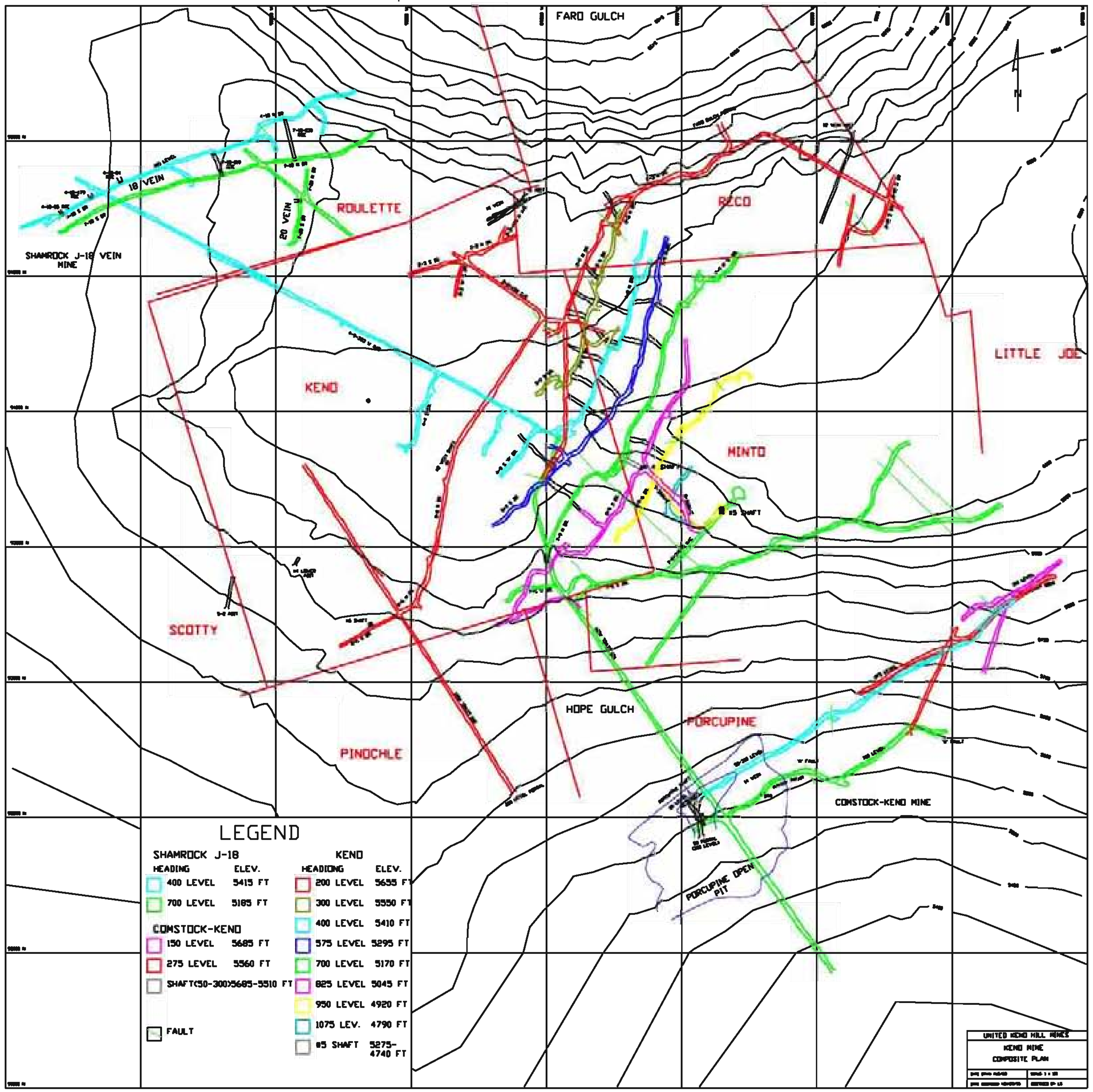
Mine Development

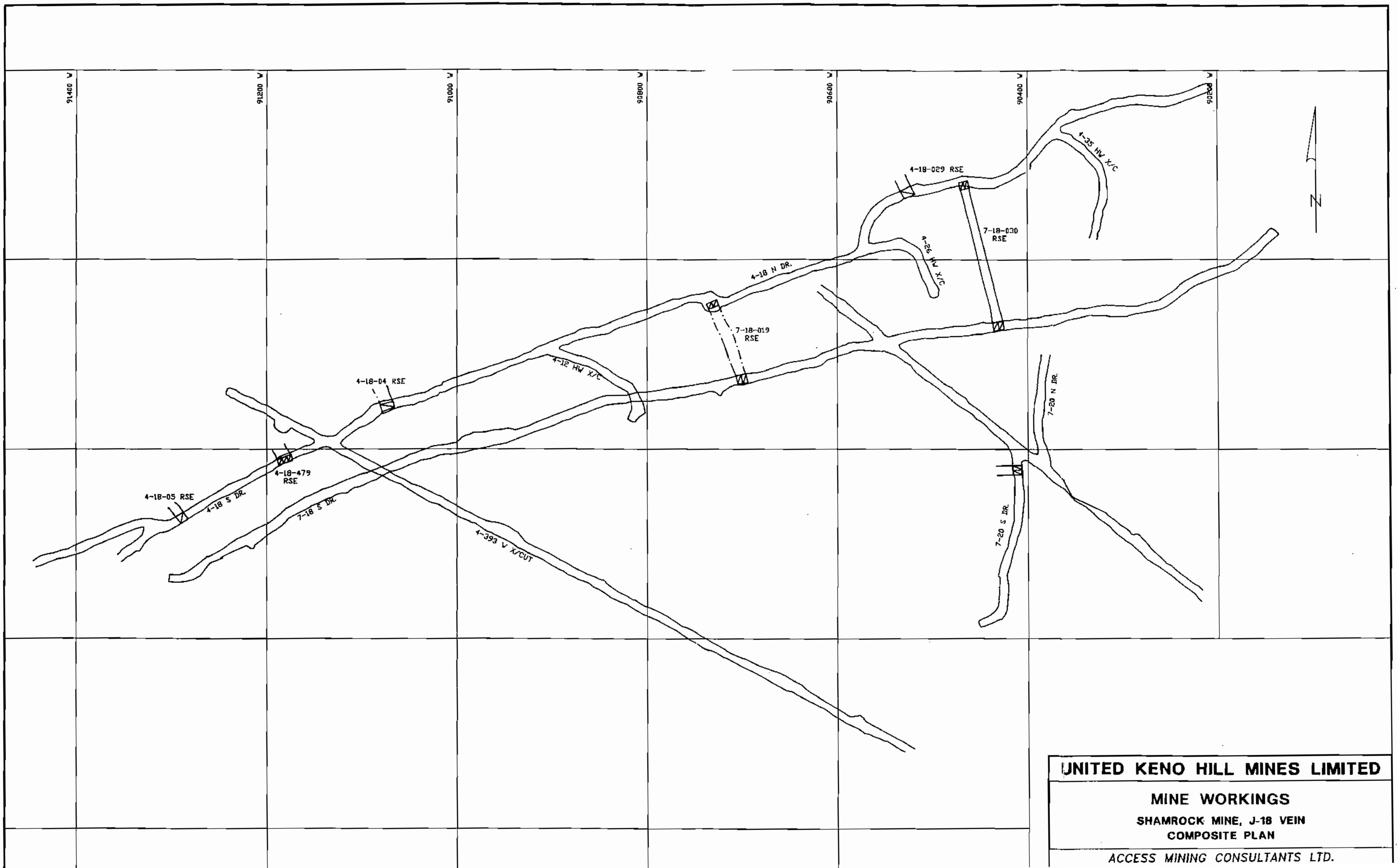
Mine:	Keno 700 and 200							
Location:	Keno Hill							
Period of Development:		1920's, 1958 to 1982, 1987						
Developed by:		1919 to 1923 Keno Hill Limited						
		1958 to 1982 UKHM						

Development at Keno

	Underground	**Shafts, Raises Portals, Adits**	**Bldgs and Equip.**	**Rock Piles @700 adit**	**@200 adit**	**Mill or Plant**	**Other**	**Townsite @700**
Period of	1919 to 1923	@100 L, shaft						
Development	1958 to 1982	@700:1958		1958 to 1982	1956 to 1982			
	1987	@200:1956		1987				
Production or								
Tonnage	283,557 tons			27,500 tons	14,600 tons			
Features	crosscut through		about 10 bldgs	country rock	country rock			houses?
	country rock	doors on both	shops, offices	quartzite and	quartzite and			bunkhouses
		adits	housing	schist	schist			offices
			vent., pumping					
			electrical					
Geometry				36^o slope	37^o slope			
Drainage	discharges in							
	pipe through							
	dump							
Monitoring				S-6				
Stations								
Remarks		700: main haulage		considerable	some reveg.			
		way for mine		water erosion				
		accessed			still has rails			
		several veins			from u/g			
		200: access to upper veins						

Site Plan: Figure 5-57


FARO GULCH
18 VEIN
20 VEIN
ROULETTE
RICO
SHAMROCK J-18 VEIN
MINE
LITTLE JOE
KENO
MINTO
#5 SHAFT
SCOTTY
HOPE GULCH
PORCUPINE
PINOCHLE
COMSTOCK-KENO MINE
PORCUPINE OPEN
PIT
LEGEND
SHAMROCK J-18
HEADING ELEV.
400 LEVEL 5415 FT
700 LEVEL 5185 FT
COMSTOCK-KENO
150 LEVEL 5685 FT
275 LEVEL 5560 FT
SHAFT(50-300)5685-5510 FT
FAULT
KENO
HEADIDNG ELEV.
200 LEVEL 5655 FT
300 LEVEL 5550 FT
400 LEVEL 5410 FT
575 LEVEL 5295 FT
700 LEVEL 5170 FT
825 LEVEL 5045 FT
950 LEVEL 4920 FT
1075 LEV. 4790 FT
#5 SHAFT 5275-
4740 FT
UNITED KENO HILL MINES
KENO MINE
COMPOSITE PLAN

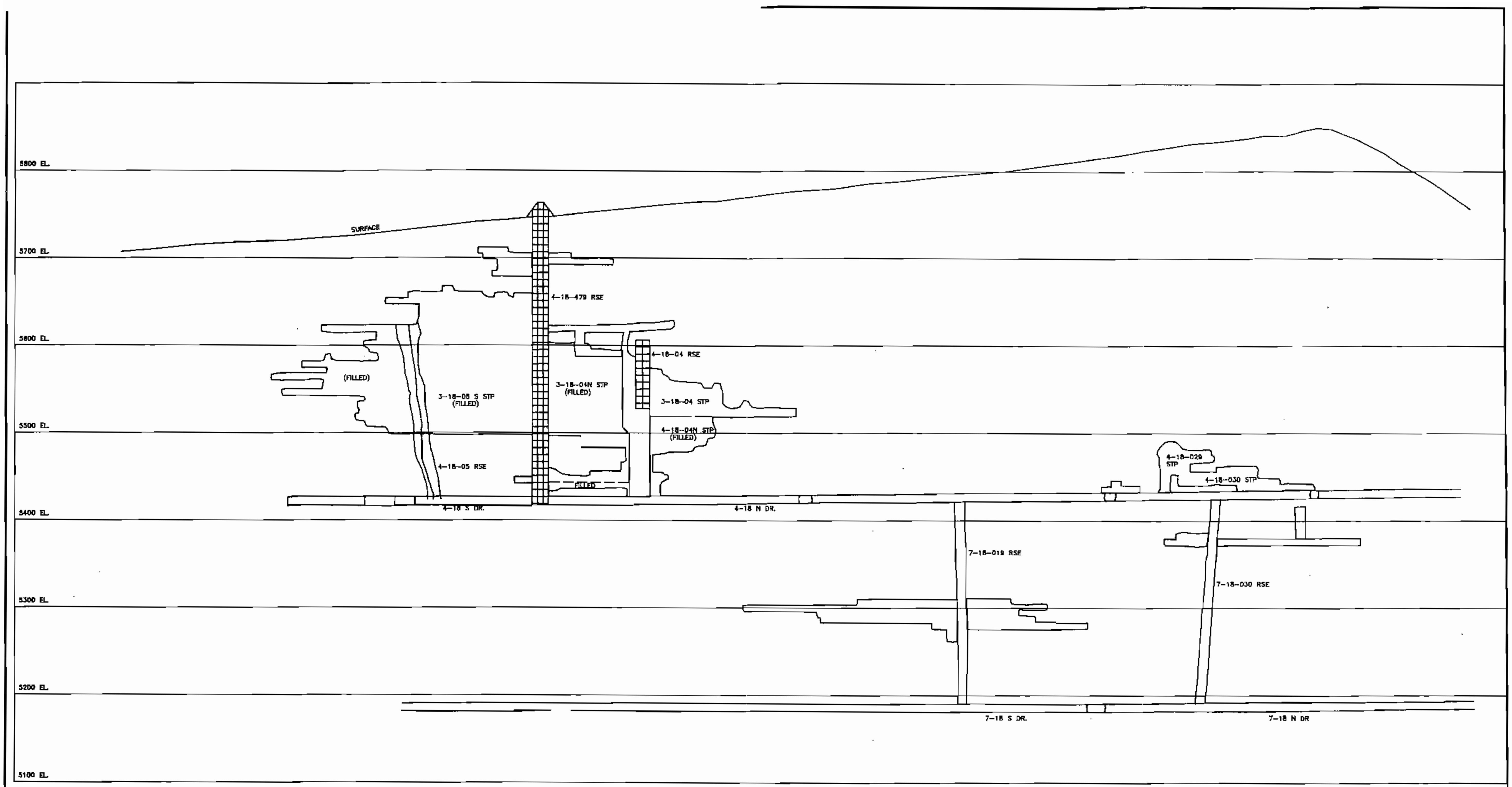


UNITED KENO HILL MINES LIMITED

MINE WORKINGS

SHAMROCK MINE, J-18 VEIN
COMPOSITE PLAN

ACCESS MINING CONSULTANTS LTD.



UNITED KENO HILL MINES LIMITED

MINE WORKINGS

SHAMROCK MINE, J-18 VEIN
VERTICAL LONGITUDINAL SECTION (Looking Northwest)

ACCESS MINING CONSULTANTS LTD.

SCALE: NONE	FILE: SHAMLSEC.DWG	DATE: 28/05/96

5.2.22 Shamrock Mine

Development: Table 5-20

Figures: Figure 5-52 (in Section 5.2.19 - Lucky Queen) Site Plan
Figure 5-58 Keno Mine Composite Plan

The original Shamrock workings, pre-dating World War II, were developed as an underground operation with a shaft from surface to the 120 level and an adit at the 60 level. About 1953 a second adit was developed on the 200 level. The Shamrock mine only produced about 5,000 tons of ore. Archer Cathro hand mined the vein near the shaft in the mid to late 1980's. The shaft is partially filled with waste rock and needs to be closed off.

The Shamrock "K" vein was mined at surface by hand from a trench 500 feet long, 20 feet wide and up to 20 feet deep. It produced 200 tons averaging 220 oz/ton Ag.

There is a small waste rock dump at the adit, and another at the Archer Cathro open pit comprising a total of less than 10,000 tons.

These workings should not be confused with the Shamrock J18 vein which is 700 m east, on a related geological structure but was accessed through the Keno 700 adit and a cross cut at the 400 level northwest from the No. 9 vein workings. This is shown in Figure 5-58, northwest corner, and Figure 5-61.

TABLE 5-20

Mine Development

Mine:	Shamrock open pit and adit, Shamrock "K" hand cobbing operation						
Location:	Keno Hill						
Period of Development:		1920's, 30's, 1954, 1980					
Developed by	?non UKHM - maybe Archer Cathro?						

Development at Shamrock

	Open Pit	**Underground**	**Shafts, Raises Portals, Adits**	**Bldgs and Equip.**	**Rock Piles open pit dump**	**"K" pit dump**	**Townsite**
Period of Development	1985 to 1989	1954	1954 @200 level	1950's?	1954, 1980's	1988 to 1989	
	"K": 1988 to 1989						
Production or Tonnage	Total production = 5,036 tons				3,000 tons	6,000 tons	
Features		drifted along vein			country rock and some low grade	pit stripping quartzite	
Geometry					several small dumps - stable		
Drainage							
Remarks							

5.2.23 Comstock - Keno & Porcupine

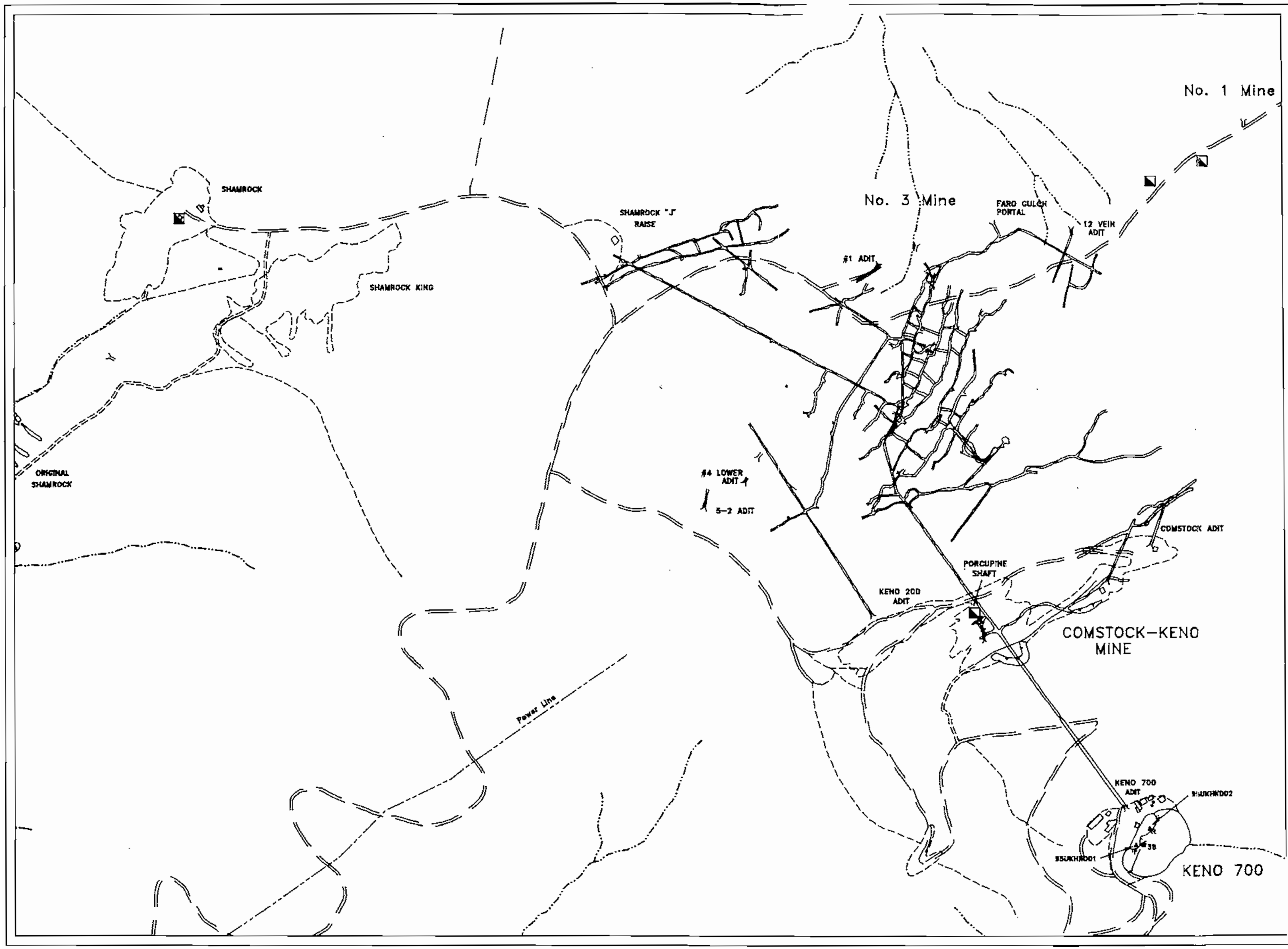
Development: Table 5-21

Figures: Figure 5-61 Site Plan
Figure 5-58 Keno Mine Composite Plan
Figure 5-62 Comstock-Keno and Porcupine Mines, Longitudinal Section

The Comstock - Keno & Porcupine underground workings exploited the No. 14 vein and are between the Keno 700 adit and the No. 9 vein underground workings. The Comstock - Keno - Porcupine workings were mined prior to the 1950's. The Comstock - Keno is on the east end of the No. 14 vein structure and the porcupine is on the west end. The two adits on the east end of the No. 14 vein at the 150 and 275 levels have both collapsed. The crown pillar of the underground workings at the west end of the No. 14 vein was later mined out by open pit; the Porcupine Pit. The Porcupine pit was the first pit mined in the district. Mining of the Porcupine pit obliterated an old opening (the 50 portal) and a shaft (the Porcupine shaft) connecting to the 300 level of the No. 14 vein. The vein was later accessed from the Keno 700 cross cut. A dam exists on this level flooding the workings behind the dam.

TABLE 5-21

Mine Development							
Mine:	Comstock - Keno - Porcupine						
Location:	Keno Hill						
Period of Development:							
Developed by:							
Development at Comstock - Keno - Porcupine							
	Open Pit	**Shafts, Raises Portals, Adits**	**Comstock 275 Adit**		**Porcupine Pit dump**	**Other**	**Townsite**
Period of Development	1977	3 adits 1 schaft	before 1950's ? 1980-81		1977		
Production or Tonnage	1 pit 4,253 tons ore	22,863 tons	dump = 3,100 t		waste rock = 3,400 tons		
Features	mined a small pillar above Porcupine Adit	2 adits at east end still exist, west end destroyed by Pit mining					
Geometry							
Drainage							
Monitoring Stations							
Remarks	old shaft and adit destroyed by pit	Dam in UG floods lowest level	150 Adit caved				



LEGEND

- Soil test pit with piezometer
- Waste rock sample
- Water quality sample site
- Disturbed area
- Building
- Power Line
- Tramway Line
- Highway #11
- Road
- Trail
- Stream or River
- Underground Workings
- Open pit, trench
- Waste rock dump
- Tailings area
- Adit entrance
- Shaft location

UTM N TN MN

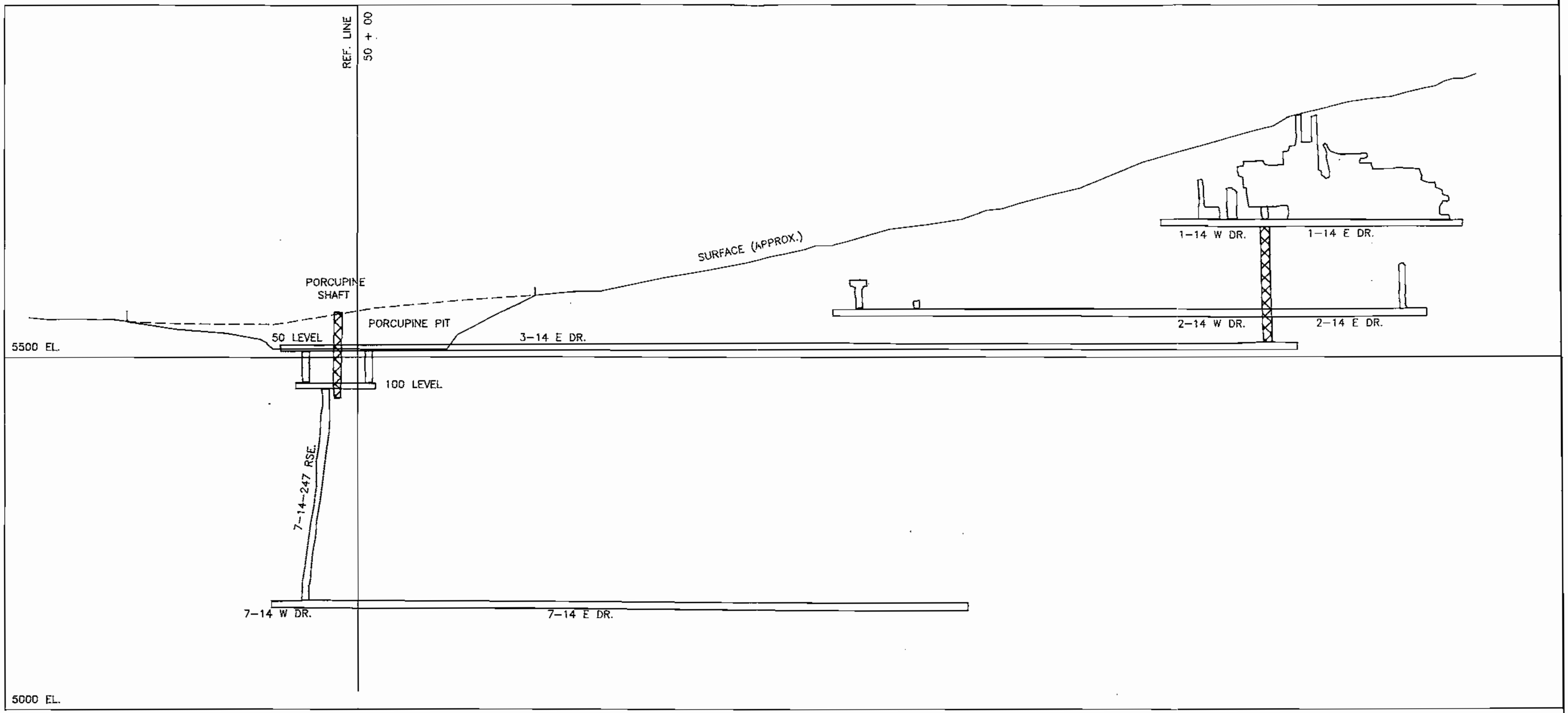
0 75 150 225 300 METRES

UNITED KENO HILL MINES LIMITED

KENO-COMSTOCK-PORCUPINE SHAMROCK SITE PLAN

Access Mining Consultants Ltd.

SCALE: 1 : 7,500	FILE: FXENOCOM.DWG	DATE: 29/05/96
DRAWN: LCP [illegible]	DWG: 95UK20	FIGURE 5-61



UNITED KENO HILL MINES LIMITED

MINE WORKINGS

COMSTOCK-KENO & PORCUPINE MINES
LONGITUDINAL SECTION

ACCESS MINING CONSULTANTS LTD.

SCALE: NONE	FILE: KENOCOML.DWG	DATE: 28/05/96

5.2.24 Black Cap Mine

Development: Table 5-22

Figures: Figure 5-52 (in Section 5.19 - Lucky Queen) Site Plan
Figure 5-53 Lucky Queen Composite Plan

The Black Cap workings comprise both open pit and underground workings. The primary access to underground was via two adits; the Brewis Red Lake Adit worked in 1951, and the UKHM Black Cap Adit worked for four months in 1966. The extent of the underground workings are small, about 1000 ft of lateral development for each. It is also reported that there were two small shafts, both located within the open pit area.

The majority of the mining of the Black Cap was from the open pit, mined in 1986 and 1987. Waste rock from the pit is deposited in a series of small dumps around the pit, as shown in Figure 5-52.

TABLE 5-22

Mine Development							
Mine:	Black Cap						
Location:	Keno Hill						
Period of Development:		1940's, 1951, 1966					
Developed by:	others then UKHM						
Development at Black Cap							
	Open Pit	**Underground**	**Shafts, Raises**	**Bldgs**	**Rock Piles**	**Other**	**Townsite**
			Portals, Adits	**and Equip.**	**waste, ore**		
Period of		Brewis Red Lake	1940's				
Development	1986 to 1987	in 1951			1986 to 1987		
		Black Cap 1966	1951, 1966				
Production or							
Tonnage	47,497 tons	1,079 tons			390,000 tons		
Features					series of		
					individual dumps		
					rocks are mostly		
					country rock		
					qtzite and schist		
Geometry		Brewis Red Lake			slopes 32 to 36^{o}		
		1110 ft					
		Black Cap 1030'					
Drainage							
Monitoring							
Stations							
Remarks							

5.2.25 Bellekeno Mine

Development: Table 5-23

Figures: Figure 5-63 Site Plan

Figure 5-64 Bellekeno Mine, Level Plan

Figure 5-65 Bellekeno Mine, Long Section 99 and Southern Zones

The only mine located on Sourdough Hill is the Bellekeno underground mine. It was originally mined by Mackeno Mines from adits at the 100 and 200 levels in the 1950's. The status of the adits with respect to closure requirements must be confirmed, although it is understood that they have collapsed at the portals. The ore was milled at the old Galkeno Mill located at Christal Lake, which has since been demolished and removed.

Mining began again in 1984 with the development of the adit at the 625 level (also referred to as 600 level in this report). This was used to mine ore from the 500, 625, 700, 750 and 800 levels from 1984 through to 1989. Dewatering and rehabilitation of the 700 through 800 levels, from the 625 adit, began in 1994. Work is still in progress for exploration and development by a decline to the lower levels at Bellekeno.

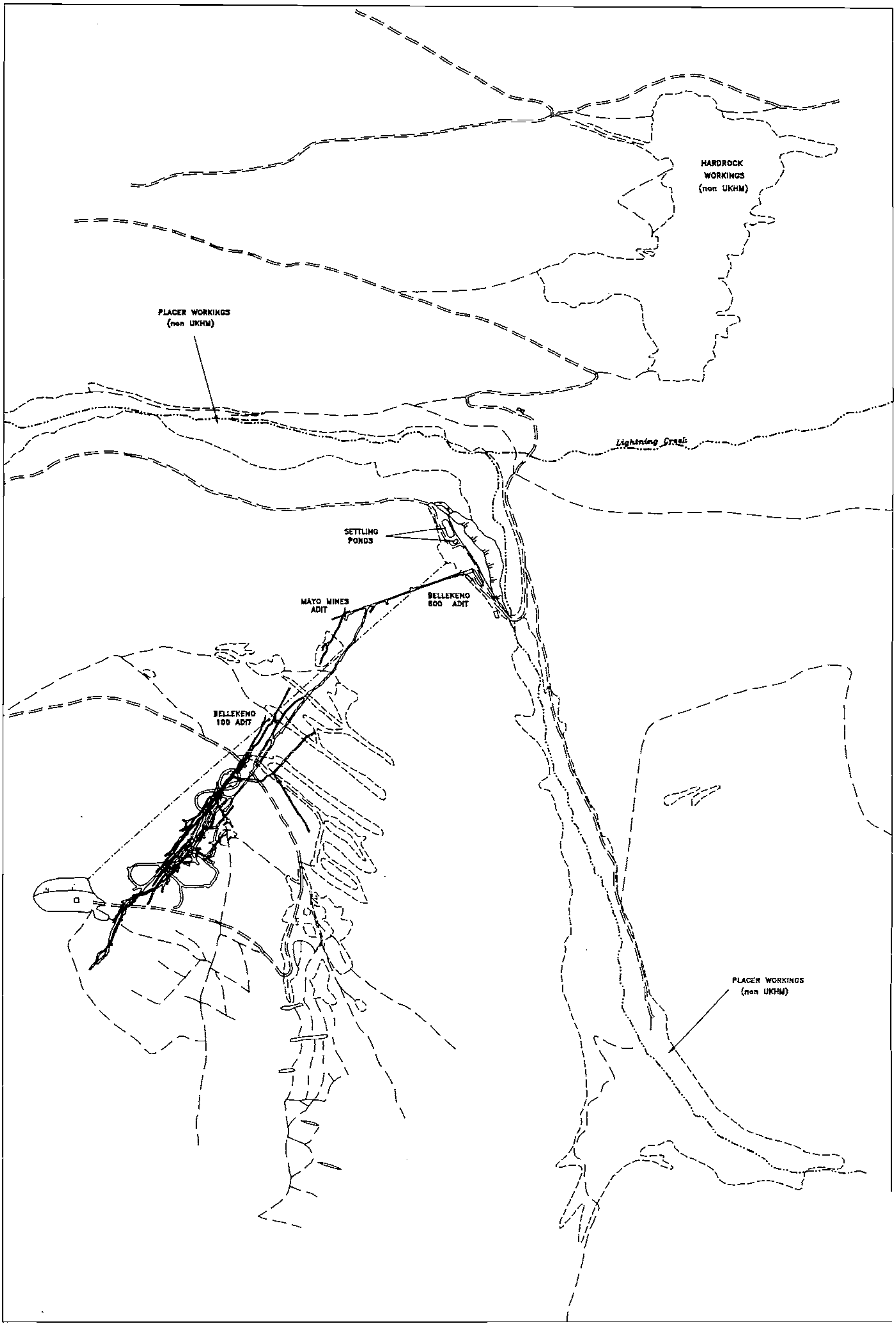
Water treatment of the underground water was initiated with the rehabilitation work in 1994. The water is treated as it is pumped from underground, and settling occurs in two settling ponds at the 625 portal.

In addition, there was some minor trenching at the upper Bellekeno adits during the 1980's.

The only buildings that remain in place are at the 625 level, associated with the adit, and are currently in use. There was some foundation preparation done at the 200 level in anticipation of building a backfill plant to supply backfill through a drill hole to the lower workings of the mine.

TABLE 5-23

Mine Development								
Mine:	Bellekeno 625 adit, 200 adit, 100 (50 Vein) adit, 100 (48 Vein) adit							
Location:	Sourdough Hill							
Period of Development:		1980's to present						
Developed by:								
Monitoring at:	S-12							
Development at Bellekeno								
	Underground	**Shafts, Raises Portals, Adits**	**Bldgs and Equip.**	**Rock Piles 625 adit**	**200 adit**	**100 adit (50 vein)**	**100 adit (48 vein)**	**Other**
Period of	625: 1984 to 1989	1984						1994 to
Development	and 1994 to present			1984 to 1989	1952 to 1954	first adit of Bellekeno		present
	200: 1952 to 1954				1987/88	1952 to 1954	1952 to 1954	Treatment
	100(50): 1952 to '54				overburden plus			plant at the
	100(48): 1952 to '54				some adit dev. rock			625 adit
Production or				48,000 tons	13,000 tons	2,450 tons	500 tons	
Tonnage	40,502 tons							
Features					overburden base			
				overburden base	waste rock			
					top is vein waste			
		100: drift along vein			7.01 oz Ag/t	3.28 oz Ag/t	9.33 oz Ag/t	
		no ore			1.82 % Pb	0.6% Pb	2.3% Pb	
					0.8% Zn	0.7% Zn	0.4% Zn	
Geometry				40^{o} slopes	3 distinct			
					terraces			
					1987/88 overburden			
		100 - broken out			shows some cracking			
		from inside						
Drainage								
Remarks					200 L was main	Extensive reveg.		
					access for "old"			
					Bellekeno mine			
					1950's			
					Extensive reveg.			



LEGEND

- Soil test pit with piezometer
- Waste rock sample
- Water quality sample site
- Disturbed area
- Building
- Power Line
- Tramway Line
- Highway #11
- Road
- Trail
- Stream or River
- Underground Workings
- Open pit, trench
- Waste rock dump
- Tailings area
- Adit entrance
- Shaft location

UTM N, TN, MN

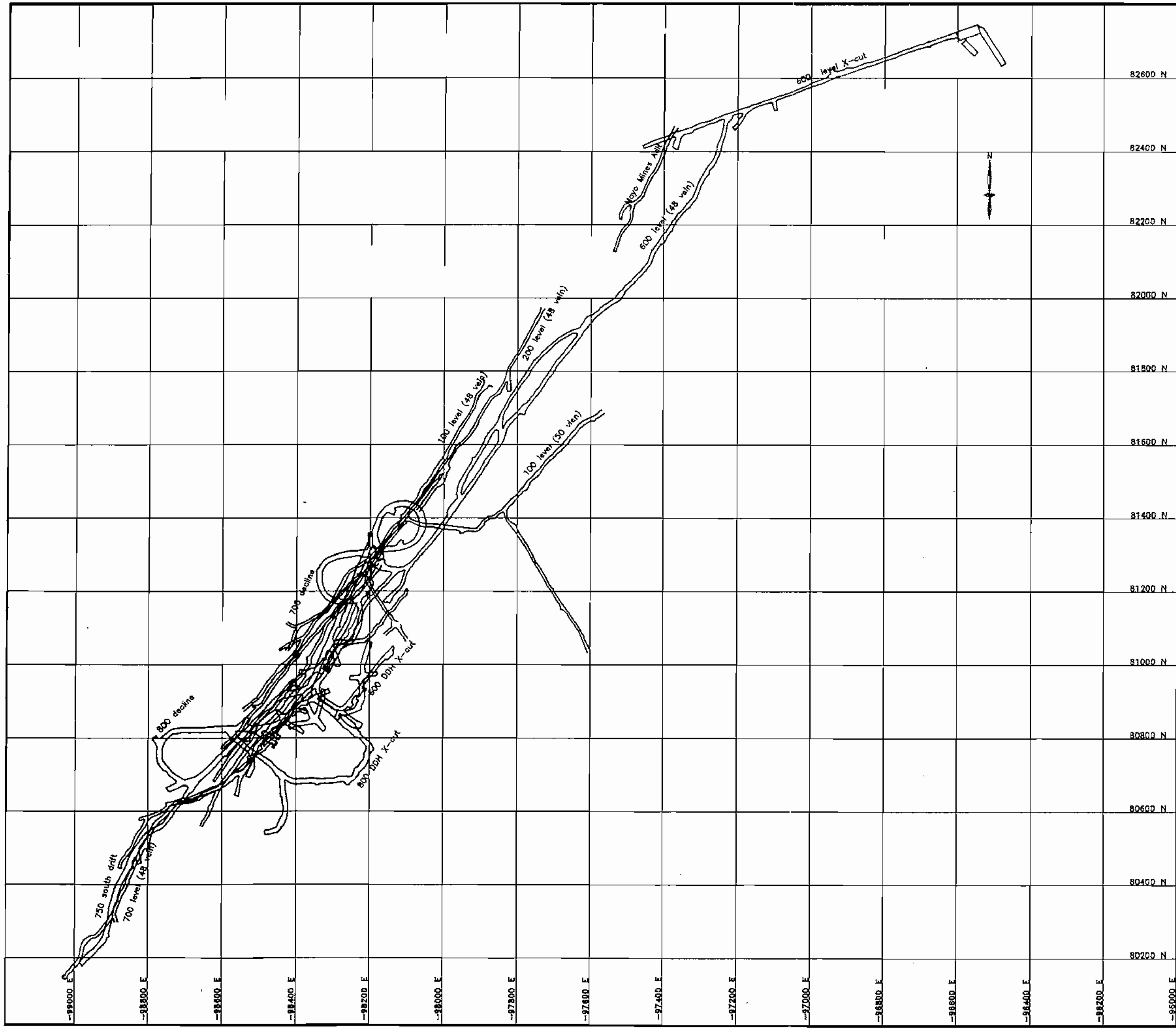
0 75 150 225
METRES

UNITED KENO HILL
MINES LIMITED

BELLEKENO
SITE PLAN

Access Mining Consultants Ltd.

SCALE: 1 : 7,500	FILE: FSKENO.DWG	DATE: 29/05/96
DRAWN: LCP Consult	DWG: 96UK22	FIGURE 5-63



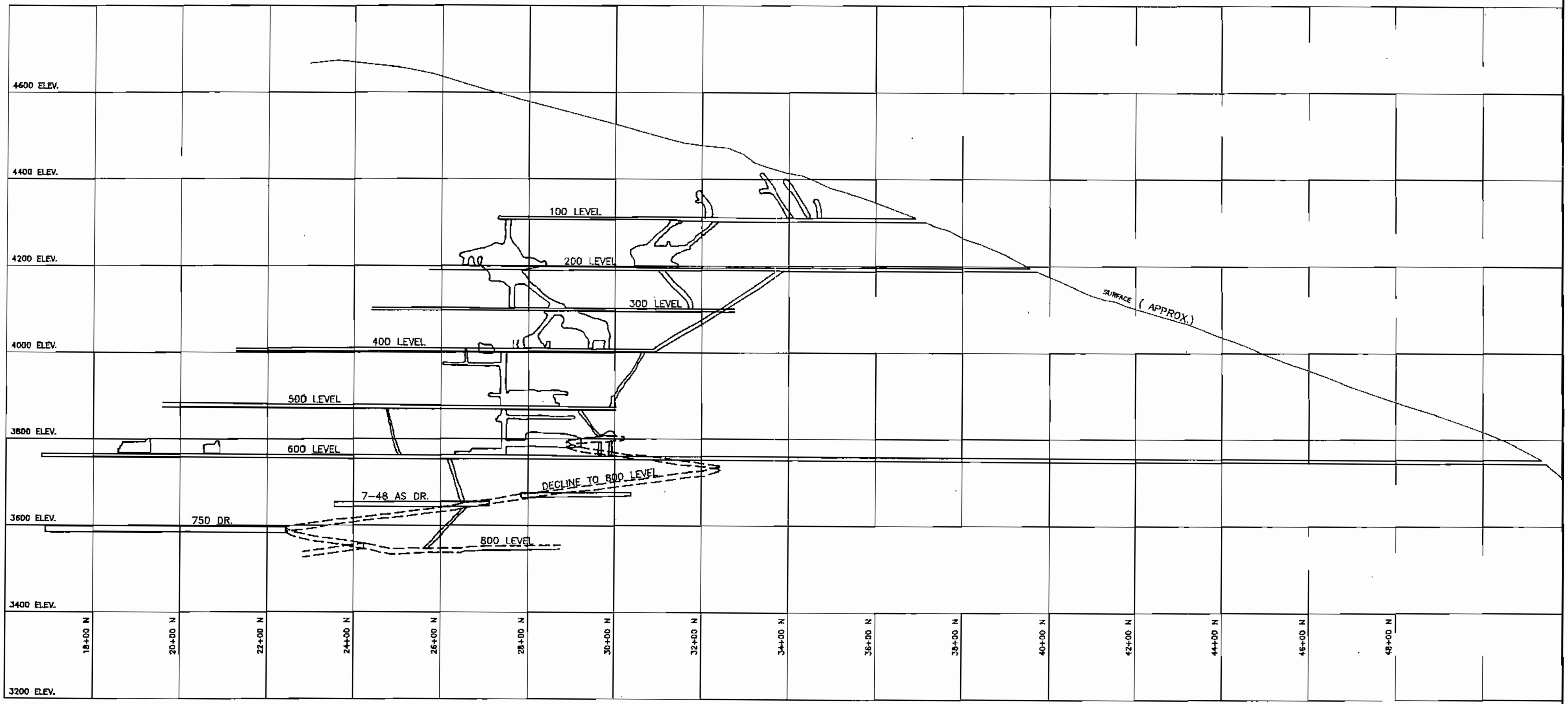
UNITED KENO HILL MINES LIMITED

MINE WORKINGS

BELLEKENO MINE
LEVEL PLAN

ACCESS MINING CONSULTANTS LTD.

SCALE: NONE	FILE: BKPLAN.DWG	DATE: 28/05/96
PLOTTED:	DWG: 95UK28	FIGURE: 5-64



UNITED KENO HILL MINES LIMITED

MINE WORKINGS

BELLEKENO MINE
VERTICAL LONGITUDINAL SECTION

ACCESS MINING CONSULTANTS LTD.

SCALE: NONE	FILE: BELLLONG.DWG	DATE: 28/05/96
PLOTTED: [illegible]	DWG: 95UK27	FIGURE: 5-65

6. Site Water Chemistry

6.1 Water Chemistry Database

6.1.1 Database Contents and Organization

Water quality sampling and analysis has been done by both the Company and by various regulatory authorities over the years of operation. The data have been compiled into spreadsheet format, and used for the calculations of metal loading and evaluations of impact on local and regional water chemistry in the following discussions.

The database comprises the following sources of data:

- monthly water quality sampling and analysis by UKHM of 20 stations, including the water licence stations, from 1990 through to 1995. There are earlier data which are not entered into the database for all stations;

- water quality sampling by UKHM with analysis at an external laboratory for samples within the above period;

- water quality sampling and analysis by DIAND periodically from 1985 through to 1995. Stations sampled were primarily receiving waters, and some adit discharge stations. In some cases this sampling was done at the same time as samples were collected by UKHM to provide a basis for comparison of data;

- water quality sampling and analysis by Environment Canada, Environmental Protection Service of receiving water stations (notably Christal Creek) and contributing point sources (notably Galkeno 900 adit), periodically from 1986 through to 1995;

- water quality sampling by Laberge Environmental Services (LES) for UKHM, with analysis at Quanta Trace Laboratories in Vancouver. These programs cover property more thoroughly and have been conducted with greater frequency than any other. The intention of these programs was to identify current and potential sources and pathways of metals. The sampling stations included all UKHM sampling stations plus receiving waters throughout the site area. Six sampling events were done in 1994 and 1995. These are summarized in Table 6-1;

- to complement the LES sampling, seep sampling was done in 1994 and 1995 by external consultants to select additional stations for more regular monitoring (including selection of groundwater monitoring stations) or to address specific water quality questions, e.g. waste dump drainage water quality. Analyses were done at Analytical Services Laboratories (ASL) in Vancouver.

The UKHM records indicate that there have been a few additional periods of duplicate sampling by regulatory and mine personnel for which the data were not collected during compilation of this database. Efforts will be made to obtain these data if available, and any additional data available from reviewers.

The water sample analyses done on the samples vary with the laboratory and the time period of sampling and include any, or all, of:

- Total metals analysis: ICP analysis on an unfiltered, preserved (nitric acid), digested water sample (methods as described in "Standard Methods for the Examination of Water and Wastewater" 18th Edition published by the American Public Health Association, 1992, or EPA Methods 3015 and 200.15). Total metals are described as "total" or "tot." in the database;

- Extractable metals analysis: by external laboratories, ICP analysis on an unfiltered, preserved water sample (APHA, 1992). Extractable metals are denoted by "ext." or "Me_E" in the database, depending on the analytical laboratory;

- Extractable metals analysis: by UKHM laboratory, AA analysis on an unfiltered, preserved water sample. Extractable metals are denoted by "ext." in the database;

- Dissolved metals analysis: ICP analysis on a filtered (0.45μm filter), preserved water sample (APHA, 1992 or EPA Method 200.15);

Table 6-1 Water Quality Site Descriptions and Sampling Frequency

LEES SITE #	SITE DESCRIPTION	1st Sampling Date	2ndSampling Date	3rd Sampling Date	4th Sampling Date	5th Sampling Date	6th Sampling Date
1	South McQuesten R upstream Christal Cr	July 26/94	Sept 7/94	Oct 27/94	July 14/95	Sept 6/95	
1B	South McQuesten R downstream Christal Cr	Oct 27/94	July 14/95	Sept 6/95			
2	South McQuesten R @ Pumphouse (S-10)	July 28/94	Sept 6/94	Oct 28/94	July 14/95	Sept 7/95	
3	South McQuesten R. upstream Flat Cr	July 28/94	Sept 6/94	Oct 26/94	Apr 27/95	July 12/95	Sept 6/95
4	South McQuesten R downstream Flat Cr (S-11)	July 28/94	Sept 6/94	Oct 26/94	Apr 27/95	July 12/95	
5	South McQuesten R 9 km downstream Flat Cr	July 29/94	Sept 5/94	Oct 26/94	July 12/95		
6	Christal Cr @ Keno Highway (S-18)	July 26/94	Sept 7/94	Oct 28/94	Apr 27/95	July 11/95	Sept 5/95
7	Christal Cr @ Hanson Road (S-19)	July 26/94	Sept 7/94	Oct 27/94	Apr 27/95	July 11/95	Sept 5/95
7B	Christal Cr. @ mouth	Oct 27/94	July 14/95				
8	Flat Cr @ Keno Highway	July 26/94	July 12/95	Sept 7/95			
9	Flat Cr upstream South McQuesten R (S-9)	July 28/94	Sept 6/94	Oct 26/94	Apr 27/95	July 12/95	Sept 6/95
10	Haldane Cr @ South McQuesten Road	July29/94					
11A	Galena Creek upstream Elsa Road	Oct 27/94	July 13/95	Sept 7/95			
11	Galena Cr upstream Silver King adit	July27/94	July 13/95	Sept 7/95			
11B	Galena Cr 700 m d/s Silver King tailings ponds	July 13/95	Sept 7/95				
12	Silver King adit (S-13)	July27/94	Oct 27/94	Sept 5/95			
12A	Silver King decant, pond # 2	July 12/95	Sept 5/95				
14	Husky South West adit (S-17)	July27/94	July 12/95	Sept 5/95			
18	Bermingham adit (S-3)	July27/94	Sept 5/95				
19	Ruby adit (S-15)	July27/94	Sept 5/95				
20	No Cash 500 adit (S-4)	July27/94	Oct 27/94	Sept 5/95			

Table 6-1 (Cont'd) Water Quality Site Descriptions and Sampling Frequency

LES SITE #	SITE DESCRIPTION	1st Sampling Date	2nd Sampling Date	3rd Sampling Date	4th Sampling Date	5th Sampling Date	6th Sampling Date
21	No Cash Creek @ Keno Highway	July27/94	Oct 27/94	July 11/95	Sept 5/95		
21A	No Cash Creek u/s Adit, above old wood culvert	Sept 5/95					
22	No Cash Creek upstream Hwy (1.4km NW of Keno Highway)	Oct 28/94					
22A	No Cash Creek just u/s of confluence with old ditch	Sept 5/95					
30	UN adit (S-2)	July27/94	Sept 5/95				
31 or 31E	Galkeno 900 adit (S-5)	July27/94	July 11/95				
31A	Galkeno 900 from Pond # 1	Apr 27/95	July 11/95	Sept 5/95			
31B	Galkeno 900 decant Pond # 2	July 11/95	Sept 5/95				
31C	Galkeno 900 seep below Pond # 1	July 11/95	Sept 5/95				
31D	Galkeno 900 seep below Pond #2	July 11/95	dry				
31 F	Galkeno 900 Seep near Swamp effluent	July 11/95	Sept 5/95				
31G	Galkeno 900 flow along old path 5m u/s Christal L.	July 11/95	Sept 5/95				
31H	Galkeno 900 Seep below wetland access road	July 11/95	Sept 5/95				
32	Galkeno 300 adit	July27/94	July 12/95	Sept 5/95			
34	Erickson Gulch @ Road to Lucky Queen	July27/94	July 12/95	Sept 5/95			
35	Sadie Ladue adit (S-7)	July 28/94	July 12/95	Sept 5/95			
37	Lightning Cr upstream Hope Gulch	July 28/94	Sept 8/94	July 12/95	Sept 4/95		
38	Keno 700 adit (S-6)	July27/94	July 12/95	Sept 5/95			
39	Bellekeno adit (S-12)	July27/94					
39A	Bellekeno decant from tailings ponds	July 12/95	dry				
39B	Bellekeno, seep below decant	July 12/95	Sept 4/95				

Table 6-1 (Cont'd) Water Quality Site Descriptions and Sampling Frequency

LES SITE #	SITE DESCRIPTION	1st Sampling Date	2nd Sampling Date	3rd Sampling Date	4th Sampling Date	5th Sampling Date	6th Sampling Date
40	Onek adit (S-8)	July27/94	July 12/95	Sept 5/95			
41	Lightning Cr @ Keno City Road Crossing	July 26/94	Sept 8/94	Apr 27/95	July 12/95	Sept 5/95	
42	Tailing Pond # 3 water	July 28/94					
45	Brefalt Cr upstream Porcupine Diversion	July 29/94	Oct 28/94	July 13/95	Sept 7/95		
46	Flat Cr upstream Porcupine Diversion	Oct 27/94	July 13/95	Sept 7/95			
47	Porcupine Diversion (Flat Creek) downstream of all inputs	July 28/94	Oct 27/94	July 13/95	Sept 7/95		
48	Hope Gulch	July 28/94	Sept 8/94	July 11/95	Sept 4/95		
50	Blank	July 29/94					
51	Combined Seepages in Porcupine Div. u/s Brefalt Cr	Aug 9/94	Sept 6/94	July 14/95	Sept 7/95		
52	Thunder Gulch upstream Bellekeno adit	Aug 11/94	Sept 8/94	July 12/95	Sept 4/95		
53	Old Galkeno freshwater pumphouse water	Aug 11/94	July11/95	Sept 4/95			
54	Thunder Gulch downstream Bellekeno adit	Sept 8/94	July 12/95	Sept 4/95			
55	Inflow to south end of Christal Lake	Sept 8/94	July 12/95	Sept 4/95			
56	Christal Lake	Sept 8/94	July 11/95	Sept 4/95			
57	Galena Cr @ mouth (just upstream of Flat Cr)	Sept 15/94	Oct 27/94	July 13/95	Sept 7/95		
58	Mystery Cr (approximately 1 km upstream of S-10)	Sept 16/94	Oct 28/94				
59	Buried Tails Seepage (Elsa side)	Oct 28/94	July 14/95	Sept 7/95			
60	Exposed Tails Seepage (Pond side)	Oct 28/94	July 14/95	Sept 7/95			
61	Small flow into Christal Cr. parallel to Hwy @S-18 near	July 11/95	Sept 5/95				
62	Small flow into Christal Cr. @ S-18, farthest from road	July 11/95	Sept 5/95				
63	Sandy Creek @ Highway	July 11/95	Sept 4/95				

Table 6-1 (Cont'd) Water Quality Site Descriptions and Sampling Frequency

LES SITE #	SITE DESCRIPTION	1st Sampling Date	2nd Sampling Date	3rd Sampling Date	4th Sampling Date	5th Sampling Date	6th Sampling Date
64	Unnamed Creek 60m towards Elsa on Keno Hwy from Hanson turnoff	July 11/95	Sept 4/95				
65	Galkeno 300 Seep below power line along Hwy	July 12/95	Sept 5/95				
66	Spring along Duncan Cr Road	July 12/95	Sept 4/95				
67	Porcupine Gulch @ Calumet Rd X-ing	July 12/95	Sept 4/95				
68	Flat Creek @ Ballpark Rd X-ing	July 12/95	Sept 4/95				
69	Flat Creek midway between tailings and Husky S.W.	July 13/95	Sept 7/95				
70	Flat Creek between Husky S.W. and Galena	July 13/95	Sept 7/95				
71	Flat Creek d/s Galena Creek	July 13/95	Sept 7/95				
72	Tailings decant (S-1)	July 13/95	Sept 7/95				
73	Seepage at toe of #3 dam	July 13/95					
74	Husky Southwest flow 500 m d/s adit	July 13/95	Sept 6/95				
75	Seepage along road between Galkeno 300 & Duncan Cr Rd.	Sept 4/95					
76	Star Creek @ Keno Hwy	Sept 4/95					
77	Husky Shaft	Sept 5/95					
78	Seep along road to Galkeno 900, 80 m from adit clearing	Sept 5/95					

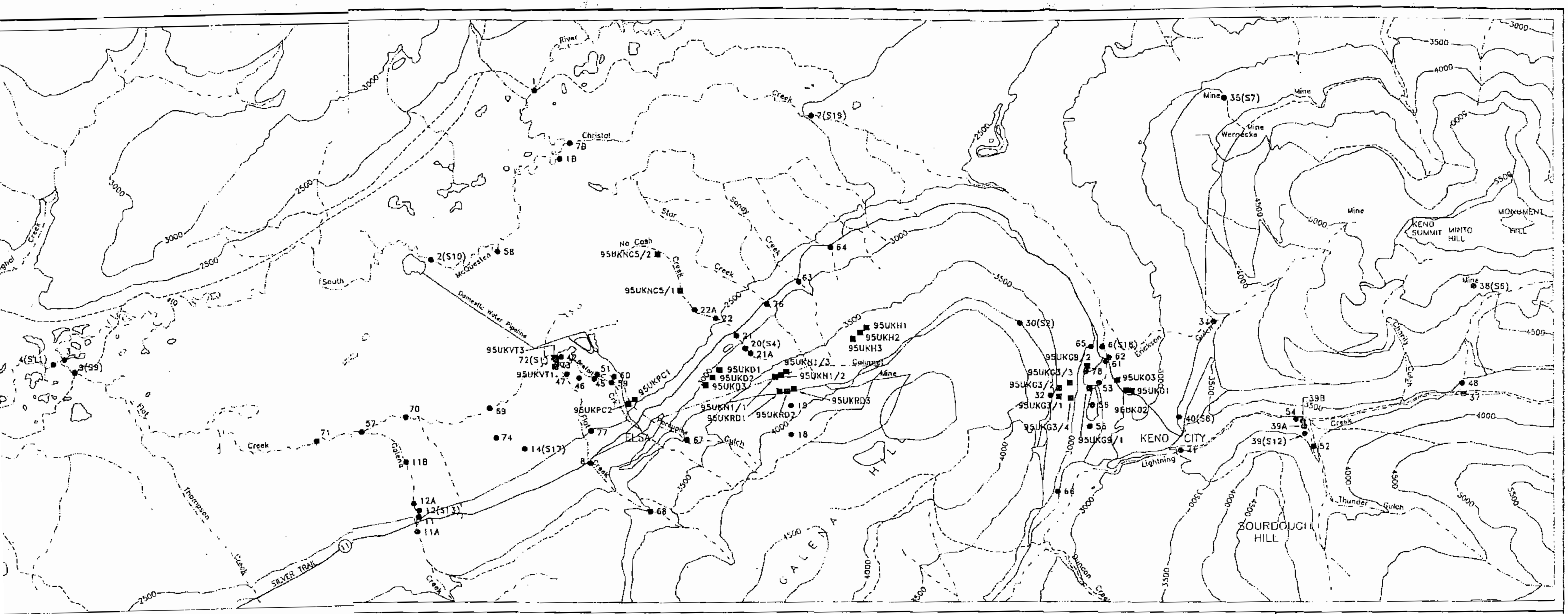
- Field pH, conductivity and TDS measurements using hand-held calibrated probes with automatic temperature correction;

- Laboratory pH, conductivity measurements using laboratory probes; and

- TDS (total dissolved solids), sulphate, ammonia, and cyanide analysis as in Standard Methods (APHA, 1992).

The water sampling stations are shown on Figure 6-1. UKHM water licence sampling stations are denoted by “2DD-S#” or simply “S-#”. The LES sampling stations are numbered, according to the descriptions in Table 6-1. In cases where the LES stations are the same as UKHM stations, both numbers are shown on the Figure.

The database is provided in its entirety in Technical Appendix VII. Calculations of seasonal statistics are also included. The database has been organized into a series of files; one for each sampling station. Within each file, there are separate spreadsheets for each the UKHM, “government”, and LES data (which includes data from other external consultants if applicable).



LEGEND

Creek, river, waterbody

Territorial Highway

Secondary road

Trail

● 71 Surface water sampling site

■ 95UK01 Soil test pit with piezometer

Elevation contour interval – 500 feet

0 1000 2000 3000

METRES

UTM GRID NORTH

UNITED KENO HILL MINES LIMITED

SURFACE WATER SAMPLING SITES
SOIL TEST PITS WITH PIEZOMETERS

ACCESS MINING CONSULTANTS LTD.

SCALE: 1 : 50 000	FILE: 224_1.DWG	DATE: 30/05/96
DRAWN:	DWG: 95UK24	FIGURE: 6-1

6.1.2 Database Analysis

As with any data set, there are a number of different statistical and graphical tools that can be used to analyze the data, and extract pertinent relationships. However, it is important to establish the objectives of such analyses. For this closure plan development, the key objectives in the data analysis were to determine or understand:

- trends in adit discharge water quality over time to anticipate future water quality concerns. These are summarized in Table 6-2;
- comparison between data sets and appropriateness of each for interpreting site geochemistry;
- changes in water chemistry along a flowpath (e.g. No Cash adit and No Cash Creek or the Christal Creek catchment) to identify and, to some extent, quantify natural and anthropogenic sources and sinks; and,
- relationships between parameters such as chemistry and flow to identify mechanisms controlling water chemistry - particularly where a physical mechanism such as the extent of flushing and the water flow path may dominate the water chemistry, rather than the geochemical processes.

The files have been set up with spreadsheets to calculate statistics for each data set. Values quoted as less than the detection limit are considered in the database as to be at the detection limit. The conclusions of these analyses are provided in this report and in the technical appendices.

6.2 Discussion of Site Water Chemistry

The following subsections discuss the water chemistry data for each of the mine areas and sampling stations. The discussions generally focus on the questions posed above for analysis, and specifically on identifying current and potential issues of water quality at the UKHM Elsa mining complex.

Table 6-2 Summary of Trends in Water Chemistry

Station	Data Source	Flow	pH	SO4 or cond.	Zn	Cd	Fe	Comments
Bermingham								
S3	UKHM	no change	no change	slight increase	no change	decreasing	peaks increasing	
LES 18	Gov't/LES		no change, variable	no change	no change	decreasing		peak in 1990, then lower
Seasonal?		yes but low	yes but variable	yes but variable	summer peak	summer peak	variable	
Elsa								
S16	UKHM	no change	no change	increasing	no change	increasing?	no change	
Seasonal?			yes - calcite?	slight	no	no	slightly	
Galkeno 900								
S5	UKHM	decreasing	no change	same	increasing	increasing	decreasing	
LES 31	Gov't/LES	no change	no change	increasing?	same	no change	decreasing	
Seasonal?		yes					variable	
Husky SW								
S17	UKHM	no change	increasing	same - variable	no change	slight increase	increasing	Zn high in 1991/1992
LES 14	Gov't/LES		same	same	slight decrease	no change		
Seasonal?		no	no	variable	slightly			
					low in winter			
No Cash 500								
S4	UKHM	var. 93 increase	no change	slight increase	slight decrease	similar to 90/91		all high in 91, then low
LES 20	Gov't/LES	overall increase	no change	slight increase	slight decrease	slight decrease		and increasing now
Seasonal?		yes	yes low in summer	yes	yes	yes	slight	
Ruby								
S15	UKHM	sl. inc	no change	no change	decreasing	slight decrease	slight decrease	current data similar to
LES 19	Gov't/LES	sl. inc	no change		decreasing	slight decrease	slight decrease	1986/87
Seasonal?		yes ice	yes	yes	yes	yes but lower	yes -lowest	
						in summer	early summer	
Silver King								
S13	UKHM	no change	decreasing	increasing	increasing	no change	increasing	
LES 12	Gov't/LES	no change	decreasing	increasing	increasing	no change	increasing	
Seasonal?		varies, no	lower late summer	peak late summe	varies	not evident	yes	
UN								
S2	UKHM	variable, low	no change	variable	slight decrease	sl.increasing	recent slight increase?	
LES 30	Gov't/LES		slight increase	slight decrease	slight decrease	no change	no change	
Seasonal?		yes	peaks related					
			directly to high flow					

Table 6-2 Summary of Trends in Water Chemistry

Station	Data Source	Flow	pH	SO4 or cond.	Zn	Cd	Fe	Comments
Keno 700								
S6	UKHM	no change	no change	no change	increasing to	no change as 90	increasing to '90	late 95 peak in metals, SO4
LES 38	Gov't/LES		no change	no change	no change?	no change	no change?	90's peak
Seasonal?		yes ice	yes increasing to 7-8 over summer			not consistent		
Lucky Queen								
S14	UKHM			increasing?	no change	no change	no change	only 2 points/year
Seasonal?		yes						
Onek								
S8	UKHM	no change	no change	no change?	no change	increasing peak?		'95 data similar to 90/91
LES 40	Gov't/LES		no change seas.	slight increase?	no change	no change		
Seasonal?		yes	yes		spring peak	spring peak		
Sadle Ladue								
S7	UKHM	increasing	no change	no change	increasing to '91	increasing to'91	increasing to '91	similar to 90/91?
LES 36	Gov't/LES	increasing	no change	no change	no change	no change	no change or	
Seasonal?		summer increase	lower in summer	no?	yes	yes?	low in winter	
					spring peak			
Bellekeno								
S12	UKHM	no change	recent slight decrea	similar to '90	slight decrease	no change	decreasing	
				variable			decreasing	
LES 39	Gov't/LES	slight decrease	no change	increasing	-	no change	no	
Seasonal?		no	no	no but variable	?sl. inc in summ	-		

In the absence of any other reference, the terms “elevated” and “high” are relative either to background values or to other data for the same site or area. The term “contaminants” is used in a general sense to refer to parameters which are considered potentially deleterious to water quality; notably metals and, to a lesser extent, sulphate and acidity.

In most cases, total and extractable metal analyses are similar and thus the term “total metals” is used to refer to results for unfiltered samples. This is necessary where there are limited data, or data for either total or extractable metals.

It must be noted that zinc analyses by UKHM in spring 1995 until July are questionable. The nitric acid used in the assay sample preparation was contaminated with zinc, and possibly cadmium and lead. Thus, the reader is cautioned to consider the source of the data and the analytical laboratory when evaluating data - particularly peaks or periodic trends in a few parameters that do not appear consistent with the remainder of the data set.

6.2.1 Bermingham

The water draining from the Bermingham adit is supplied both by groundwater flowing into the underground, and by surface precipitation funnelled through the main open pit via old shafts and faults.

Water quality sampling data sets are consistent, and show a distinct seasonal trend. Peaks in both flows and concentrations tend to occur in the spring or early summer months. These can be seen both in the water quality graphs, Figures 6-2, 6-3 and 6-4, and in the seasonal statistics appended.

The drainage water chemistry is somewhat different than other zones, in that there is no evidence of on-going oxidation, acid generation, or acid neutralization. The pH is alkaline, at pH 7. Alkalinity values are high, close to saturation. Sulphate concentrations are low at 70 mg/L, similar to surface streams (Galena Creek). The carbonate minerals in the deposit are primarily iron carbonates (siderite) which do not provide neutralization above about pH 5. There is no evidence of neutralization reactions by calcite minerals occurring underground in response to acid generation as Ca and Mg concentrations are consistently low.

However, the data do show that there is leaching of both cadmium (summer peaks in the 0.3 to 0.5 mg/L range) and zinc (summer peaks in the 6 to 8 mg/L range), and periodically arsenic, copper, lead. The dissolved values tend to be similar to the total or extractable metals, indicating that most of the metal is in the dissolved form, and thus is a result of a dissolution (leaching) mechanism.

There has been little change in the water chemistry over time for most parameters. The apparent peak in the 1995 UKHM data is due to sample contamination in assay preparation. While other data is limited, it indicates lower zinc concentrations in 1994 and 1995.

Historic data suggests higher metal levels were found in the adit drainage during the 1970's, approximately 20 years after completion of the underground mining but nearing the end of the open pit oeprations. This may be due in part to elevated suspended solids in the drainage, influenced by the open mining activities. The average zinc concentration for 1979 in the adit drainage was 5.5 mg/L at a pH of 7.4 and 26 mg/L suspended solids.

The data therefore indicate that the Bermingham adit drainage contains dissolved metals, as a result of dissolution of soluble minerals. The source is probably a combination of precipitation on the pit wall flowing down through the exposed vein material and then percolation along the vein structure to the adit. The vein is noted to be strongly oxidized by Boyle (as discussed in Section 3.2) and the workings are not deep, which may explain the high dissolved metals but lack of any indication of ARD. There is no evidence in the past 10 years of acid production. It appears the water chemistry has improved in the long term, and has been relatively stable over the past five years and that there is no reason to anticipate any worsening of drainage water quality.

Figure 6-2

Bermingham Adit (S 3)
(LES 18)

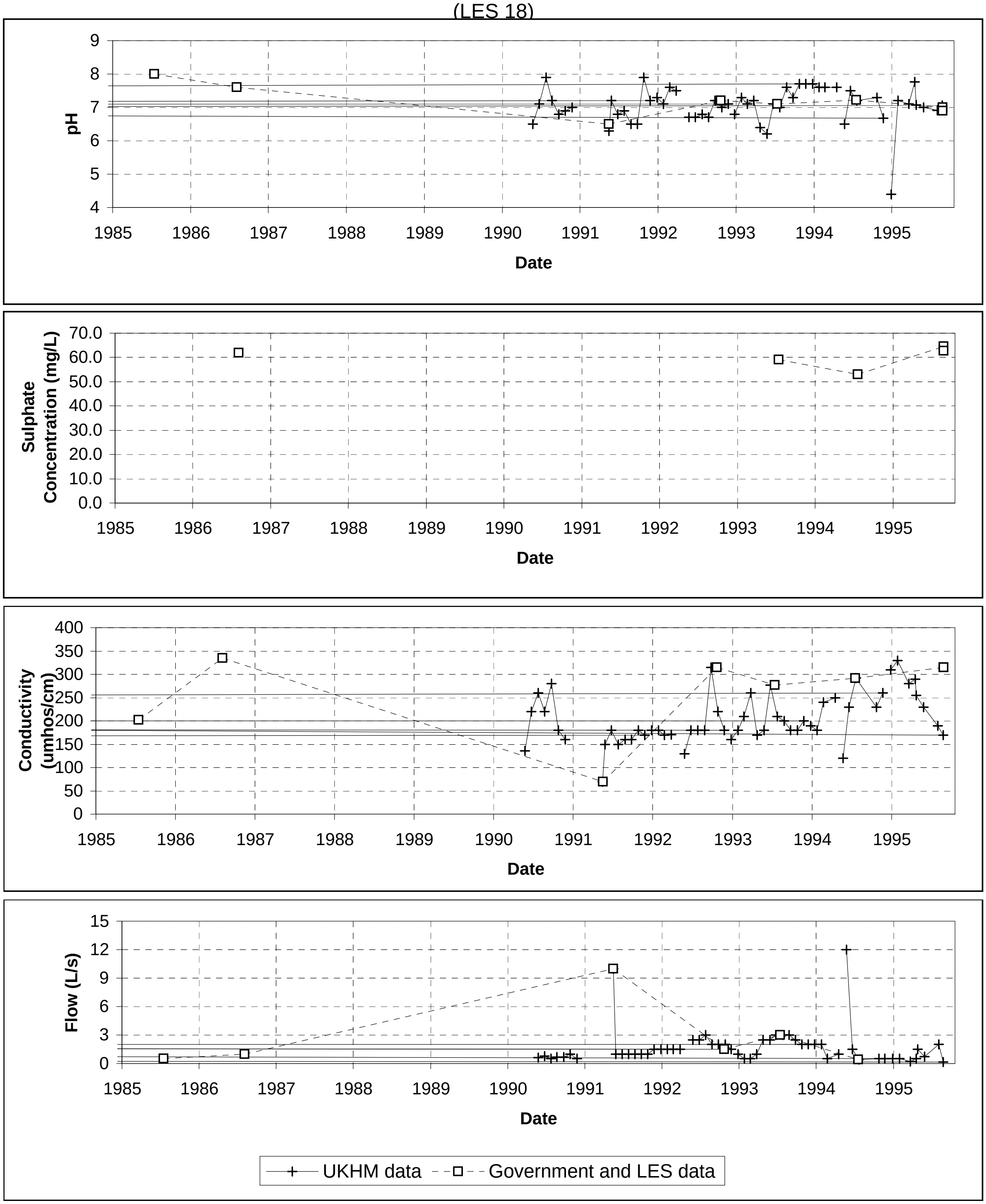


Figure 6-3

Bermingham Adit (S 3)
(LES 18)

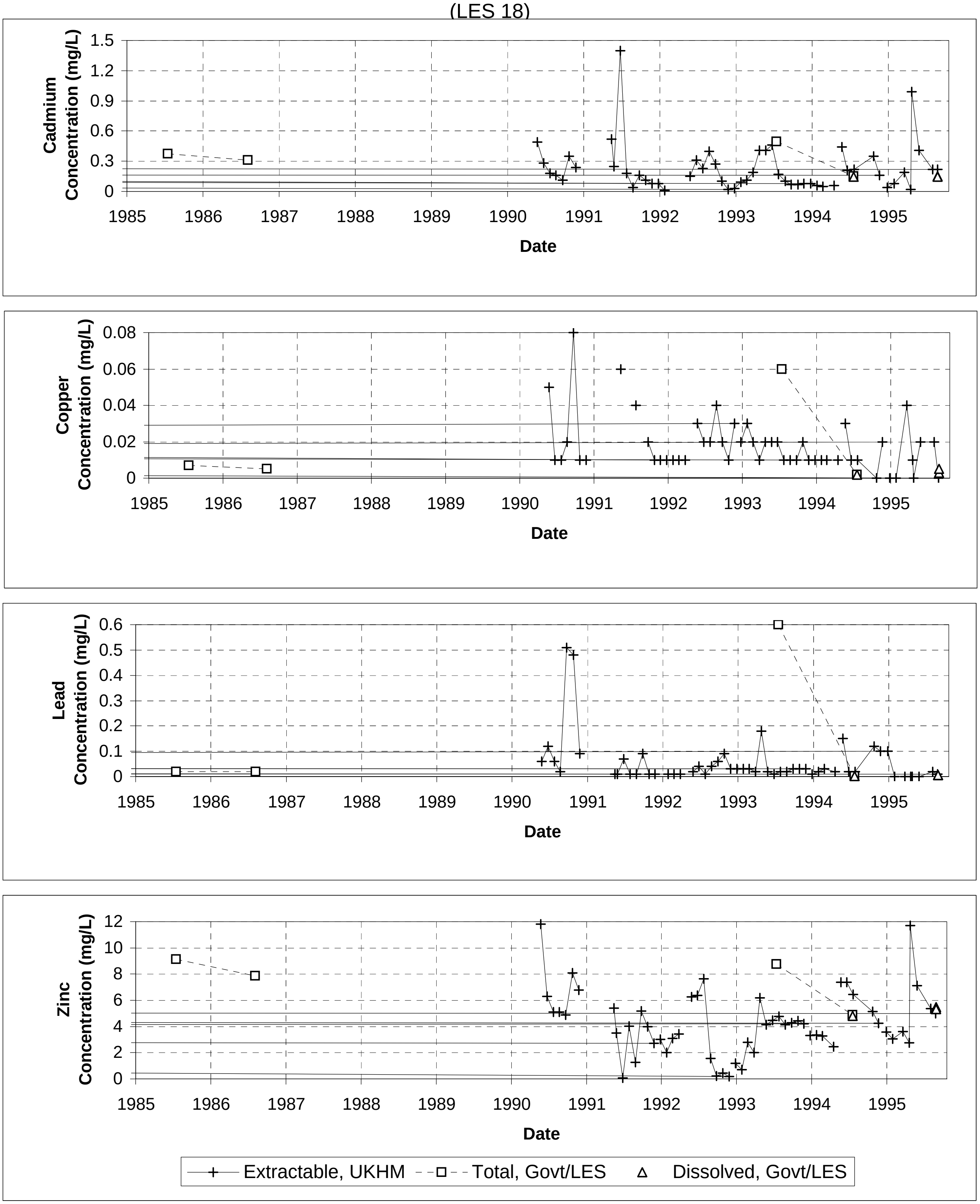
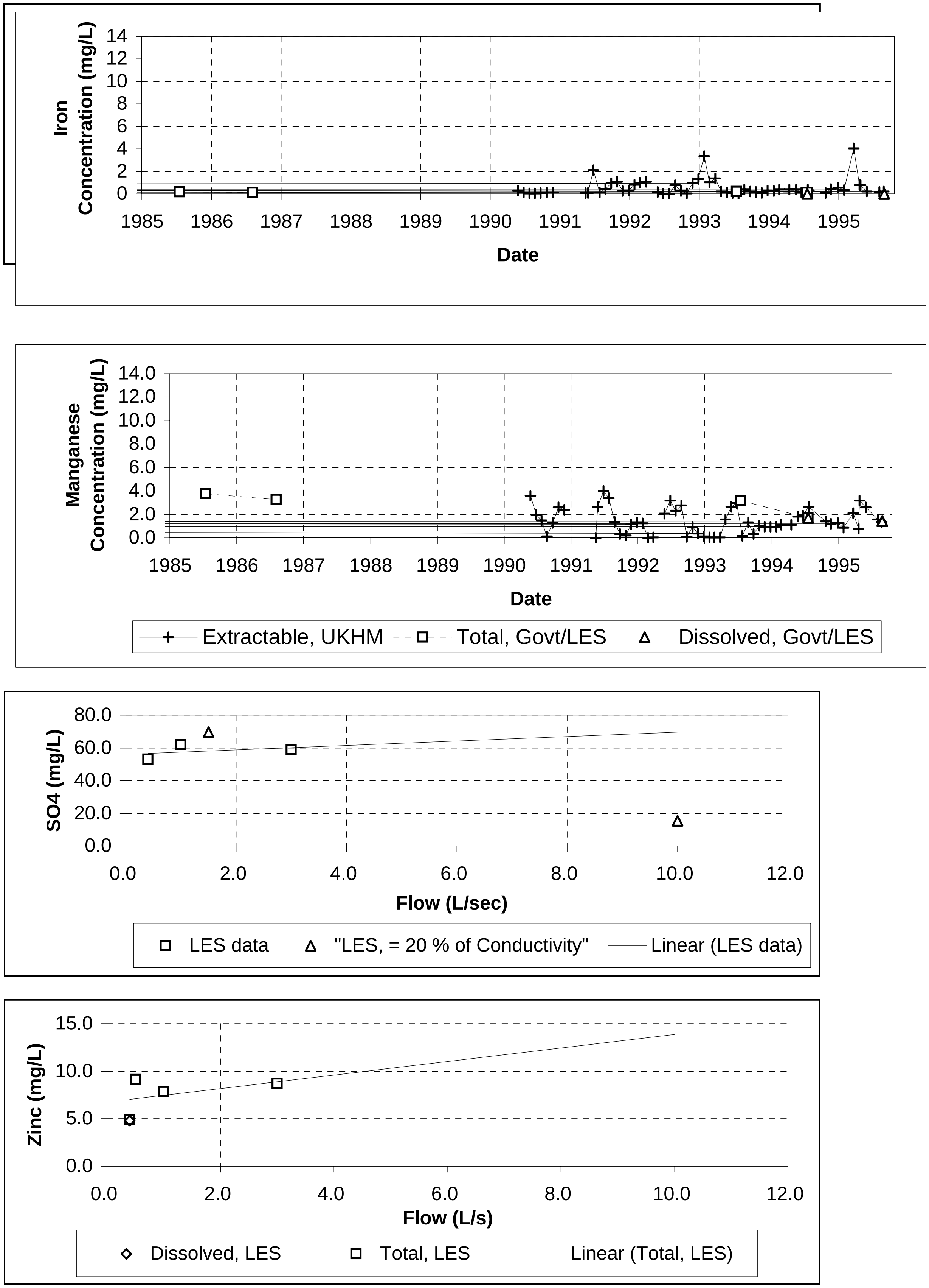


Figure 6-4

Bermingham Adit (S 3)
(LES 18)



6.2.2 Elsa

Since the Elsa 400 adit is not a point of discharge to the receiving environment, most of the sampling has been done by UKHM, and not by others. Since the Elsa underground has been in operation since the 1930's however, it is instructive to look at the water chemistry over time from an "old" mine. In addition, the water from the Elsa shaft is believed to report to the Husky underground, thus it is important to determine the parameters that may affect the water quality at the Husky Mine.

The UKHM data for this station is summarised in Figures 6-5 and 6-6. The data show consistently alkaline pH values and generally low suspended solids and extractable metals. Conductivity values seem somewhat elevated and appear to be increasing from values about 400 to 600 in the 1980's to values between 600 and 800 μmhos/cm since 1992. These values are within the range reported by Bolye (1965) for underground waters in the Keno Hill-Galena Hill area based on samplng in the 1950's and early 1960's. The elevated zinc concentrations in 1995 of 0.3 mg/L, compared to less than 0.1 mg/L, correspond to the period of known sample contamination in the assay laboratory.

The historical water chemistry from the Elsa Mine will be examined in more detail for assessment of closure requirements; both for Elsa and for the other mines. The older data do have to be interpreted with some caution as the metal levels may be underestimated, due to differences in analytical techniques - particularly sample digestion for assay.

Operational records from the 1970's suggest that the Elsa underground drainage contained elevated zinc with slightly acidic pH values. As an example, the average concentrations for the period December 1978 to November 1979 were pH 5.75, 42 mg/L total Zn, 0.4 mg/L Cd, and 0.13 mg/L Pb. This drainage was discharged to the tailings pond as of 1979. These values are well above the measured concentrations for recent years in the adit drainage, suggesting that the peak in metal leaching from the adit occurred in the late 1970's and early '80's.

Figure 6-5 Elsa Adit (S16)

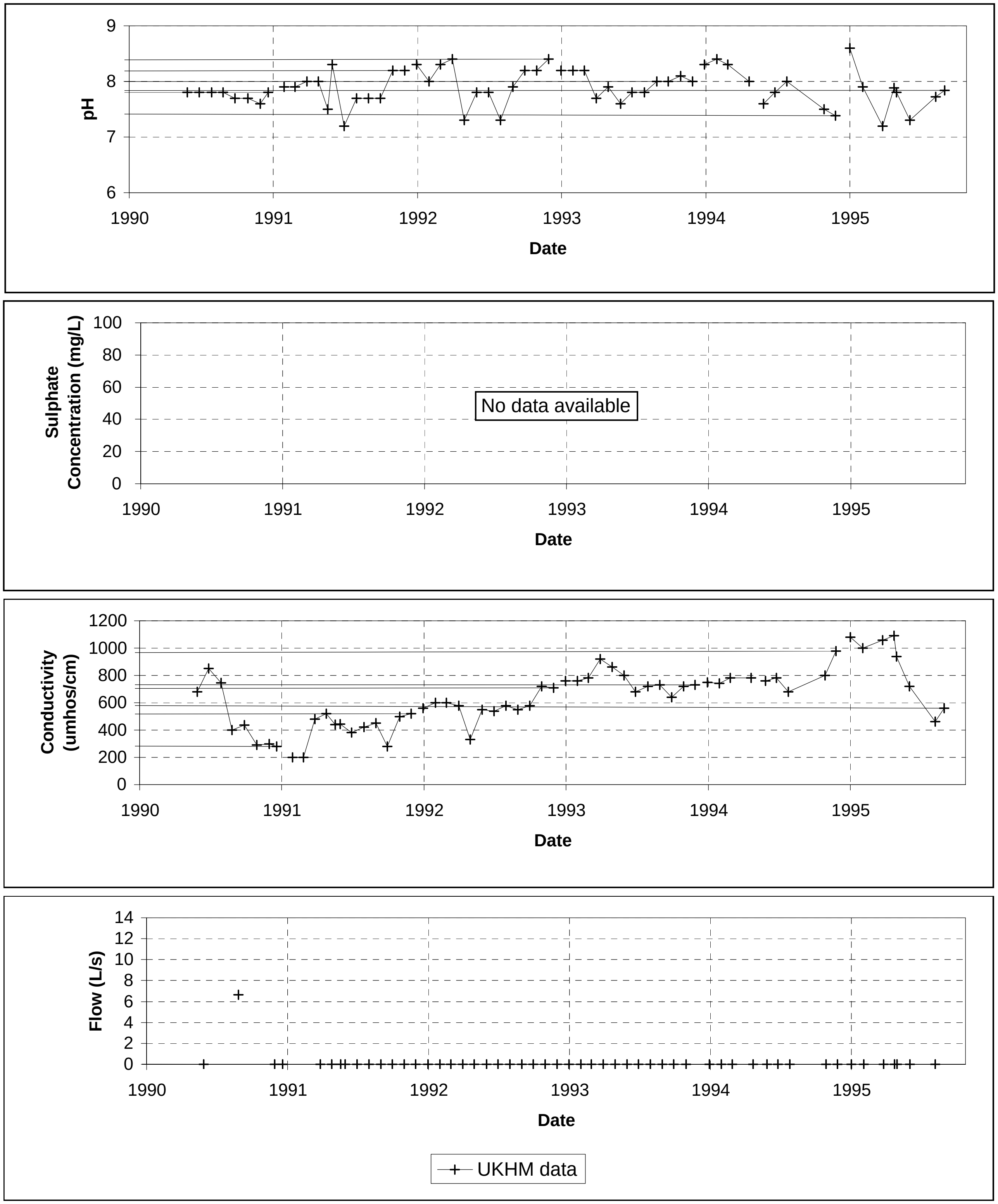
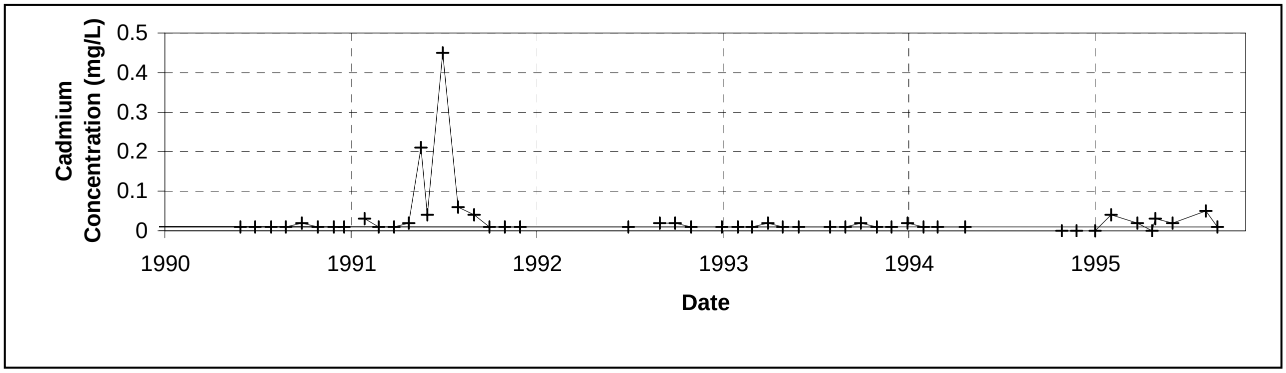
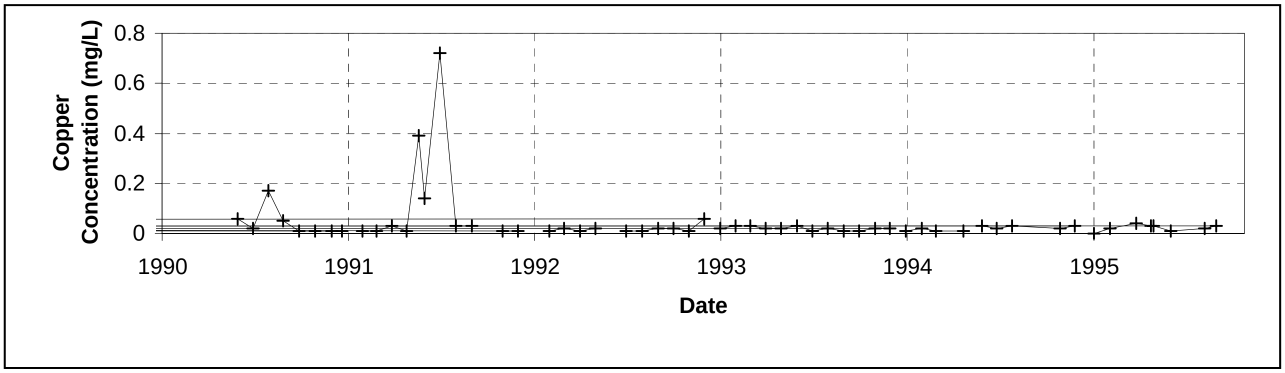
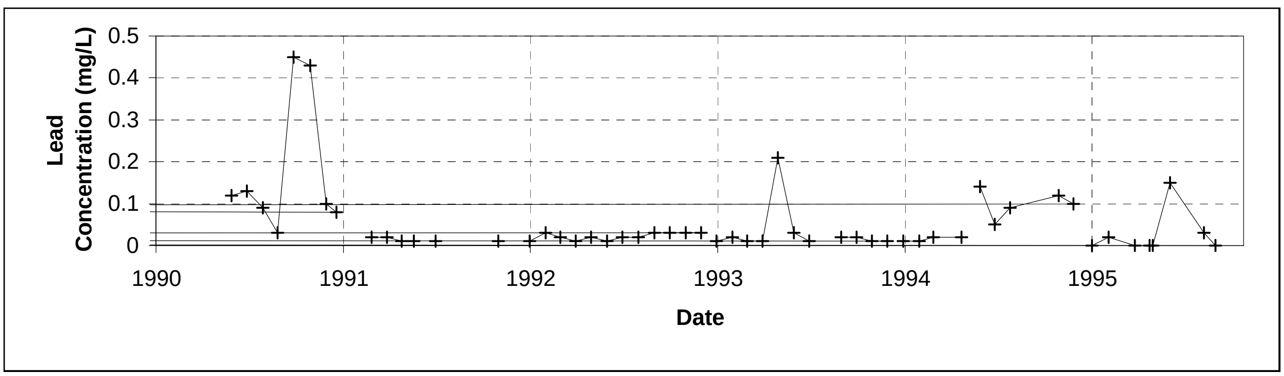
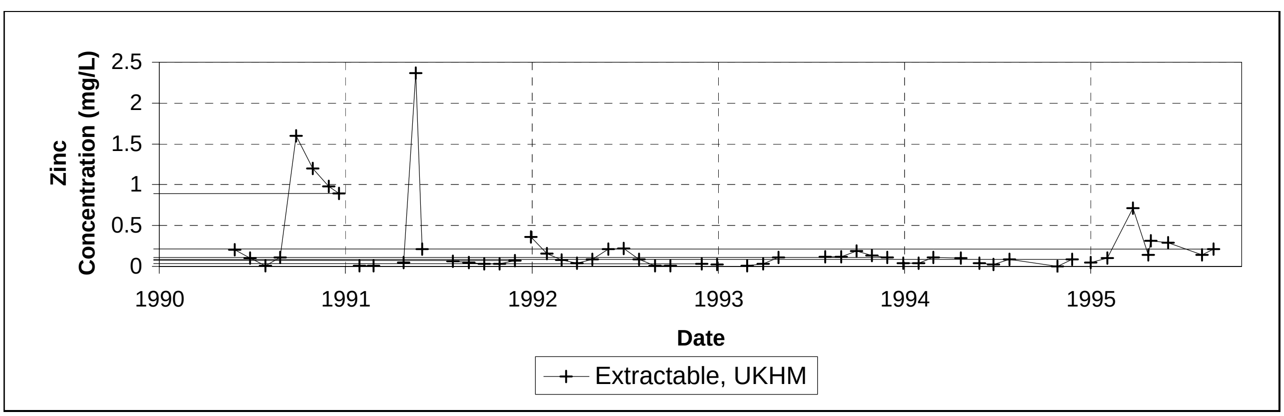


Figure 6-6 Elsa Adit (S16)









6.2.3 Galkeno

Concerns with respect to the high zinc concentrations and loadings in the Galkeno drainage water led to the installation of an hydraulic bulkhead in the Galkeno 900 adit in October of 1993. In order to install the bulkhead, the adit was dewatered and a water treatment system established for this drainage. After that installation, the water sampling station was moved to the water treatment settling pond decant, although sampling was continued by UKHM between the bulkhead and “treatment plant” feed.

The history of the water chemistry at the Galkeno 900 adit was further complicated in 1992 when broken rock, clay and till temporarily blocked the adit as a result of sloughing during excavation. This was removed prior to dewatering and bulkhead installation.

The drainage from the Galkeno 900 level has consistently shown elevated dissolved and total metal concentrations, the primary concern being zinc and occasionally cadmium if UKHM data are considered alone. Sulphate and conductivity values are also consistently elevated, at about 1400 mg/L and 1500 μmhos/cm respectively, although still below chemical saturation. These are shown in Figures 6-7 through 6-9.

Despite the indications of sulphide oxidation and metal leaching, the drainage water remains alkaline. Dissolved calcium and magnesium concentrations indicate that there is acid generation and neutralization by carbonate minerals, but it appears that there is considerable buffering capacity within the system. It also does not appear from the water chemistry data that there has been acceleration in oxidation rates to date, as indicated by the ratio of dissolved calcium plus magnesium to sulphate.

It is somewhat surprising that the drainage water chemistry has changed very little since the bulkhead was installed and the workings began to flood. In fact, it appears from some data that there may be a slight decrease in zinc concentrations. Typically, flooding of oxidation zones results in a short-term flush of stored oxidation products, followed by a gradual decrease as the stored products are removed and the oxidation mechanism limited by flooding.

Figure 6-7

Galkeno 900 Adit (S 5)
(LES 31or 31E)

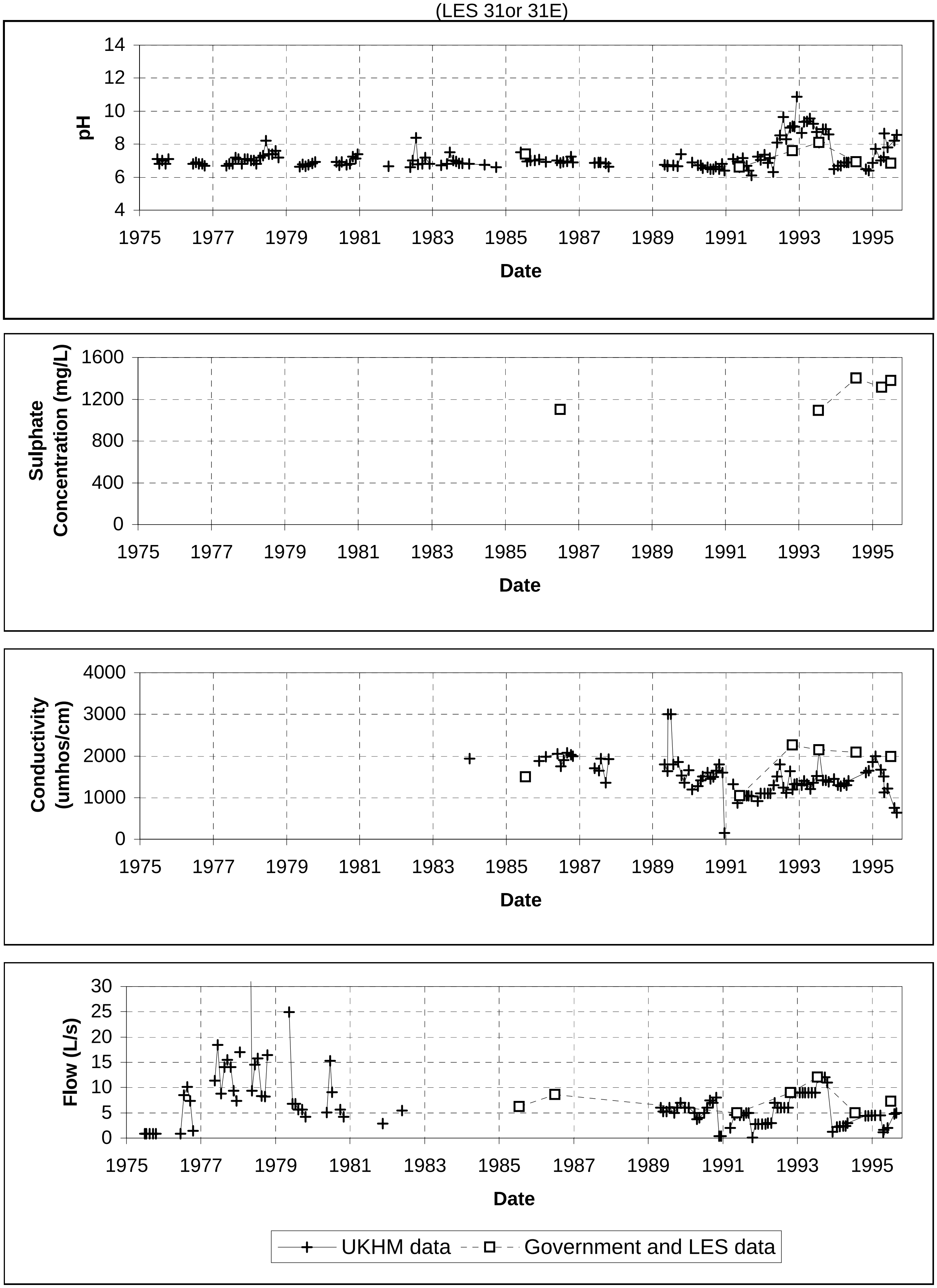


Figure 6-8

Galkeno 900 Adit (S 5)
(LES 31or 31E)

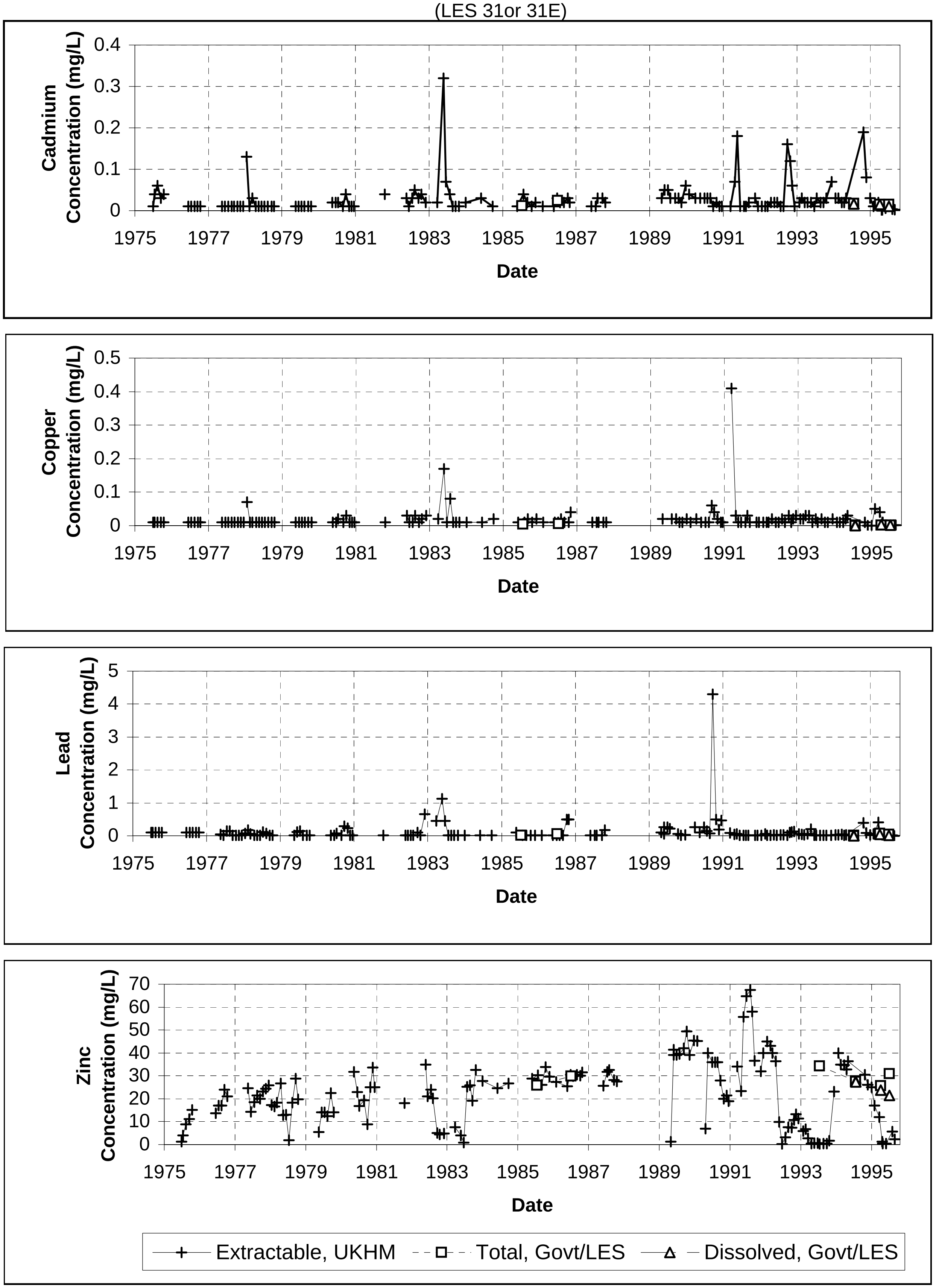
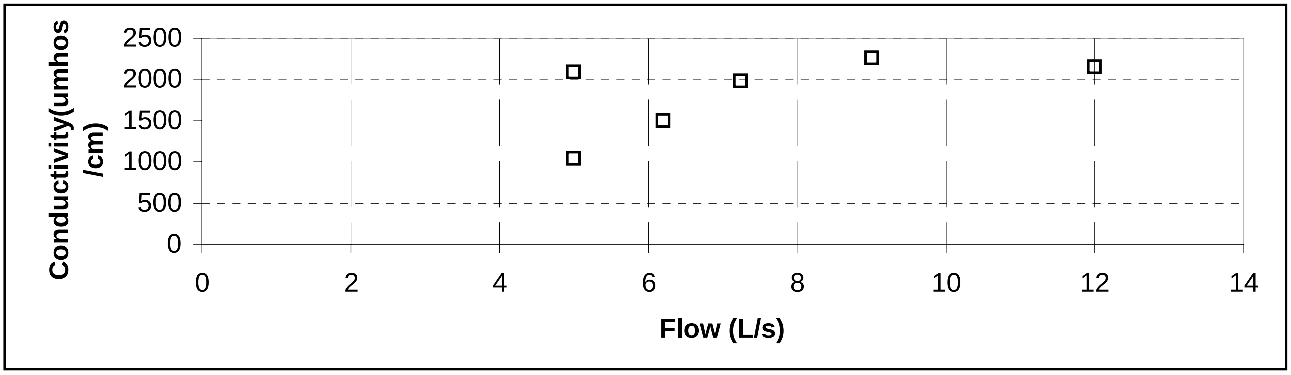
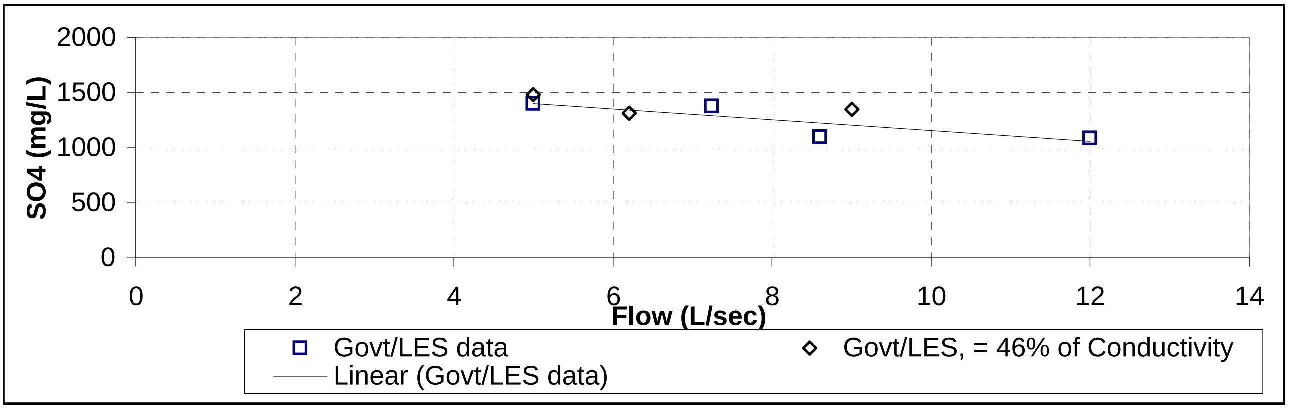
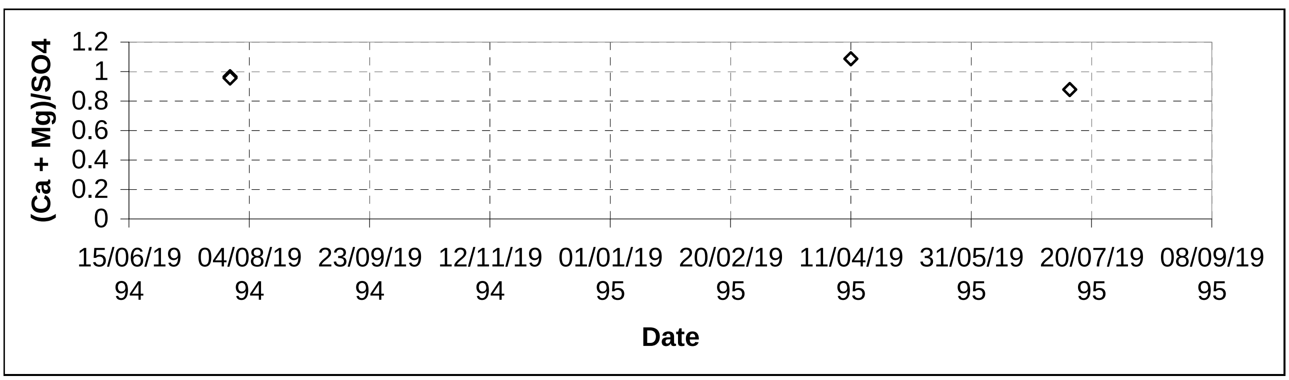


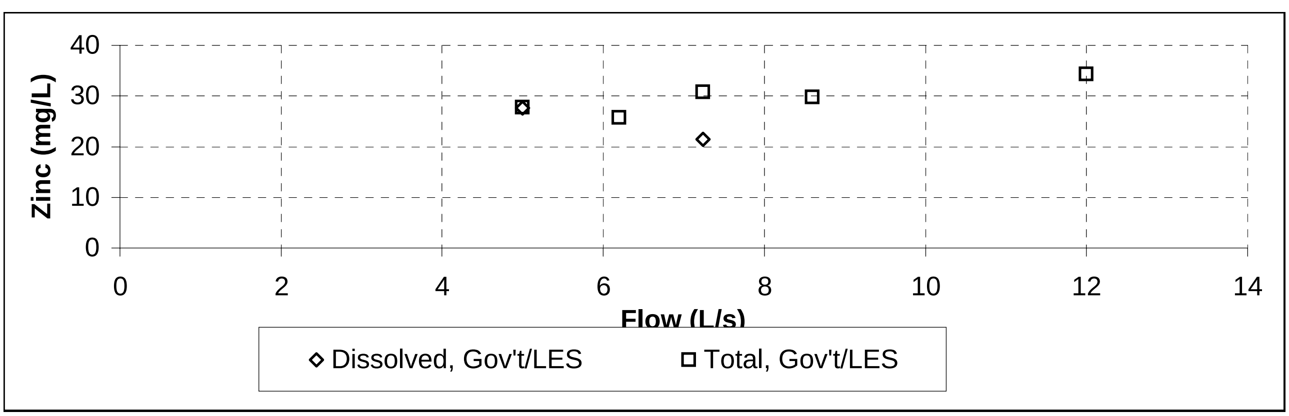
Figure 6-9

Galkeno 900 Adit (S 5)
(LES 31or 31E)









This suggests that some or all of the following factors may be controlling water chemistry:

- the source of the oxidation products has not yet been flooded and the water impounded behind the bulkhead is still flowing through the same source zone. Records show that the vein in the Hector-Calumet is highly oxidized down to at least the 400 level, is liekly hydraulically connceted to the Galkeno 900 adit via the upper Glakeno workings and the MacLeod vein fault, and may be a source of some of the metal loadings to the Galkeno 900 drainage;
- there are several sources of water contributing to the stored volume and to the adit and seep drainage, each with different chemical constituents depending on the flowpath, i.e. "clean" groundwater not flowing through mineralized areas or workings, and water from zones of oxidation and/or stored soluble products. Prior to "plug", installation adit water chemistry dominated discharge chemistry; with this water now impounded behind the plug, other groundwater may be moving into the adit between the bulkhead and the portal, and mixing with adit water flowing around the plug thus lowering Zn concentrations (although SO_4 is still high);
- there are chemical controls on the concentrations of the species in solution.

The implication of this observation is that there may continue to be elevated zinc concentrations in the drainage for some time into the future. In light of this, a pilot project was initiated in the summer of 1995 to test wetland treatment of the adit drainage water. The project is discussed in more detail in Appendix II. The results show that zinc can successfully be removed from the drainage waters flowing through the wetland. Testwork indicates that the primary mechanism for metal removal is sulphate reduction and subsequent metal sulphide precipitation. This is encouraging for treatment in the Yukon, in that:

- unlike proposed mechanisms for metal removal by surface wetland vegetation, sulphate reduction processes are not seasonally dependent (on plant growth cycles) and can continue as long as there is flowing water. Rates of reaction are of course diminished as the temperature decreases;
- freezing causes the bacteria to go dormant, but does not kill the bacteria; and,

- analyses of plants from the wetland show no evidence of metal uptake, thereby removing any concerns for vegetation or wildlife from ingestion of the plants or concerns for maintenance and plant harvesting required in wetland treatment systems based metal removal by surface plants.

Flooding of the workings has, as expected, resulted in an apparent increase in the number and volume of seeps from the hillside in the portal area, and surrounding hillside. These seeps were sampled in the 1994/95 sampling program and results are included in Appendix VII. The zinc concentration in all seeps is lower than the adit discharge water, ranging from 10 mg/L (seep below wetland access road) to less 0.12 mg/L Zn (spring along Duncan Creek Road). The physical location of the seeps and the water chemistry indicate that seepage from the adit or from the settling ponds is not the only source for each of the seeps as shown below in Table 6-3.

Table 6-3 Galkeno Creek Seep Survey Data for 95/07/11

Seep Location	**SO_4**	**Zn_t**	**Zn_d**	**Ni_d**	**Cd_d**	**Ca_d**
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Galkeno 900 adit	1380	30.8	21.4	0.344	0.01	447
Pond 1 effluent	1380	0.771	0.18	0.165	0.0008	498
Pond 2 effluent	1400	0.05	0.03	0.128	<0.0005	460
Slope below pond 1	1400	1.17	1.12	0.034	0.0038	476
Slope below pond 2	1700	5.21	4.96	0.142	0.0066	534
Near swamp effluent	1300	7.66	5.61	0.178	<0.0005	468
On old drainage path	1280	4.89	4.64	0.11	0.0023	471
Below road to wetland	1430	10.1	7.85	0.127	0.0193	460
Duncan Creek Road	174	0.118	0.112	0.005	0.0012	83.1

This range of values further lends credence to the theory that there are a number of sources. The seeps from the natural hillside appear to be of a mixture of waters; neither “clean” groundwater nor adit drainage chemistry but all waters near the 900 adit appear to have interacted with oxidized sulphides as all show high sulphate.

There is also a small and intermittent drainage from the Galkeno 300 adit. This drainage also shows elevated sulphate (1180 mg/L), zinc (112 mg/L), and cadmium (0.5 mg/L) concentrations.

Arsenic is not a concern in these waters, nor in the seeps described above. Total arsenic concentrations were elevated in two samples from the Galkeno 900 in the 1980's, but not in any samples since 1986.

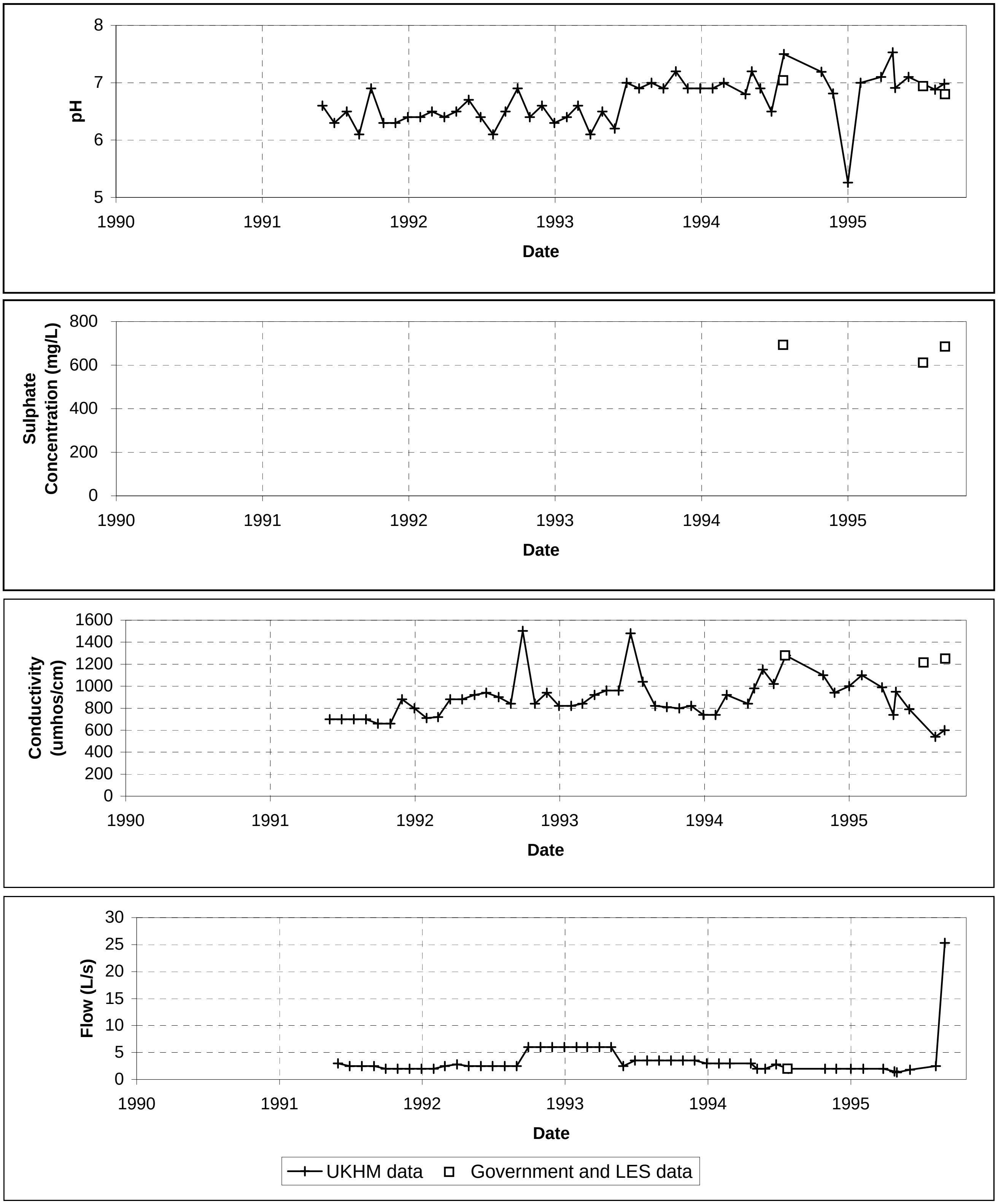
There is an apparent increase in zinc concentration in Galkeno 900 waters since the mid-1970's. This may correlate with degradation of Christal Creek waters. The cause of this could be related to geochemical process, however, it seems more likely that it is due to rise in groundwater tables in Galena Hill following shutdown of the major underground mines and, therefore, cessation of dewatering as well as the onset of open pit mining and creation of the funnel effect from the Calumet, Hector and Sime pits, all of which are connected to the Galkeno 900. This would result in flushing of previously "dry" areas.

6.2.4 Husky

The Husky shaft is flooded but does not discharge to surface. Rather, water flows from Husky to Husky SW via the drift. Two water samples were taken from the shaft in the summer of 1995, however caution must be used in interpreting the results as there was ice in the shaft, below the surface of the water. Thus, the water sample may represent melt water from the ice, water not yet frozen, or flow into the shaft from elevations above the ice.

The two samples showed quite different results, probably due to disturbing the water on top of the ice in sampling. However, it does show that there may be dissolved zinc in drainage from Husky and low alkalinity, although the pH values were near neutral (6.4, 7.6 in the field).

Husky SW Adit



6.2.5 Husky SW

The drainage from the Husky SW shaft has been reasonably consistent in terms chemistry and flow over the past five years, as shown in Figures 6-10 and 6-11. However there is an unexplained apparent peak in the 1994 UKHM data, particularly for Pb, and to a lesser extent in 1995. Since this is not evident in the external data, it is expected that this is a sampling or analytical error. The drainage is generally alkaline (>125 mg/L $CaCO_3$ eq.), with pH values around 7. As shown in the figures, there are no distinct seasonal trends in flow. The metal concentrations are variable over the year, with a peak generally occurring in the spring.

Zinc is the primary contaminant of interest in this drainage, with concentrations in recent years between 0.5 and 1.0 mg/L. The UKHM data show occasional “spikes” of other metals above detection levels, including iron, lead, cadmium, and copper although this is not supported by data from external sampling. In all metal analyses at this station, the UKHM data show higher concentrations than do external samples, however these analyses are close to detection limits. The lack of seasonal trends and low metal levels are consistent with a flooded working, without oxidized material.

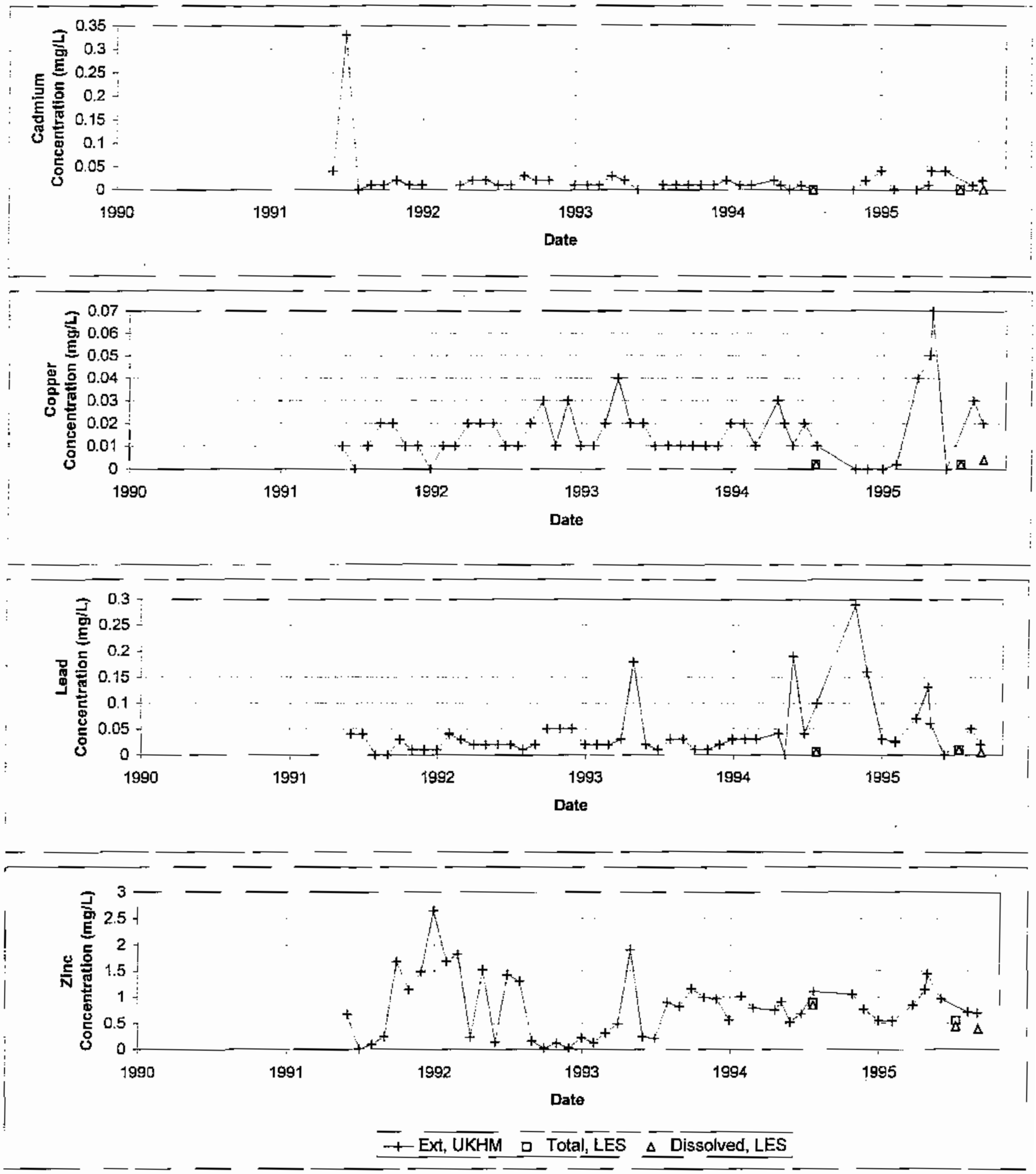
Water samples were also collected along the adit discharge drainage flowpath, approximately 500 m downstream from the discharge point. The following Table 6-4 summarizes some of the more interesting results for one of the sampling events.

Table 6-4 Sampling at Husky SW for 95/07/12 and 95/07/13

Sample	pH	Alkalinity	SO_4	Fe_t	Fe_d	Zn_t	Zn_d
Shaft discharge	6.9	135	685	16.3	9.68	0.555	0.45
500 m downstream	8.2	120	762	4.3	0.01	0.071	0.024

The small change in the sulphate and conductivity values suggest there has been very little dilution of the discharge water with background water. The marked change in zinc and iron concentrations though suggest that there has been removal of metal, by either or both co-precipitation or sulphate reduction along the flowpath. Iron precipitation is evident along the flowpath, as fine orange particulates and precipitates.

Figure 6-11 Husky SW Shaft (S17/LES 14)



6.2.6 No Cash 500

The discharge from the No Cash 500 adit has been of interest both from a scientific and an environmental impact point of view. The volume of discharge is relatively high compared to most of the adits, at about 4 L/s (compared to the highest which was Galkeno 900 at about 10 L/s). Despite elevated zinc concentrations in this discharge though, there is little evidence of the metal loading in downstream water samples. No Cash Creek has been the subject of investigation by Kwong, et al (1994), to evaluate the geochemical controls on zinc mobility and removal along the flowpath.

The water quality data sets are consistent, showing elevated zinc concentrations at the discharge, ranging between 5 and 20 mg/L. There are also peaks in the UKHM measured cadmium concentrations to values of 0.6 mg/L. External sampling however tends to show concentrations of <0.1 mg/L with most of the cadmium in the total rather than the dissolved form. Arsenic is not a concern in the drainage water samples. These data are shown in Figures 6-12 through 6-14.

The adit water discharges to No Cash Creek and flows down the hillside towards the wetlands northeast of the Elsa tailings. Water quality sampling along No Cash Creek by UKHM, LES and Kwong show a consistent decrease in metal (zinc) loadings over the length of the creek. This is shown graphically in Figure 6-15.

The water quality data have been consistent over the past five years, indicating a steady rate of production of soluble metals, but with no significant increase or decrease in production. UKHM data indicate a slight increase in conductivity from 1990 to 1995, however, values decreased to 1991 levels in the latter part of 1995. The flow data show variations over the year with peak flows occurring in the spring months. Spring/early summer pH decreases may reflect flushing of acid salts in the workings. This seasonality is reflected in the water chemistry with peak flows coinciding with peak concentrations. The decreases in early summer may reflect flushing of stored soluble products and/or a decrease in the surface area being flushed.

Figure 6-12

No Cash 500 Adit (S 4)
(LES 20)

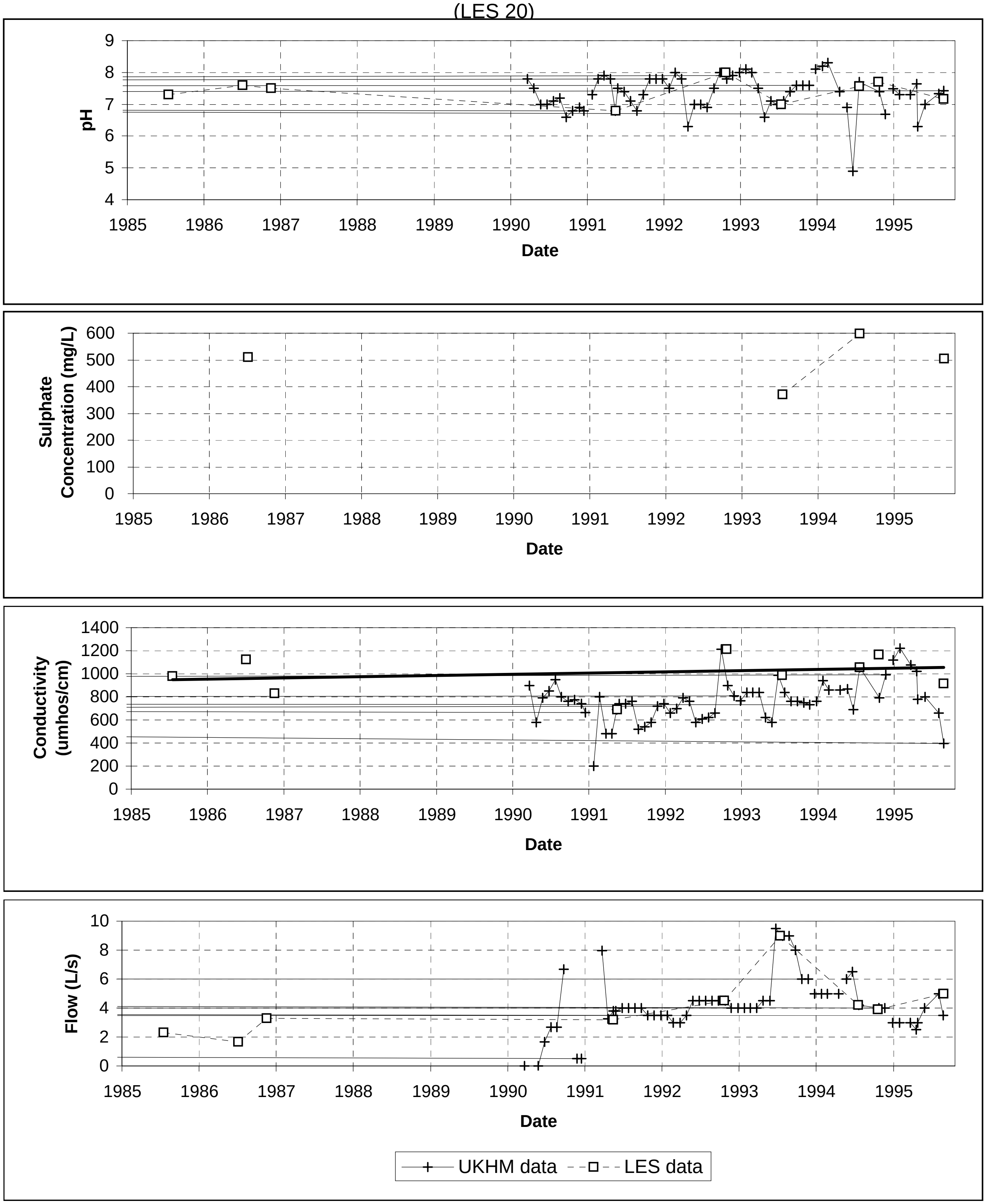


Figure 6-13

No Cash 500 Adit (S 4)
(LES 20)

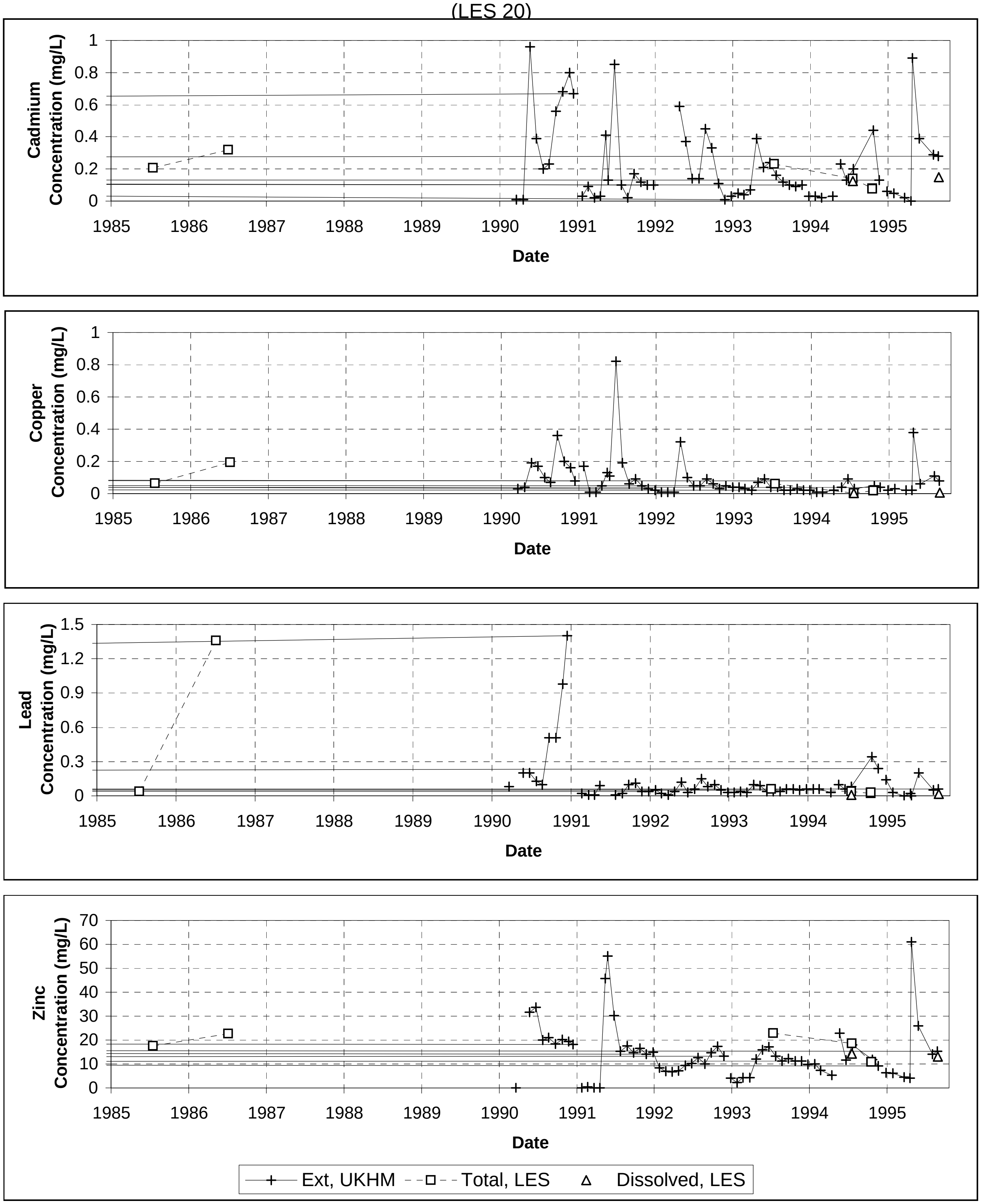
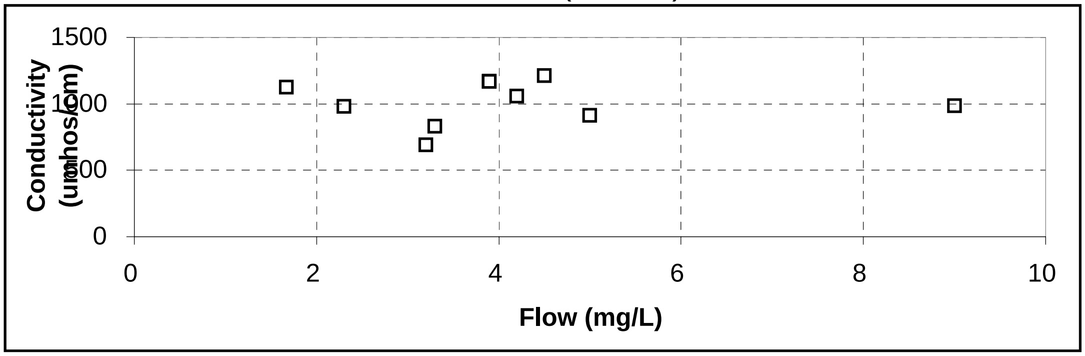
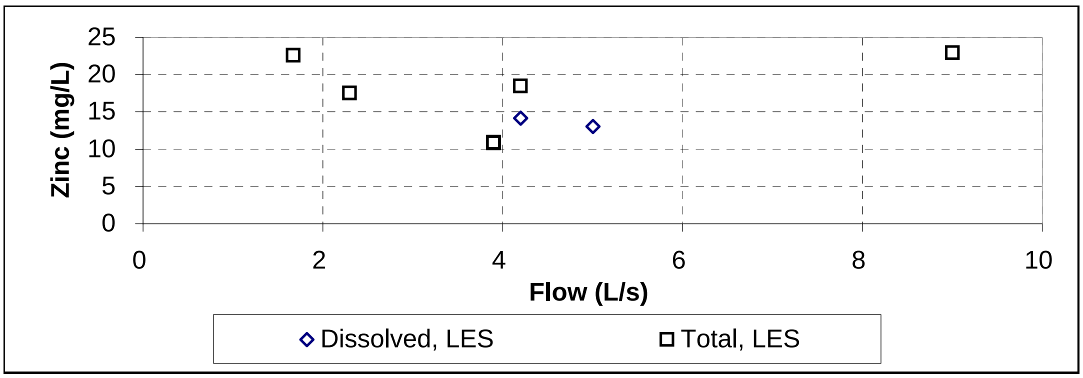
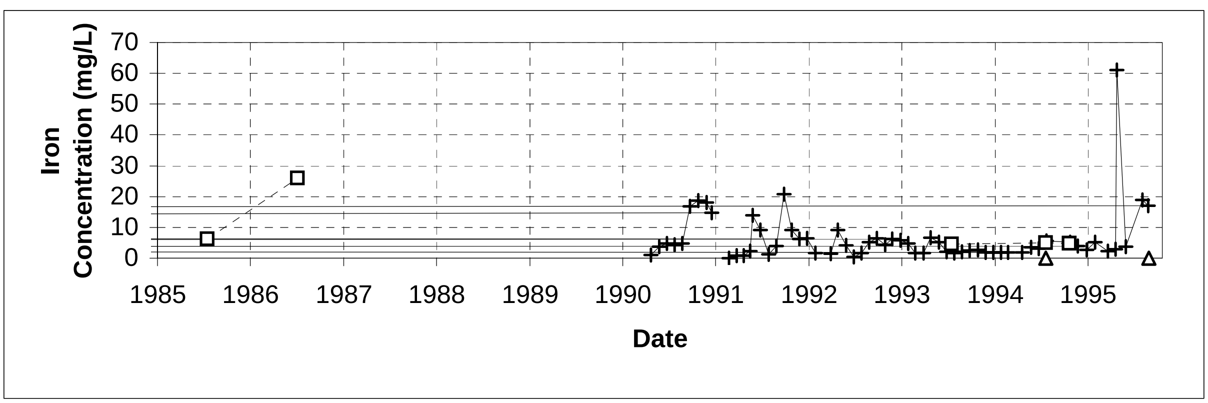


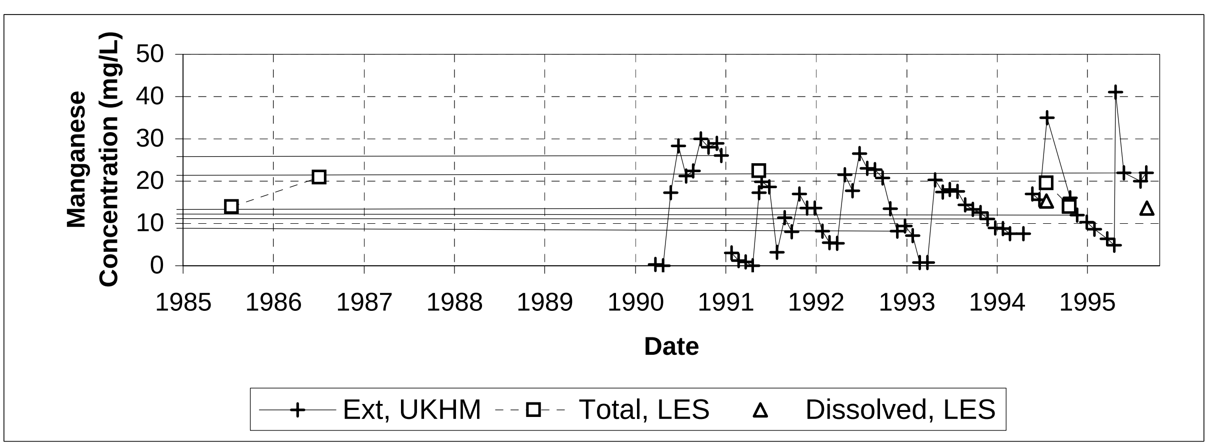
Figure 6-14

No Cash 500 Adit (S 4)
(LES 20)

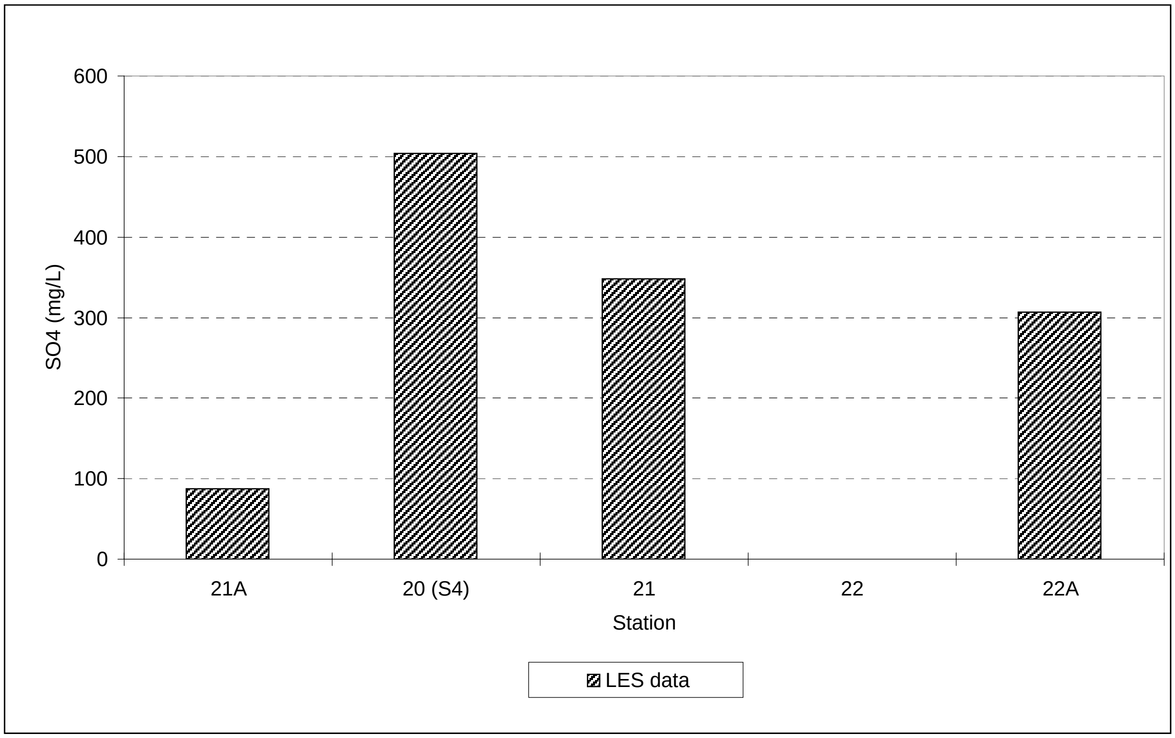


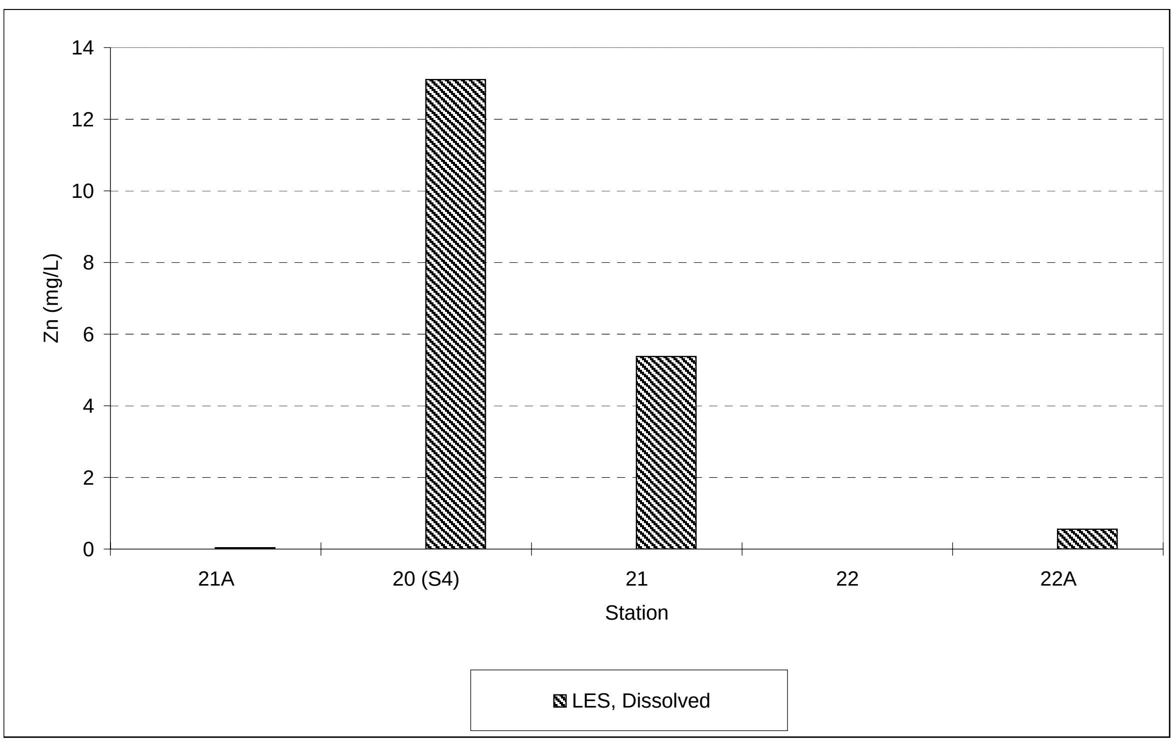






No Cash Creek





6.2.7 Ruby Adit

The water quality monitoring data from the Ruby Adit shows more variability over each year, and over the monitoring period than do most of the other adits on Galena Hill (Figures 6-16 and 6-17). This is probably due in large part to the formation of ice in the adit. Ice is present year round at the portal, so for much of the year the adit drainage water chemistry will be affected by freezing and thawing of the ice.

The flows from the Ruby adit are relatively low, averaging about 1.5 L/s when flowing. Zinc concentrations in 1995 peaked at 2 mg/L, however there has been a consistent decrease in the peak and average concentrations over the past five years. There are occasional excursions of other metals in the drainage water, including copper, lead, cadmium and arsenic. These other metals, and conductivity, do not exhibit a similar decreasing trend in concentrations and have been consistent for the past five years.

Figure 6-17

Ruby Adit (S15)
(LES 19)

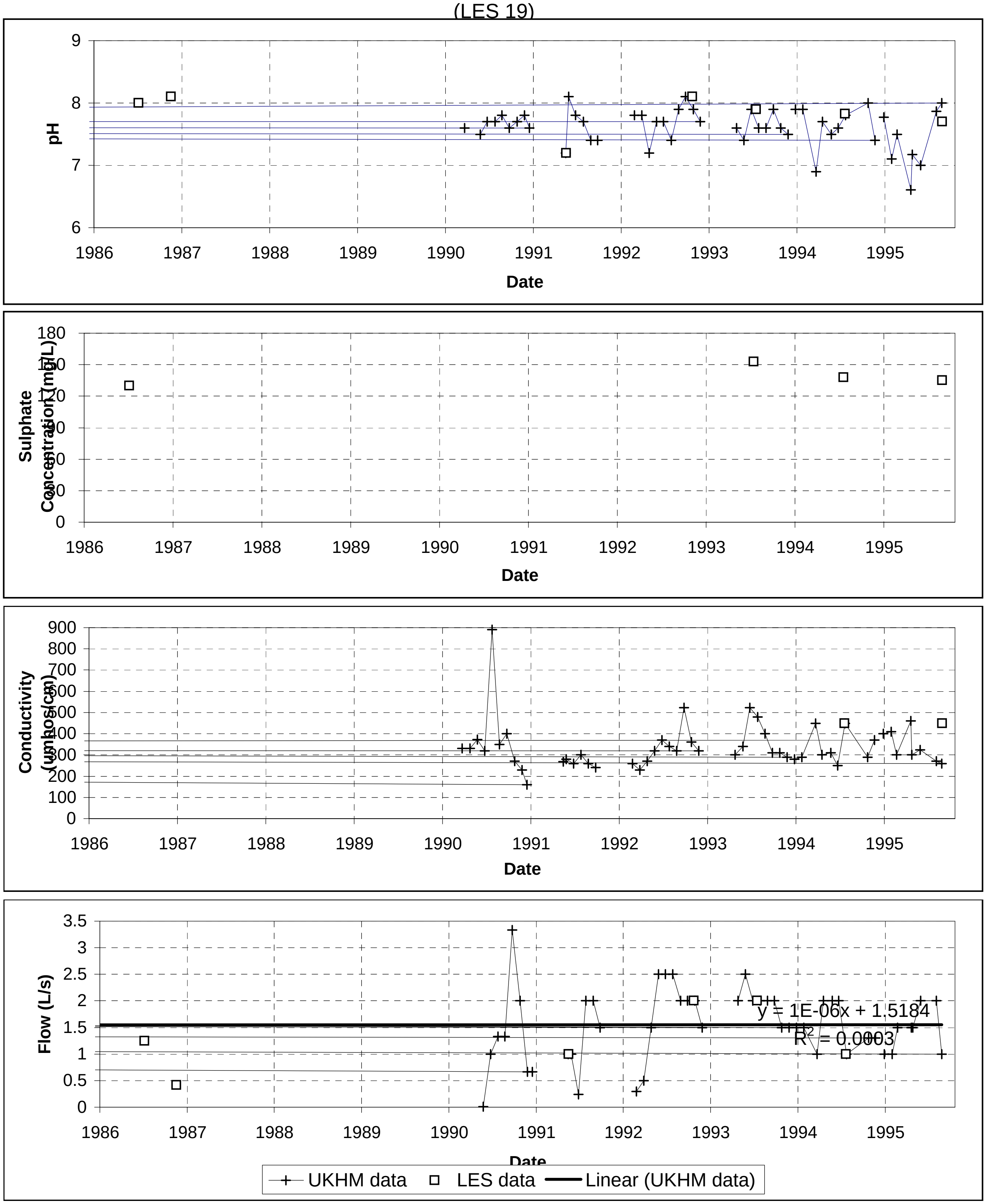
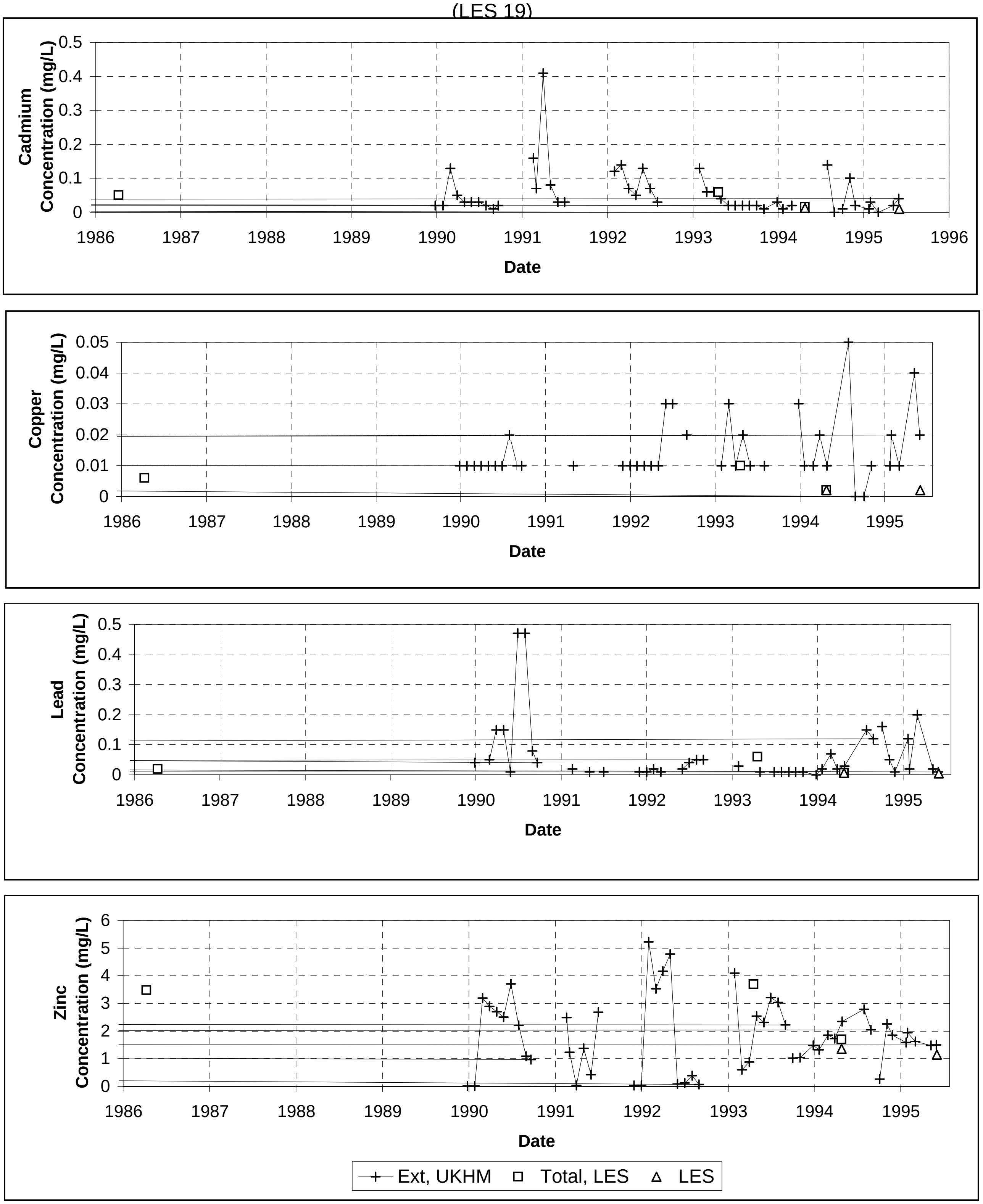


Figure 6-18

Ruby Adit (S15)
(LES 19)



6.2.8 Silver King

Water quality monitoring at Silver King has been primarily for the adit discharge and, since 1994, of the discharge from the adit water treatment settling ponds. Dewatering and treatment began in early December of 1994. The results of the monitoring show reasonable consistency between the government, LES and UKHM sampling, with the exception of conductivity and total/ext. zinc in some recent sampling events. Figures 6-18 and 6-19 summarise the data for key parameters over time. Figure 6-20 shows the relationship of flow to sulphate, conductivity and zinc.

Review of this data to determine trends over time must recognize two key changes that occurred:

- dewatering of Silver King for exploration in December, 1994;
- drilling of RC hole in June 1994, increasing flow of water from Galena Creek.

The trends in water chemistry over time that are indicated by the graphs are:

- slightly lower pH in the 1990's (pH 6 to 7) when the mine was partly flooded than in the 1980's (pH 6 to 8) when the mine was operating and dewatered;
- slight increase in conductivity and possibly sulphate in the 1990's compared to the 1980's in sampling by government although the UKHM data sets are reasonably consistent and comparable. Conductivity and sulphate values have been consistent since 1992;
- there are individual peaks in all data sets for conductivity, copper and sometimes cadmium about once a year during the summer or fall months;
- slight increase (<25%) over the 10 year period in calcium/magnesium in waters, and decrease in alkalinity suggesting that there has been oxidation and acid production, but which has been neutralized by carbonates (Ca, Mg and possibly some siderite as there has also been an increase in Mn);
- higher concentrations of both iron and manganese in the sampling since 1994 compared to the two data points available for 1986/87;
- no measurable acidity and still excess alkalinity in water samples.

Figure 6-18

Silver King Adit (S13)

(LES 13)

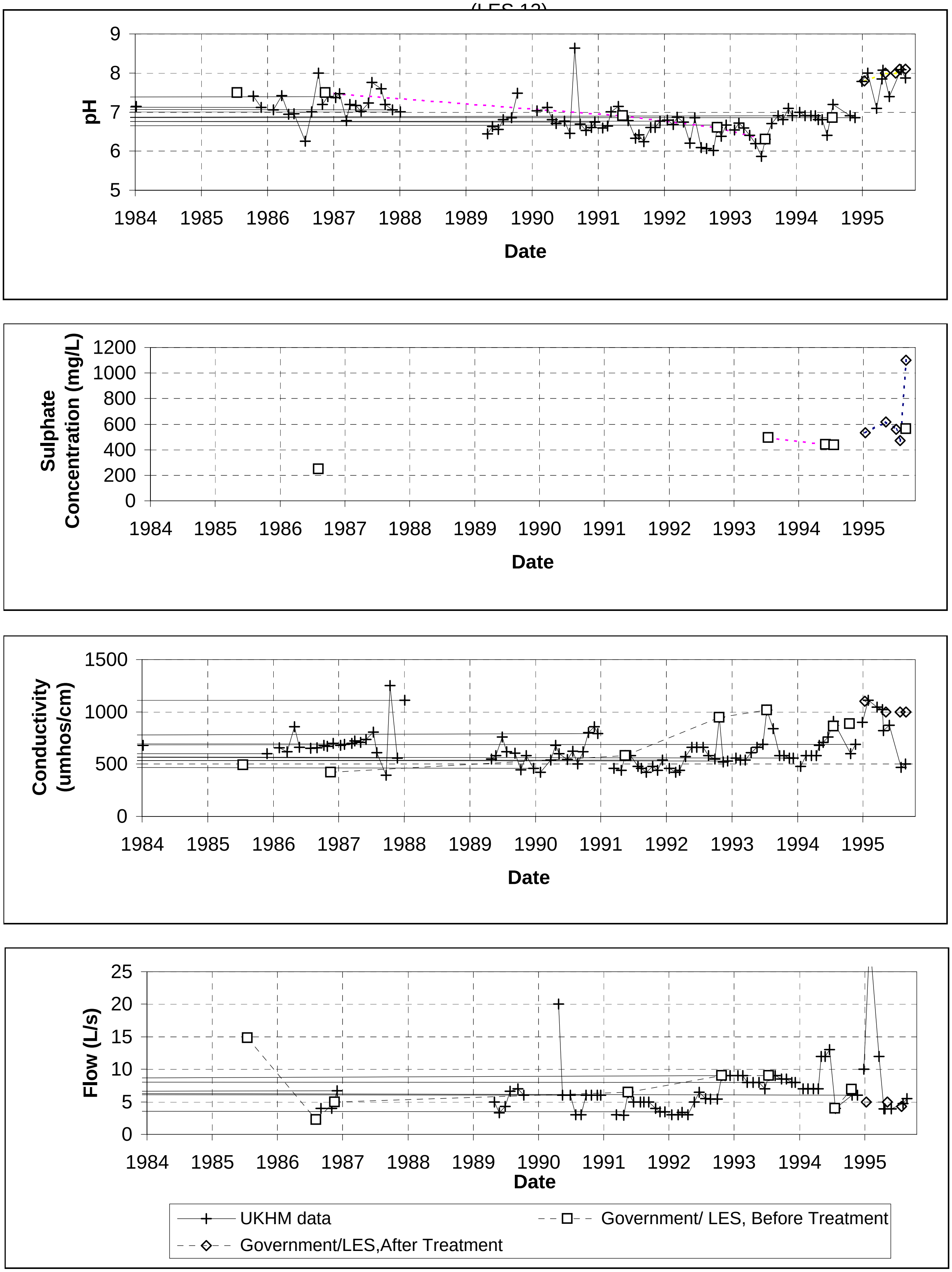
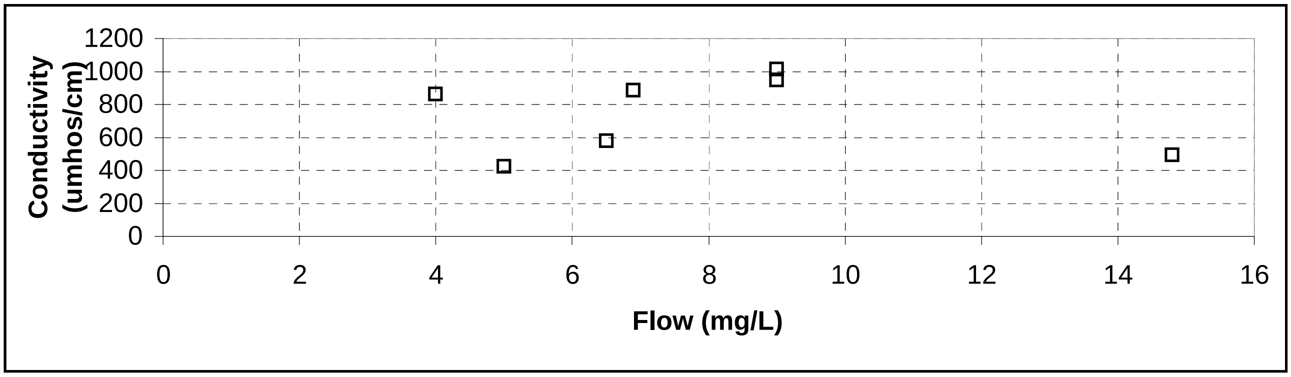
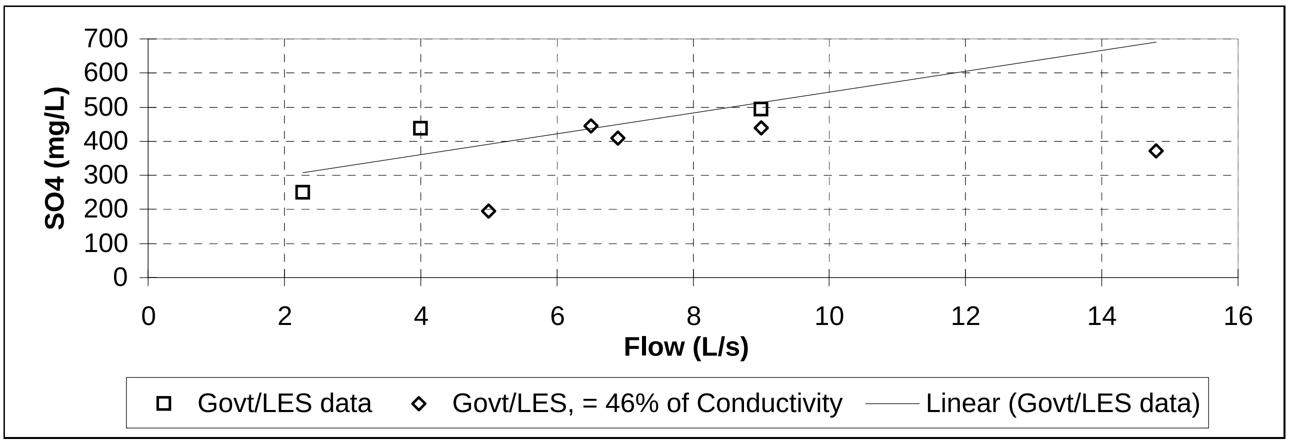
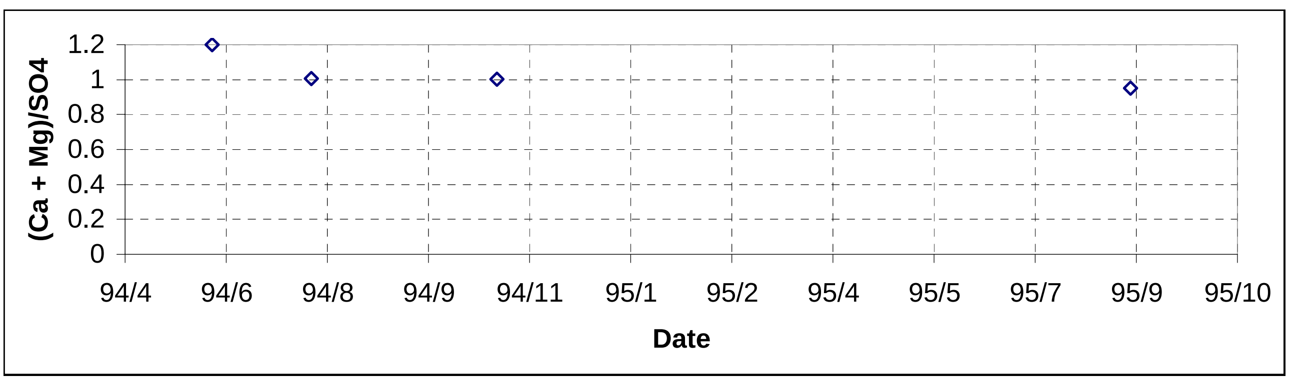


Figure 6-19

Silver King Adit (S13)
(LES 12)







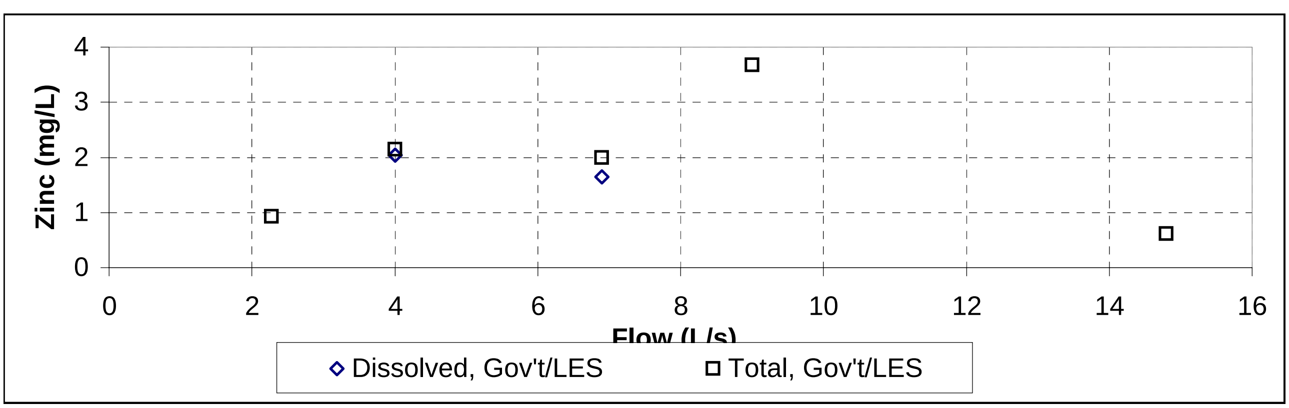
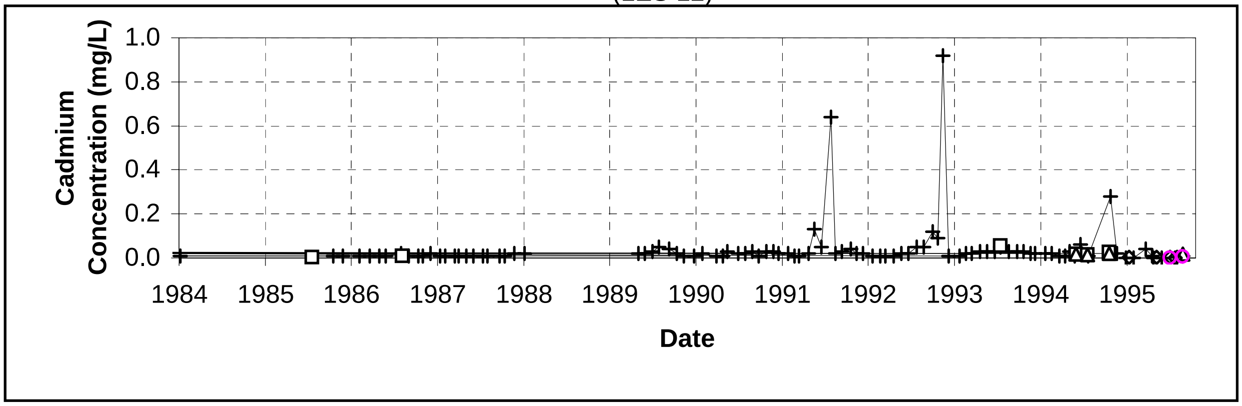
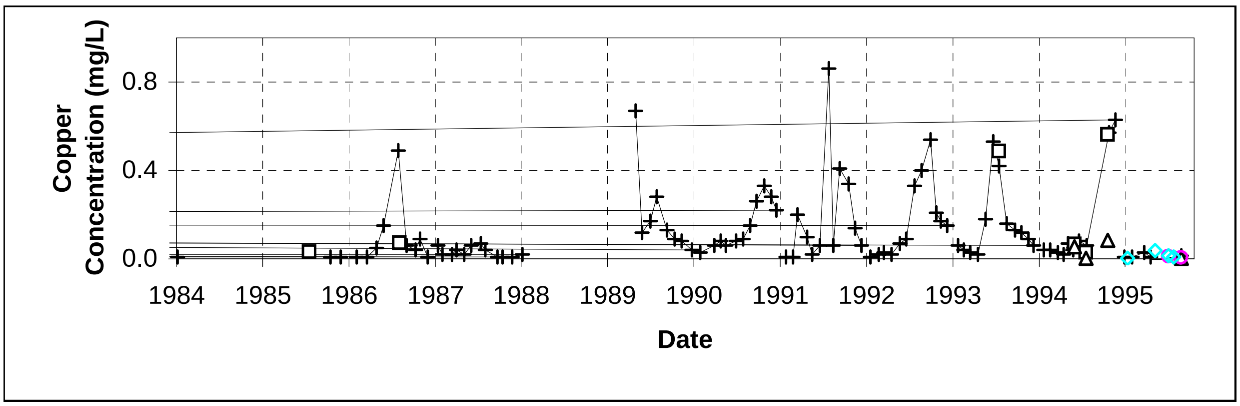
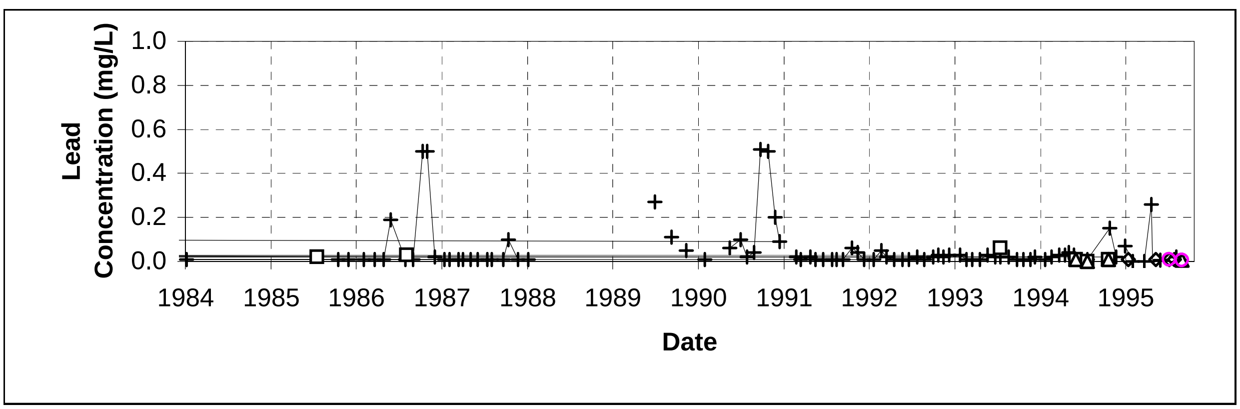


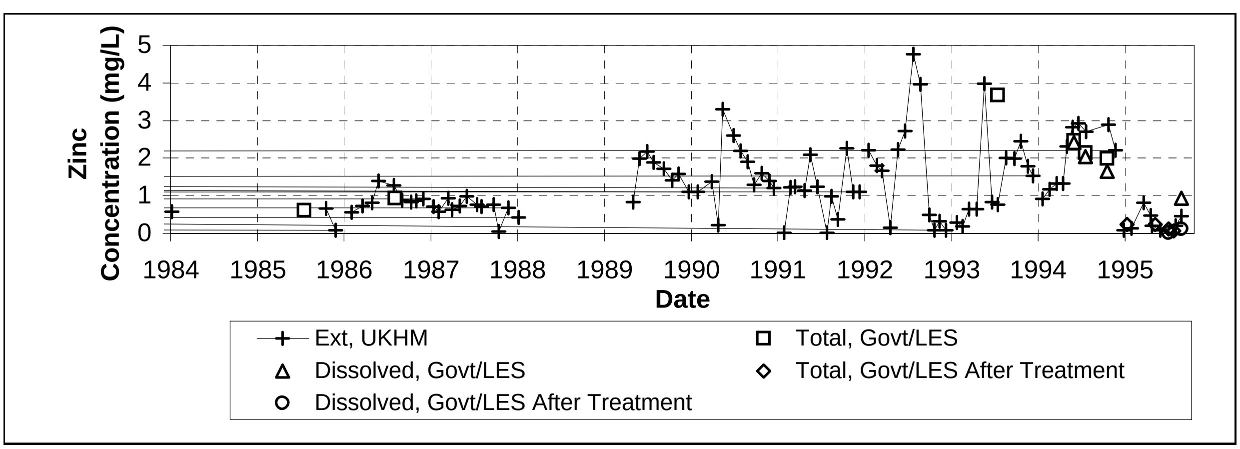
Figure 6-20

Silver King Adit (S13)
(LES 12)









The above points suggest that there may be an increase in oxidation rates in the Silver King underground workings over a 10 year period, but that the rate of oxidation is low. There is no net acid production. This is reasonable to expect from oxidation of zinc sulphides with low pyrite (<5%) contents. Although it is recognized that much of the carbonate mineralization associated with the veins is siderite, there is clearly also calcite available for buffering in the pH range above about pH 5.

The main geochemical issue is the leaching of metals, such as zinc, and periodically copper and cadmium into the adit drainage waters. The only other metal of note in the drainage is arsenic. Arsenopyrite can be associated with the Silver King ore and most of the arsenic is present in the particulate form, i.e. as a "total" metal. Dissolved values are generally less than half the total value, at <0.05 mg/L.

The current water treatment is a simple lime addition and settling circuit. From the available data, it appears to be effectively removing metals, including arsenic, to within discharge limits.

It is interesting to note that Galena Creek upstream of Silver King has shown conductivity values of 450 μmhos/cm and dissolved Ca of 71 mg/L; about half of the adit drainage values. This further supports the assertion that there is not a net acid generation concern at Silver King, in that "background" streams already carry measurable sulphate and calcium concentrations.

6.2.9 UN adit

The UN adit generally drains only seasonally, with low flow rates at <1 L/s. The drainage is alkaline with pH values about 8. Sulphate concentrations have been consistently about 210 mg/L (Figures 6-21 and 6-22). The drainage water chemistry is generally compliant. Comparison of the UKHM and government data sets indicates that the UKHM data tends to show higher values than at external laboratories at these low concentrations.

Figure 6-21

UN Adit (S2)
(LES 30)

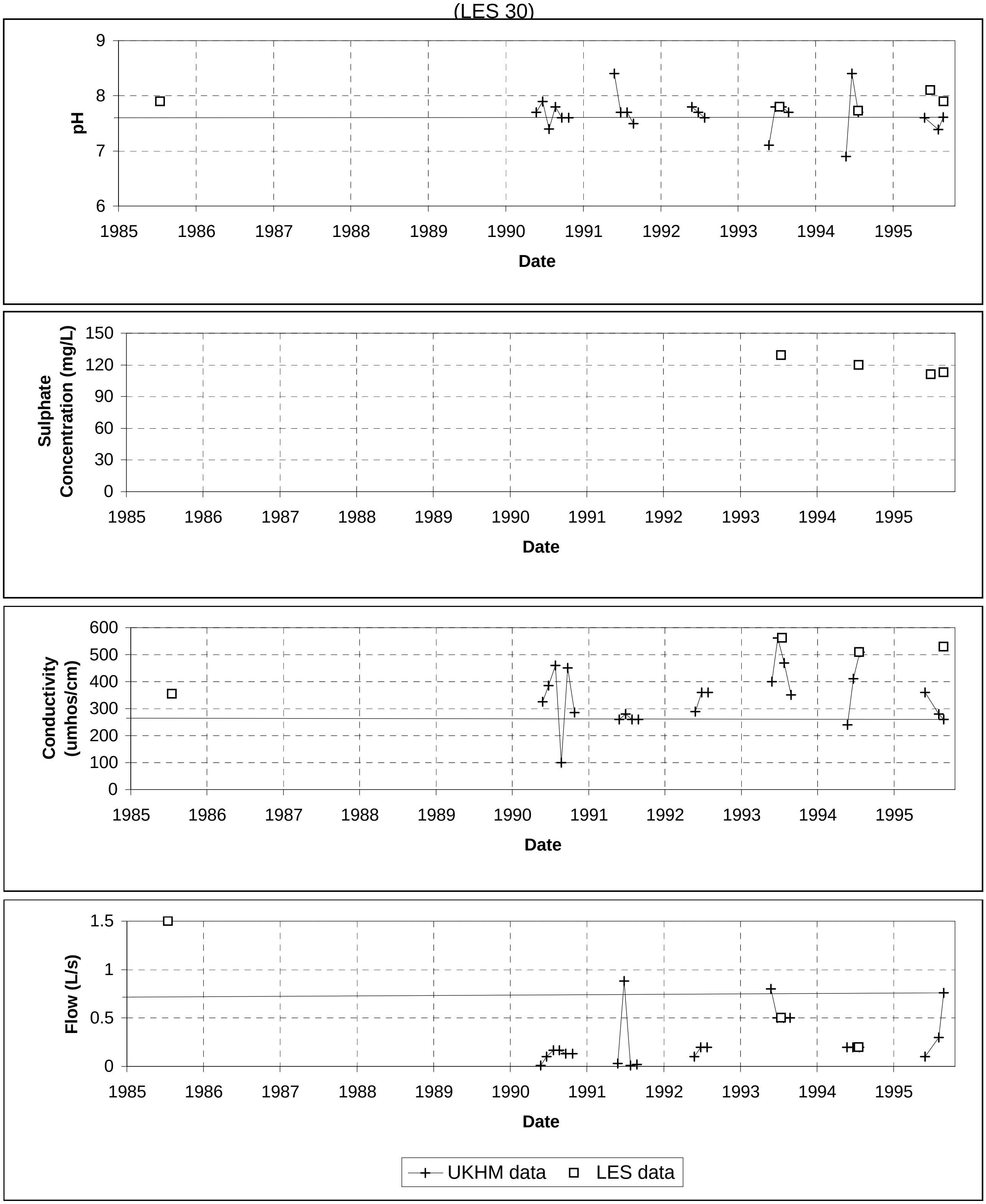
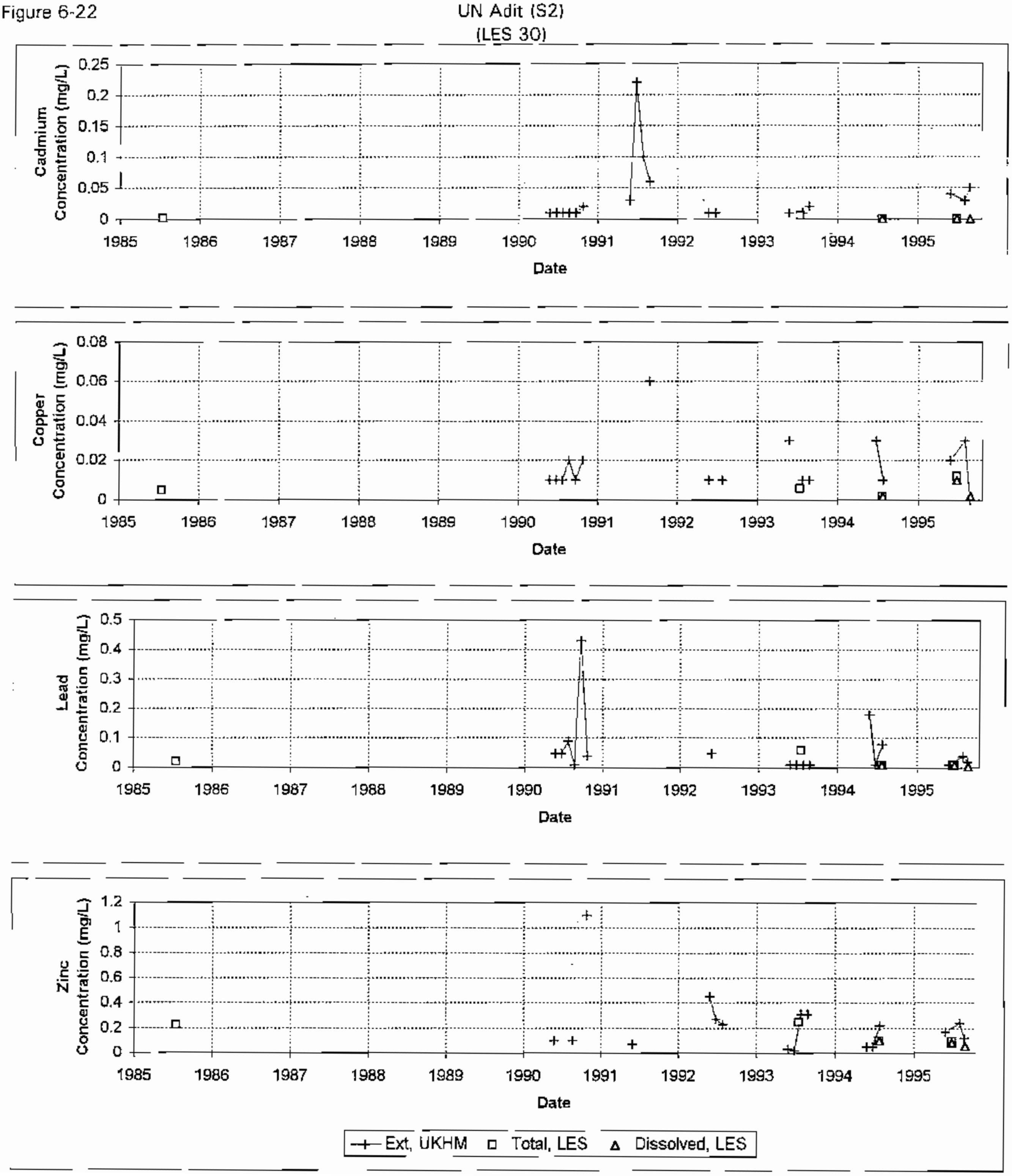


Figure 6-22



UN Adit (S2)
(LES 30)
Cadmium Concentration (mg/L)
0.25
0.2
0.15
0.1
0.05
0
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
Date
Copper Concentration (mg/L)
0.08
0.06
0.04
0.02
0
Lead Concentration (mg/L)
0.5
0.4
0.3
0.2
0.1
Zinc Concentration (mg/L)
1.2
1
0.8
0.6
0.4
0.2
Ext, UKHM
Total, LES
Dissolved, LES

6.2.10 Keno 700 adit

The Keno 700 adit drains a large expanse of underground workings, and workings that are up to 70 years old. In general, the drainage water chemistry shows more variability over the year than do most stations. This is probably due to freezing and thawing, as the adit is frozen for about 6 months of the year. Ice tends to form from "pure" water, concentrating dissolved contaminants into the surrounding drainage water. Thus as the adit ices, it could be expected that metal levels would increase. Conversely, thawing water would tend to have lower dissolved metal levels, although there would be particulates entrained in the ice.

The drainage pH values are alkaline, and tend to increase from 7 to 8 over the summer months as shown in Figure 6-23.

Sulphate concentrations and conductivity values are about half the values typically seen at Galena Hill. The values have increased slightly over time, from conductivity values of 400 μmhos/cm in 1986 to about 550 in 1995 (govt. data). Again, there are some discrepancies between the UKHM and external data for conductivity (Figure 6-24).

Zinc, and to a lesser extent cadmium and arsenic, are the metals of note at Keno 700. Total zinc values were consistently just less than 1 mg/L in the LES sampling, although UKHM values can be up to 1.5 mg/L. The LES values though are consistent with measurements in Hope Gulch, downstream of the Keno 700 discharge. Arsenic and cadmium tend to be close to the licence limits of 0.05 mg/L for each. Dissolved and total concentrations are similar for each.

Thus, metal leaching rather than acid mine drainage is the primary geochemical issue at Keno 700.

Figure 6-23

Keno 700 Adit (S6)
(LES 38)

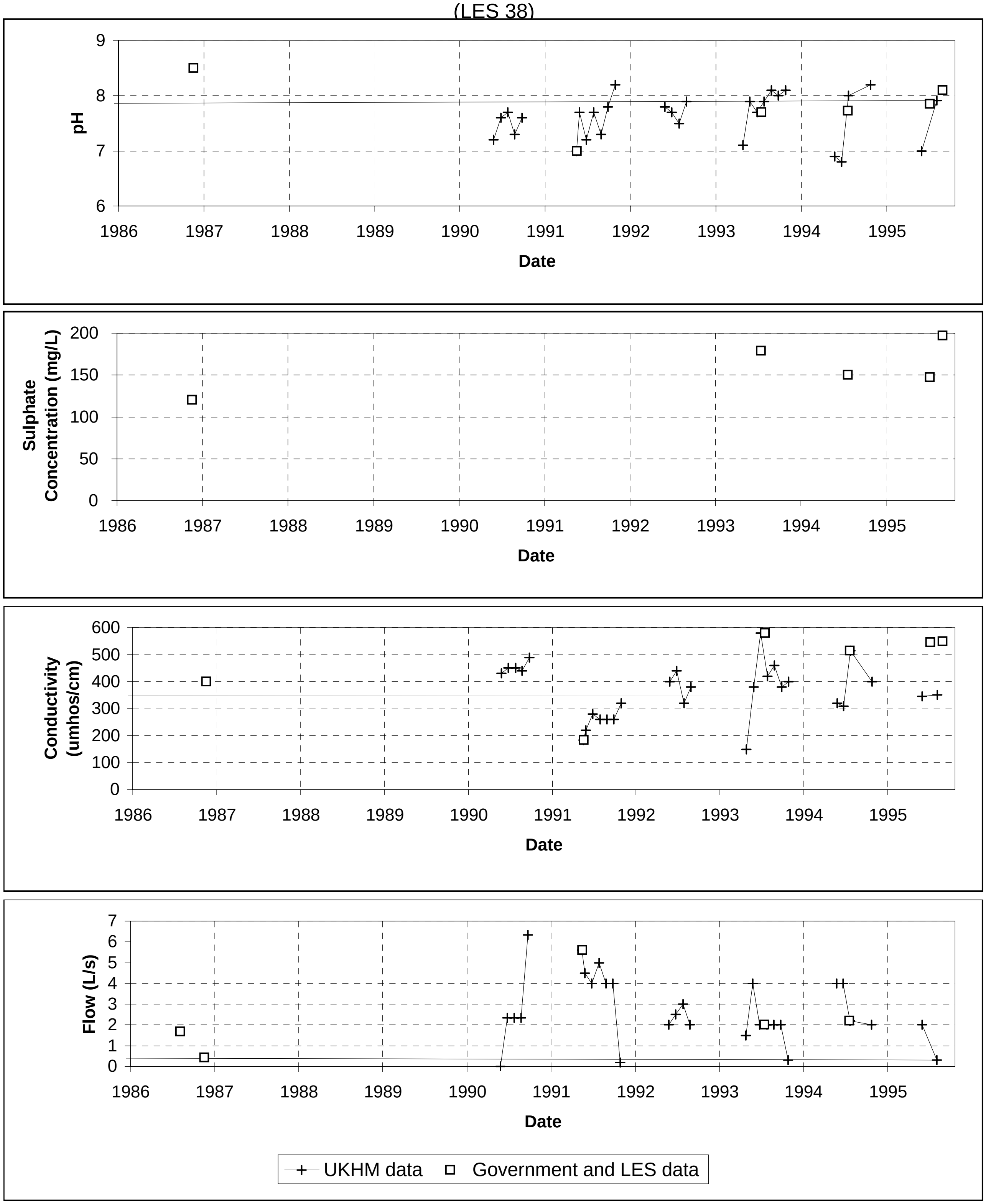
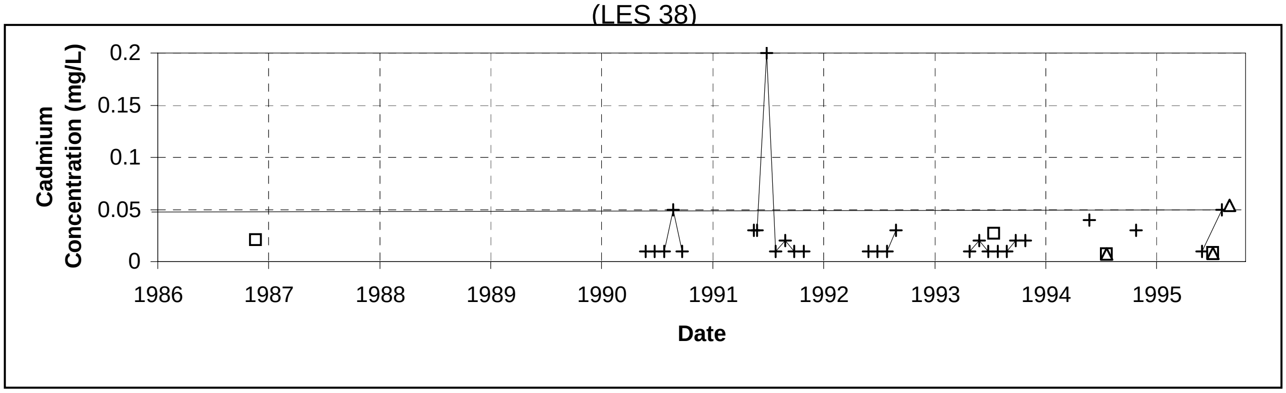
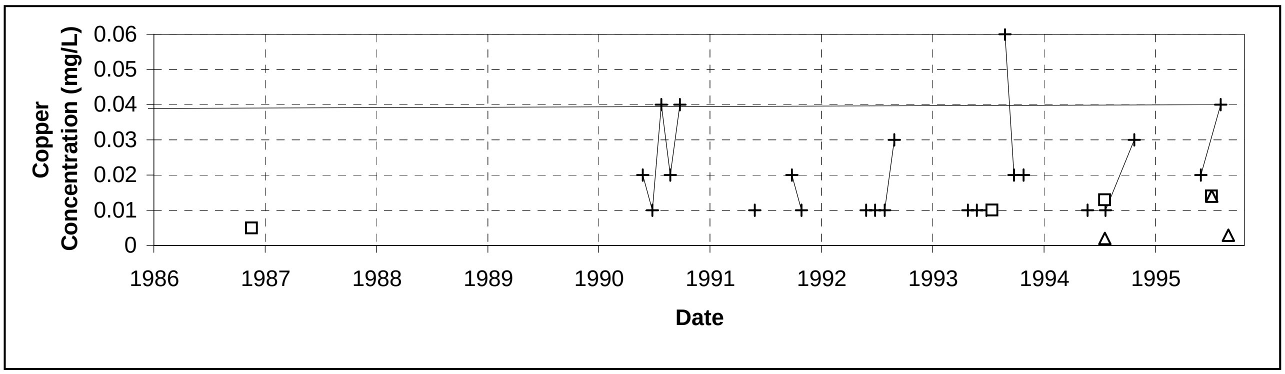
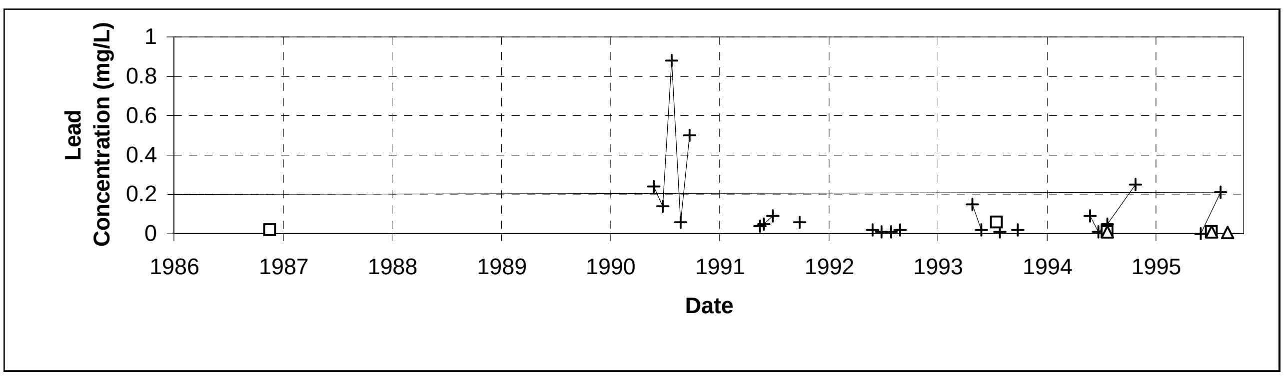


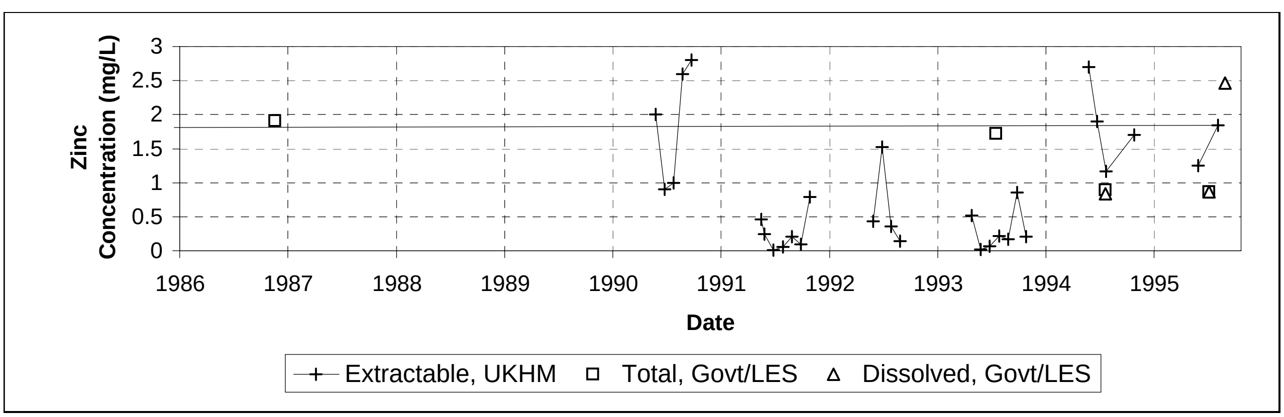
Figure 6-24

Keno 700 Adit (S6)
(LES 38)









Sampling has also been done in Hope Gulch, the drainage to which the Keno 700 discharge reports. The adit drainage discharges via a culvert in the adit waste rock dump at this level, and drainage from both the adit and the dump reports to Hope Gulch. Although the data set is limited periodic sampling for two years, it appears from a load balance that there is very little, if any, additional contaminant loading from the waste dumps. An example of one sampling event is shown in the table below for July 28, 1994.

Table 6-5: Keno 700 Water Chemistry

Station	Flow (m^3/s)	SO_4	Zn_t	Zn_d	As_t	Ca_t
Keno 700 discharge	.0022	150	0.89	0.83	0.05	110
Hope Gulch	.0062	87	0.23	0.23	<0.02	44.5

6.2.11 Lucky Queen

The Lucky Queen adit is frozen for most of the year with drainage for, at most, two months in the spring/summer period. The flows are low, at less than 0.5 L/s in recent years. The drainage waters are generally compliant, with low metals concentrations. Figures 6-25 and 6-26 summarize these data.

6.2.12 Onek Adit

Drainage from the Onek adit is the most significant potential water quality concern on Keno Hill. The adit drains only seasonally, with ice forming during winter months, and relatively low flows during summer (<1 L/s) as shown in Figure 6-27. However, the concentrations of both zinc and cadmium are high during these flow periods, with peak values in the UKHM database of up to 200 mg/L Zn and 7 mg/L Cd.

The primary mechanism for metal release appears to be metal leaching from the vein material as a result of oxidation. There is no net acid generation, and no indication that net acidic conditions would be expected in future given the following observations from the data. The drainage water is alkaline, with pH values greater than 7 (Figure 6-28).

Figure 6-25 Lucky Queen Adit (S14)

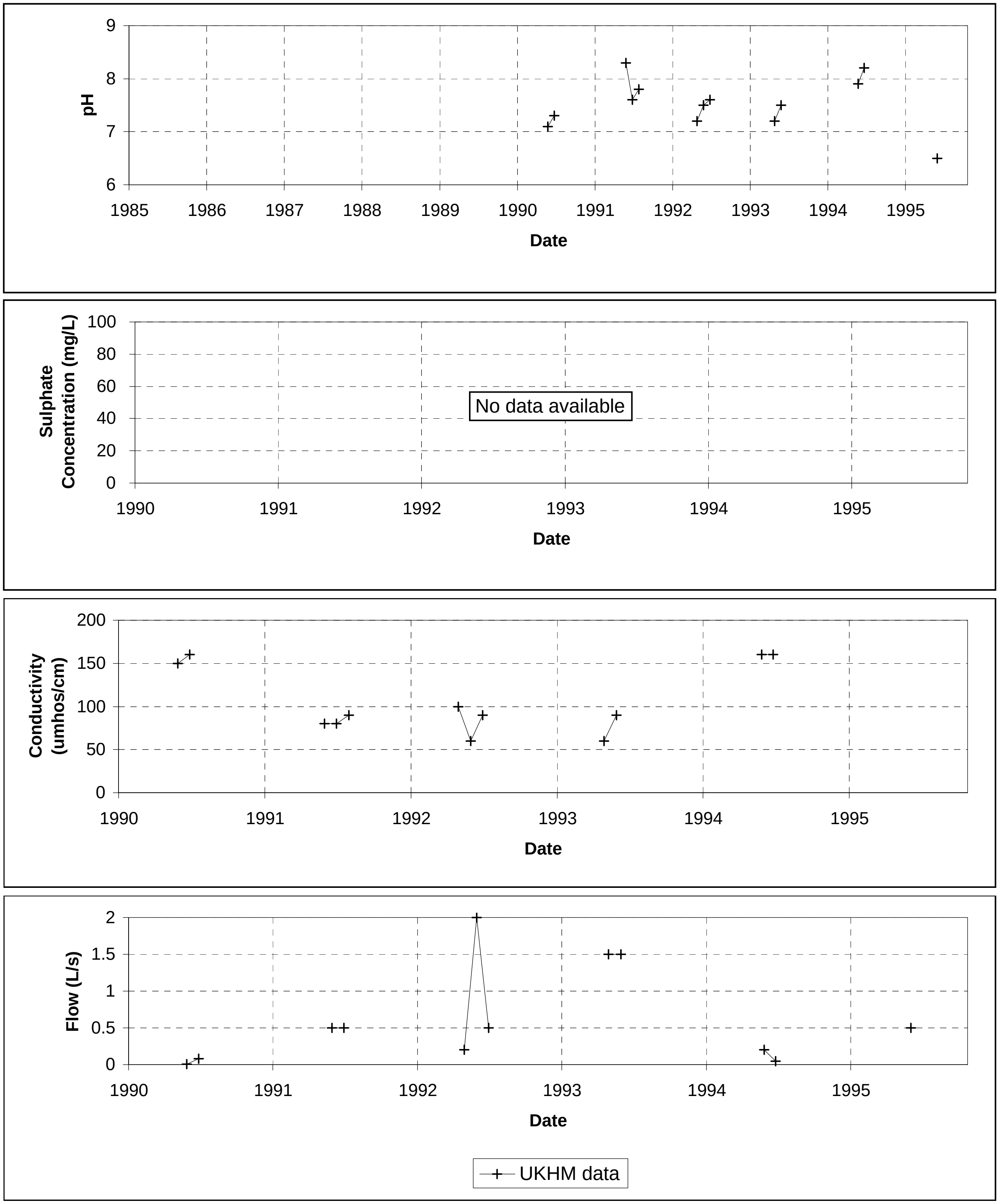


Figure 6-26 Lucky Queen Adit (S14)

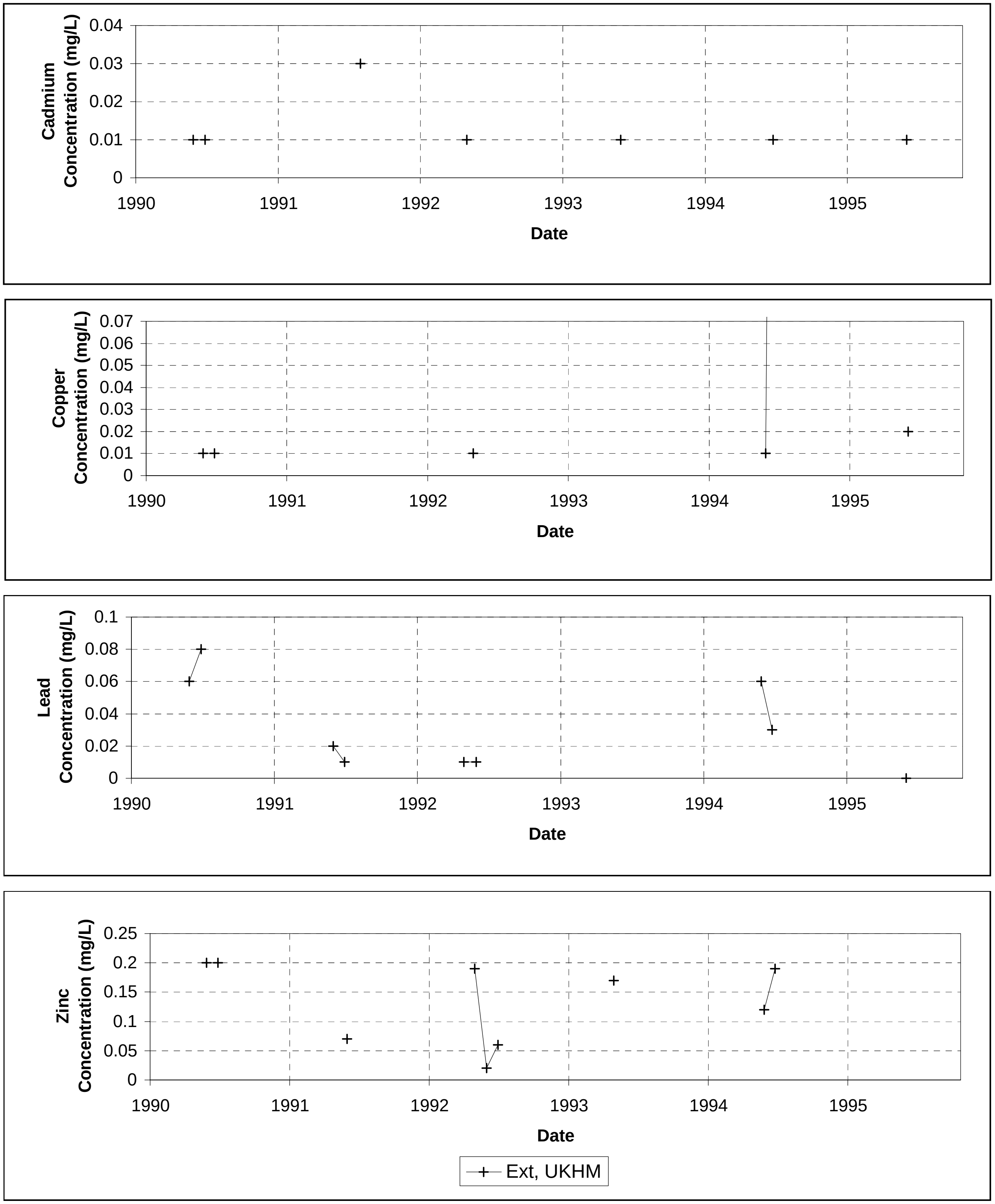


Figure 6-27

Onek Adit (S8)
(LES 40)

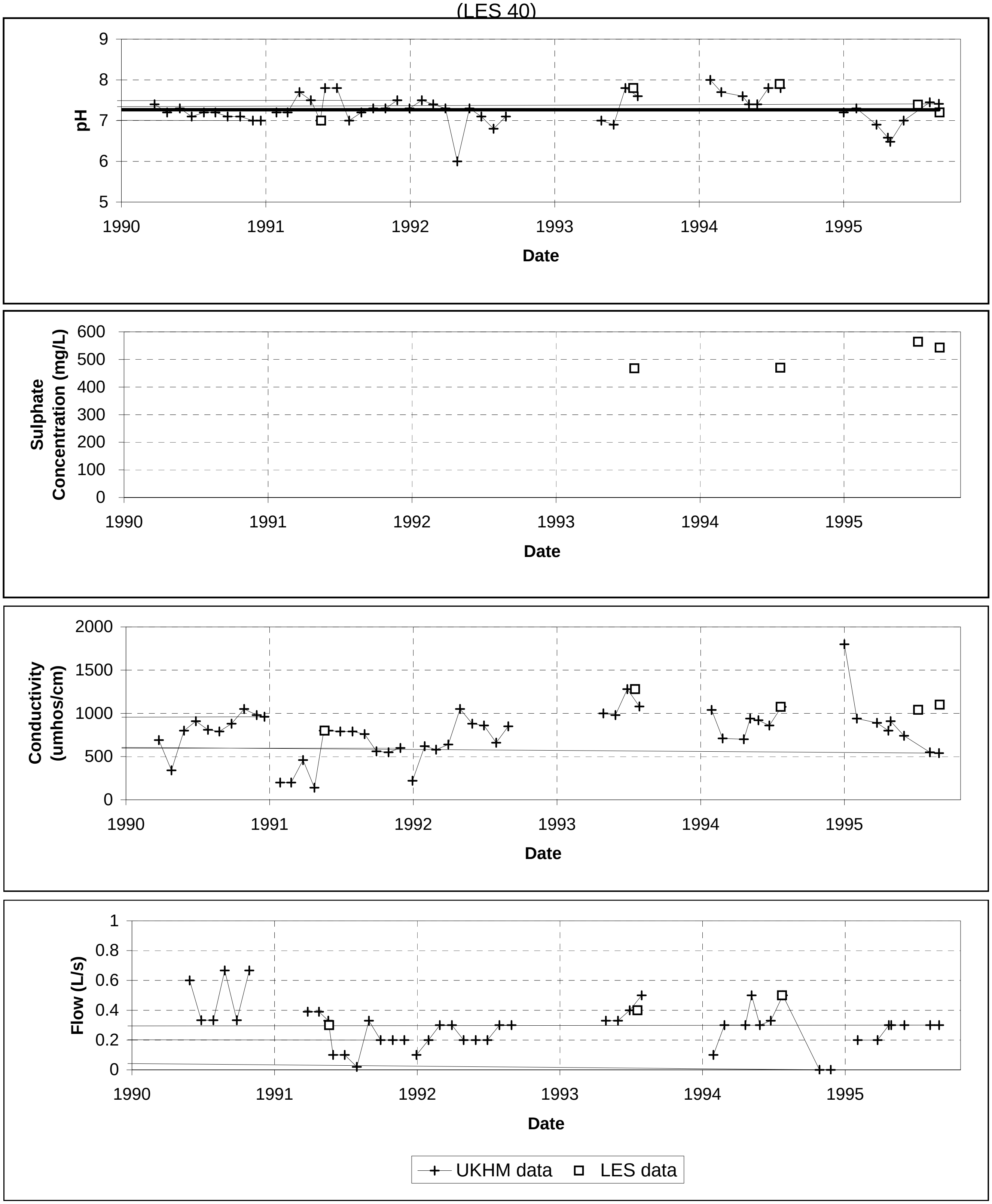
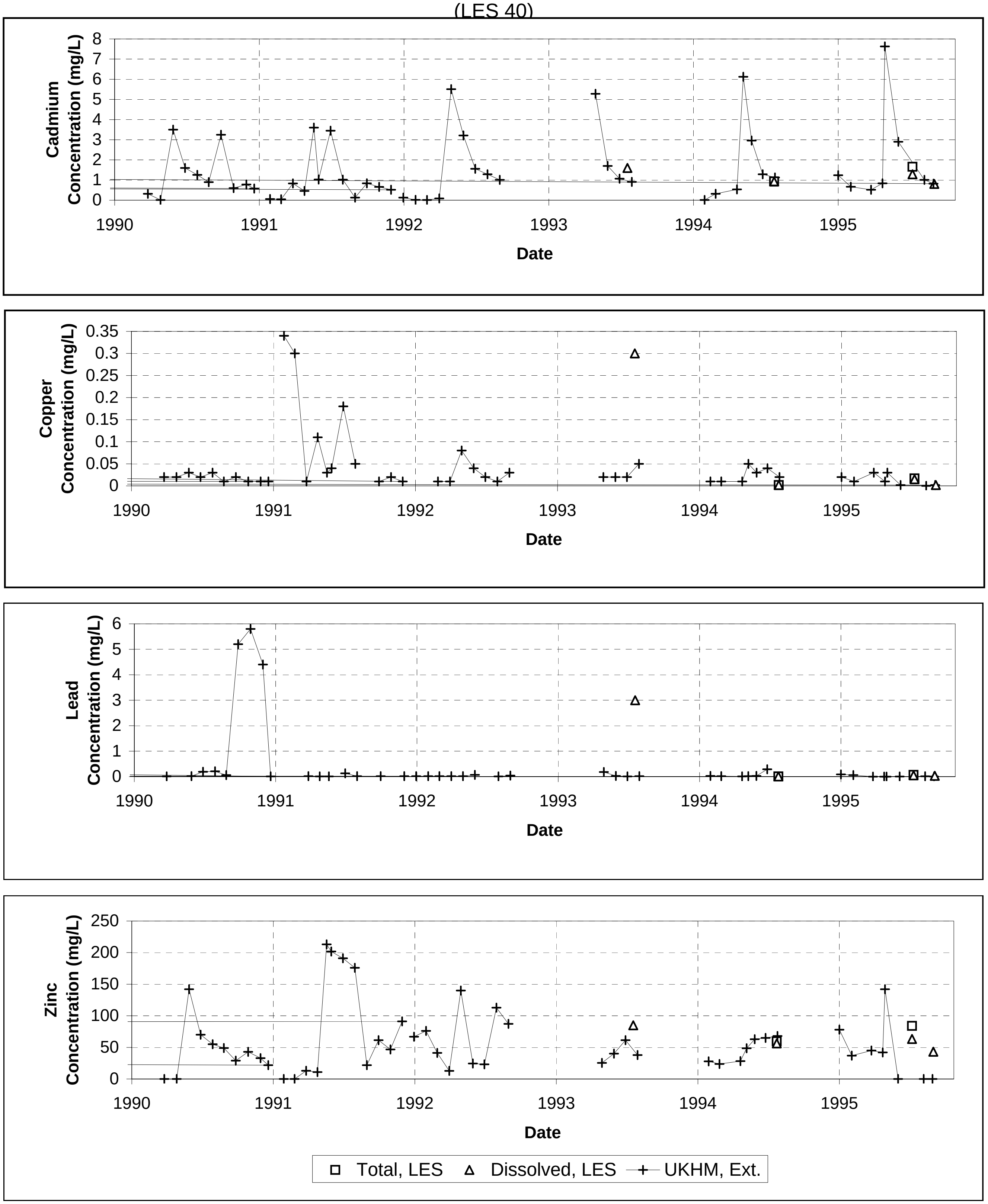


Figure 6-28

Onek Adit (S8)
(LES 40)



Calcium and magnesium concentrations are consistent with other adits with lower metal concentrations, suggesting that there is a comparatively low acidity production. Iron concentrations are low, with the highest total concentrations being 1 mg/L. There is iron staining along the drainage channel from the adit though, suggesting that there has been iron discharge from the workings in the past, although this may have resulted from ice plugging followed by rapid flows carrying particulate iron. Sulphate concentrations and conductivity values have not changed appreciably over the monitoring period.

The flowpath of the drainage from the Onek adit and the ultimate receiving water has not been established to date. It appears that the drainage flows towards Christal Lake, but may daylight downstream of the lake. Surface water sampling stations were established in 1994/95 along three channels that were considered possible conduits for the Onek drainage. The results of the sampling are shown in Appendix VII, and summarized in Table 6-6 below for July 11 and 12, 1995.

Table 6-6 Onek Drainage Sampling, July 1995

Station	Flow m^3/s	pH	SO_4 mg/L	Cd_d mg/L	Cd_t mg/L	Zn_d mg/L	Zn_t mg/L
Onek adit	<0.0005*	7.9	470	1.29	1.66	63.3	84.1
Site 53	0.003	7.6	276	0.0006	0.0007	0.06	0.062
Site 61	------	7.6	175	<0.0005	<0.0005	0.01	0.012
Site 62	------	7.6	110	<0.0005	<0.0005	0.007	0.008

* estimated as too low to measure

No other drainage was visible downstream of the adit during these sampling events. In the fall of 1995, piezometers were installed in test pits in an attempt to monitor shallow groundwater and identify the Onek adit drainage water flowpath. The results above would suggest that either:

- none of these three streams downslope from the adit are carrying Onek drainage, in which case the drainage must report to groundwater; or,
- there is some mitigation of the water chemistry along the flowpath, removing metals and to a lesser degree sulphate.

Soil samples were also collected from the test pits for metals analysis and pore water or extraction testing.

Sampling within Christal Lake, and calculation of metal loadings does not indicate any load is reaching the lake from Onek adit, although it is recognized that the flow is very low compared to the volume of the lake.

6.2.13 Sadie Ladue Adit

The water chemistry of the drainage from the Sadie Ladue adit is summarised in Figures 6-29 and 6-30. Peaks in metal concentrations and, to a lesser degree in flows, are evident in the spring sampling. The UKHM data set seems to suggest that metal concentrations (zinc) in the drainage have increased in recent years, however this is not supported by sampling data for external laboratories. As seen in other data sets, at concentrations approaching detection limits the UKHM data tends to overestimate metal concentrations.

While flows can be significant from the adit at up to 15 L/S for most of the year, metal concentrations are low. Zinc generally does not exceed 0.5 mg/L, arsenic is <0.02 mg/L and cadmium is less than 0.003 mg/L.

Figure 6-29

Sadie Ladue Adit (S7)
(LES 35)

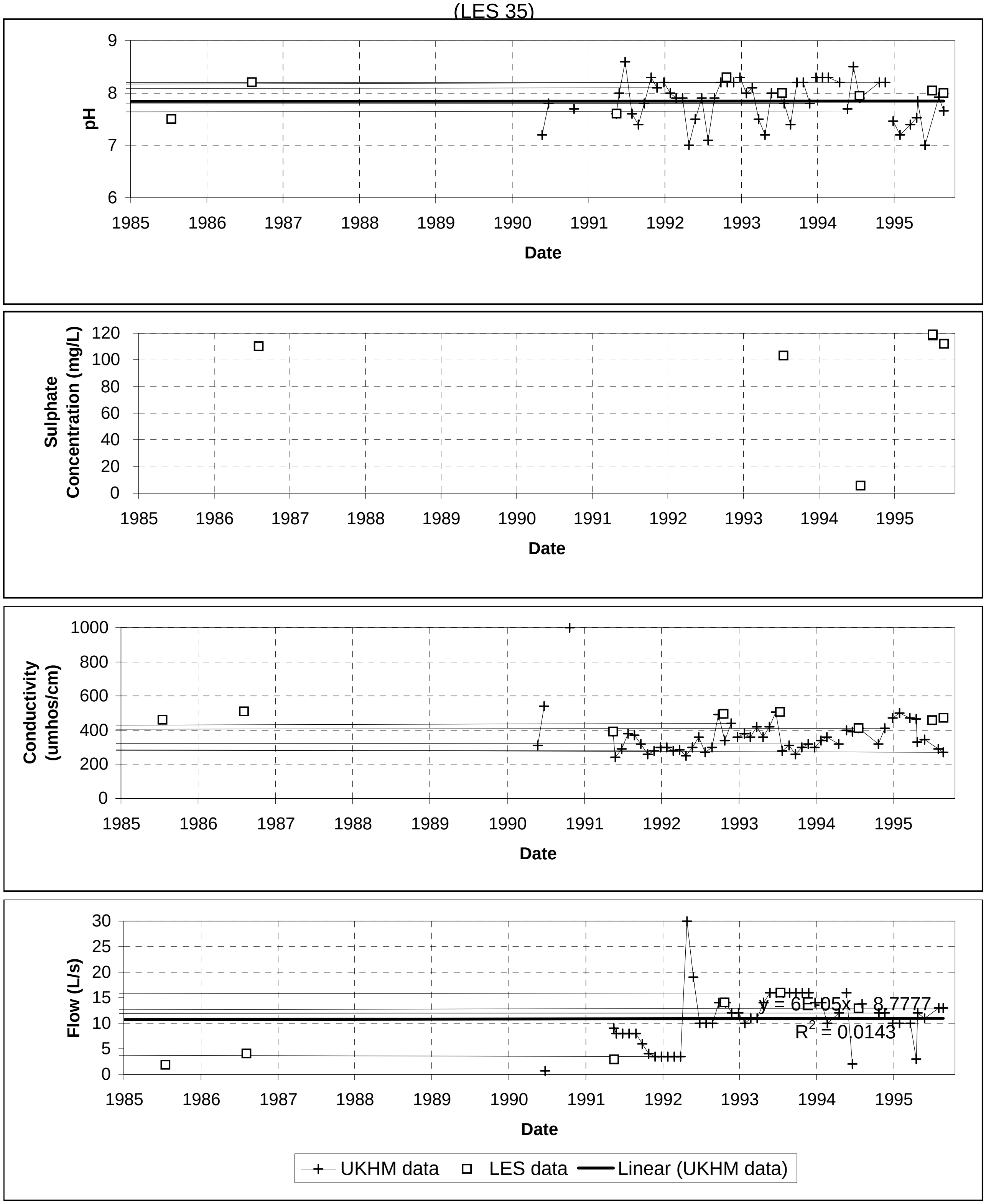
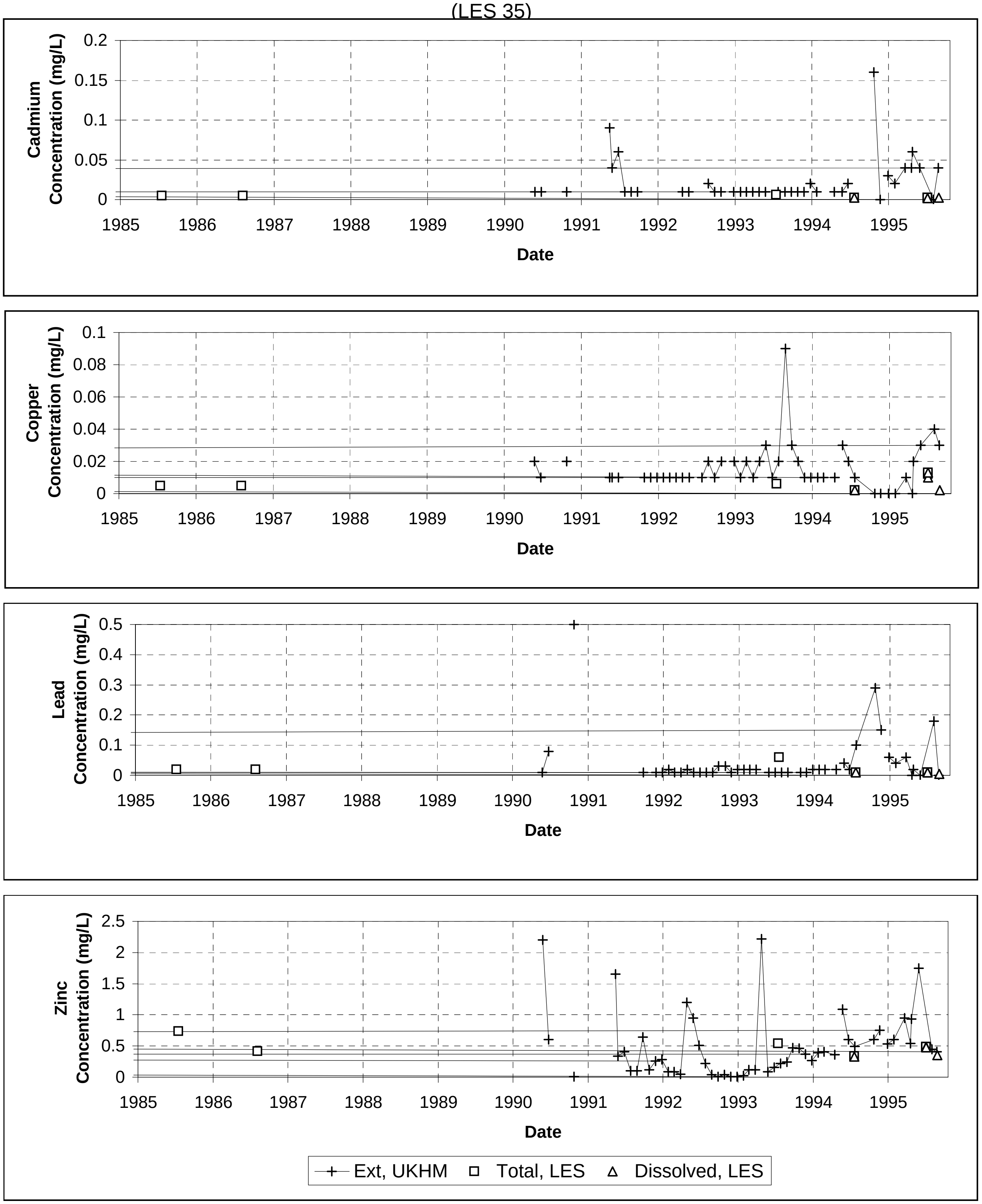


Figure 6-30

Sadie Ladue Adit (S7)
(LES 35)



6.2.14 Bellekeno

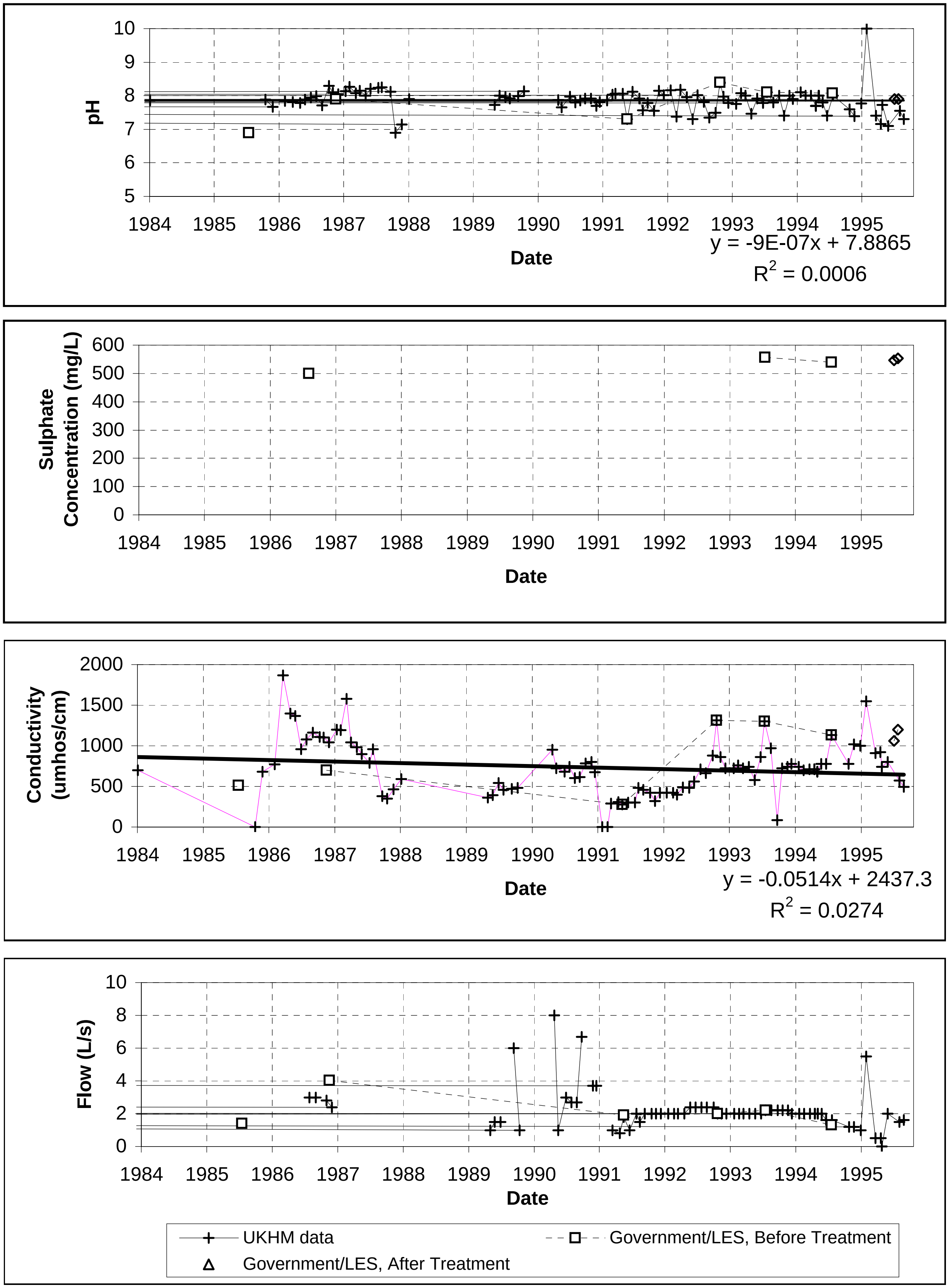
This station is sometimes referred to as the "600" adit but is more correctly the 625 level.

Since exploration began again in 1994, the flooded underground workings have been dewatered and pumping continues. The water quality data summarized in Figures 6-31 and 6-32 show:

- consistently alkaline pH values, between 7 and 8;
- variable conductivity values in the range of 700 μmhos/cm, but no clear and consistent change over time in conductivity, sulphate or TDS;
- no clear seasonal variations in either drainage chemistry or flow, indicating that there is little surface recharge to the workings;
- the UKHM and government data sets are reasonably consistent in the 1990's, with the exception of conductivity measurements;
- iron concentrations are very low, consistent with the alkaline pH and lack of sulphide oxidation;
- data from the company indicate that there have been cadmium values above detection, however analyses at independent laboratories consistently show total cadmium at <0.05 mg/L;
- zinc is the only metal to show an apparent increase in the last three years however the values in 1993/94 are comparable to those in the mid 1980's;
- high Pb and Zn during production in 1985 to 1988 (no settling pond).

Thus Bellekeno underground workings, and therefore the associated waste rock, are not of concern with respect to ARD. The chemistry of the drainage water appears to be reasonably constant with time, and there are no parameters which indicate that there is an ARD "problem" developing. Leaching of zinc, probably from oxidation of zinc sulphides, is the only real concern from this adit. It appears from the data that zinc concentrations in the range of 2 mg/L can be anticipated although monitoring must continue to be evaluated, to determine if there is an increasing trend (beyond the 1980's level).

Bellekeno 600 Adit (S 12)
(LES 39)



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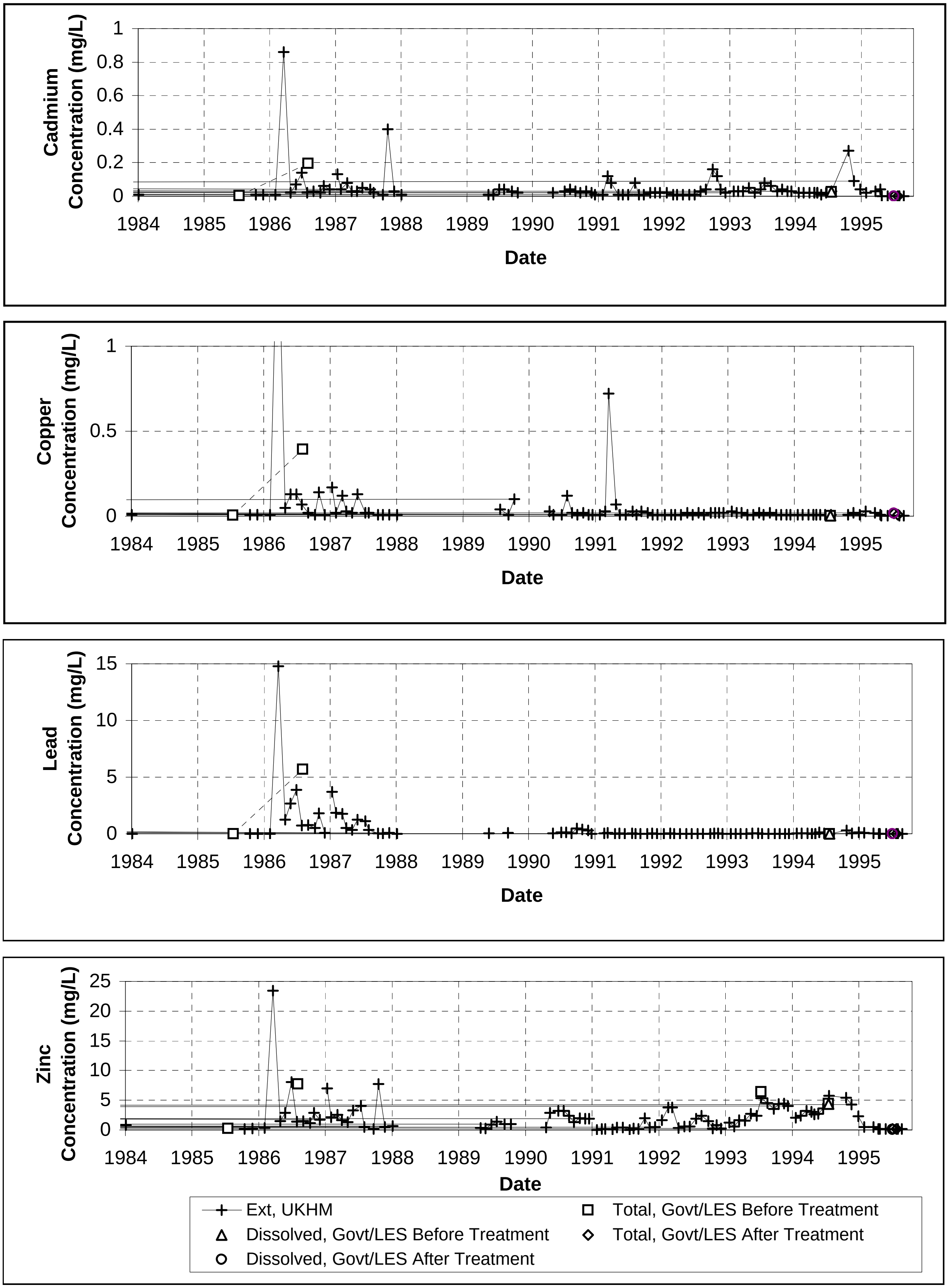
Bellekeno 600 Adit (S 12)
(LES 39)



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6.2.15 Receiving Waters

Sampling stations are located along each of the creeks and rivers in the study area. The locations of stations were selected to address three main issues:

- identification of the sources and sinks for contaminants along the natural water courses;
- identification of “background” water chemistry i.e. in areas unaffected by mining; and,
- effect of the different mine discharge areas on the quality of water and therefore aquatic life in the receiving environment.

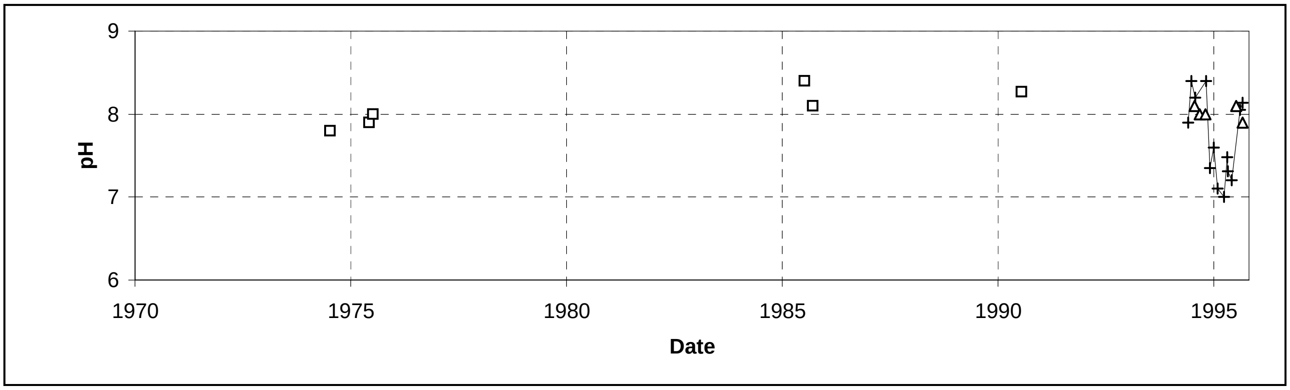
As seen in Figure 6-1, there are a large number of stations along Christal Creek, Flat Creek, Galena Creek. These data are presented in the Appendices, and used for the load balance model. Following this section, there is a series of graphs which illustrate the changes over time and in some cases changes with flow, for these stations. A few of the key stations are discussed below to highlight current water chemistry. The detailed discussions are presented with the site contaminant loading balances and the impact assessment in Chapter 8.

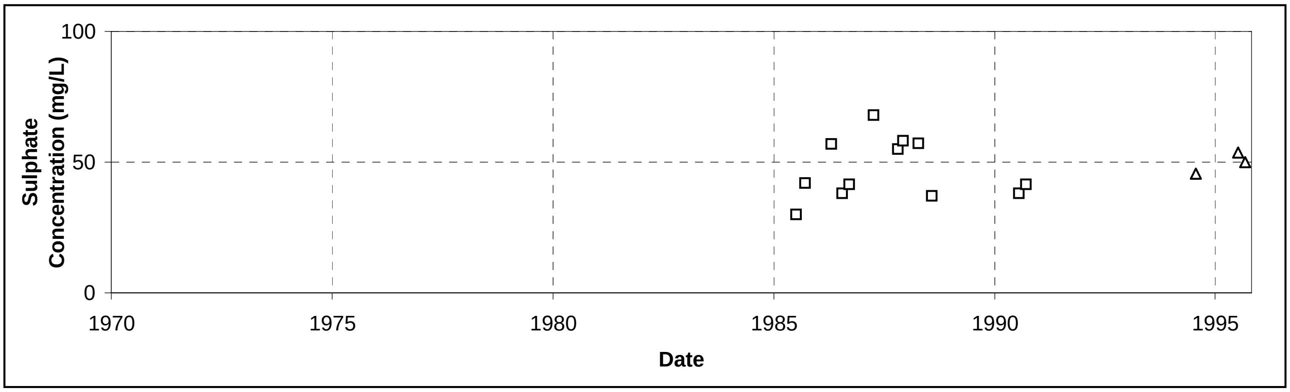
As a general observation, the UKHM data for receiving waters tend to show concentrations of metals higher than do the external data sources when values approach detection. All data sets are shown on the figures and used to discuss trends in water chemistry, however, the discussion of specific concentrations is generally based on sampling by external laboratories.

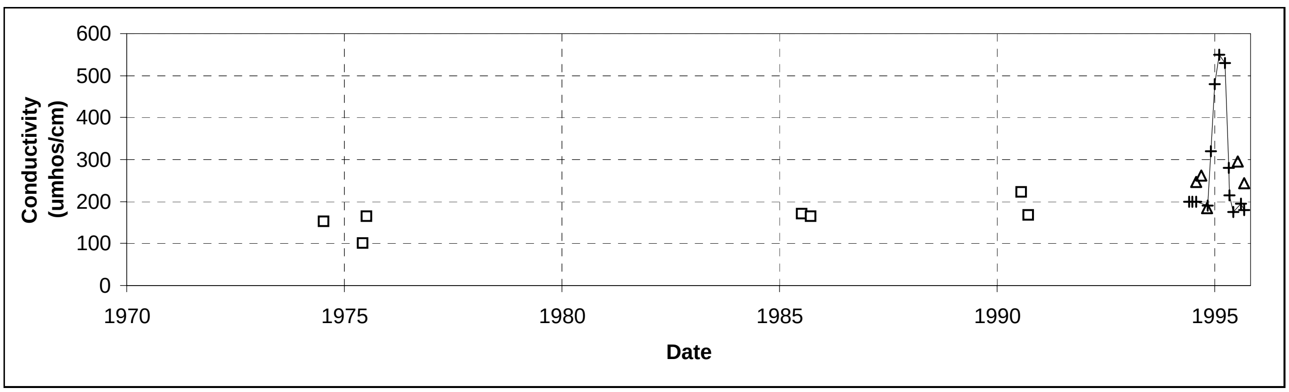
6.2.15.1 South McQuesten River upstream from Christal Creek (LES 1)

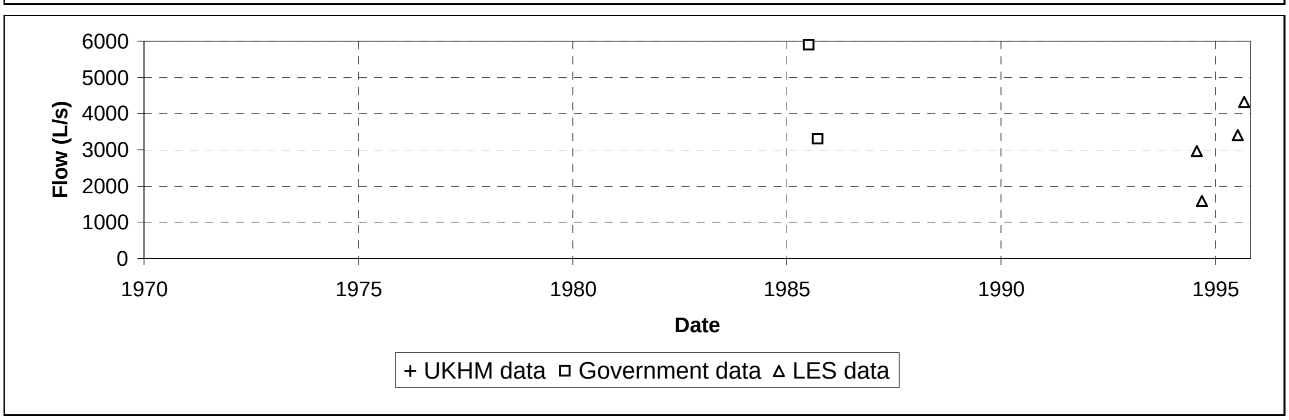
As seen on the map, this station most closely represents the upstream or background station on the River for the Elsa area. The results are summarized in Figures 6-33 and 6-34.

S. McQuesten River
Upstream from Christal Creek
(LES 1)

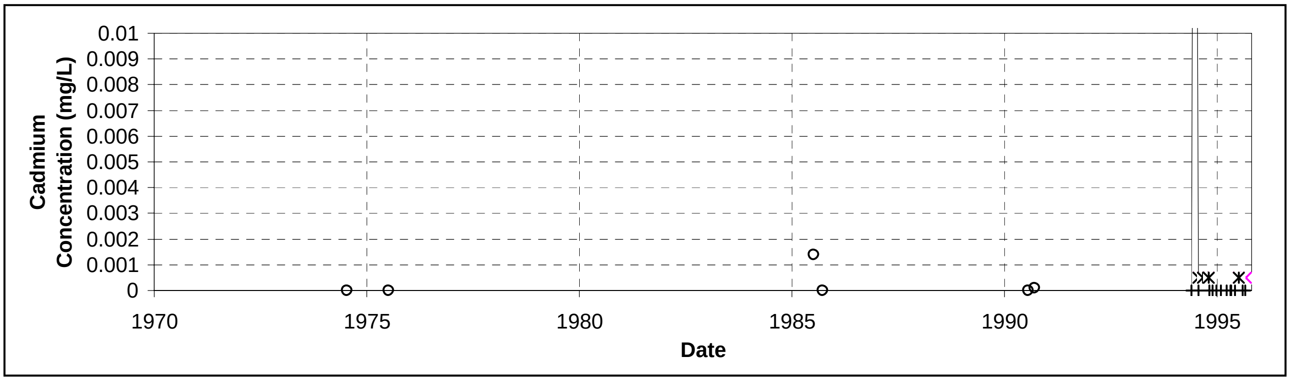


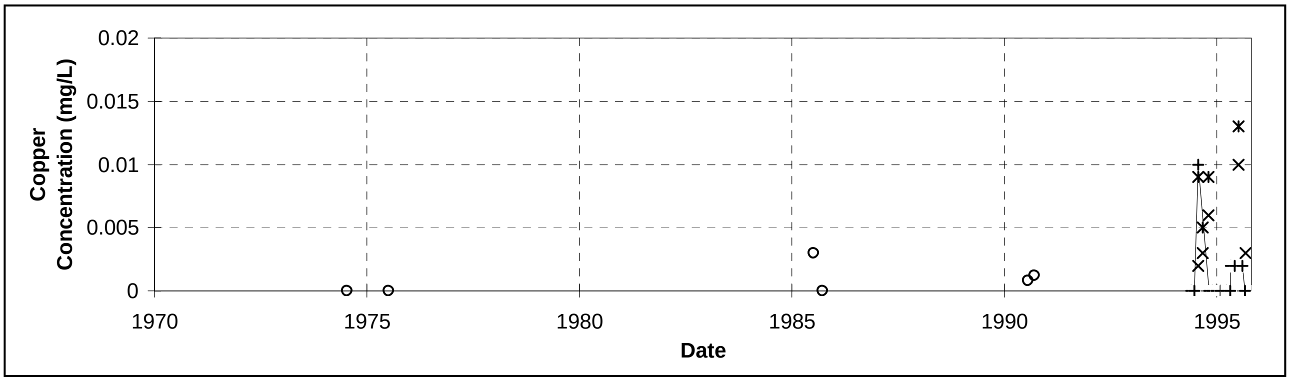


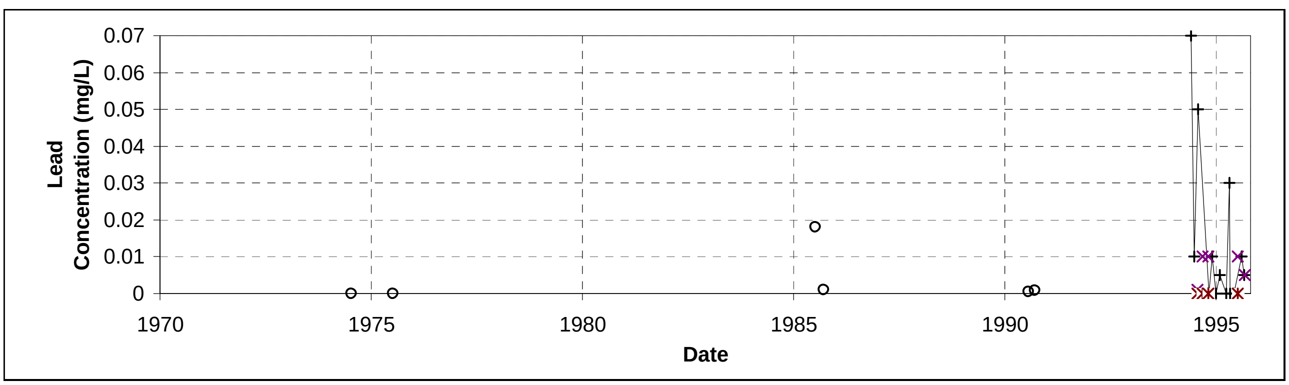


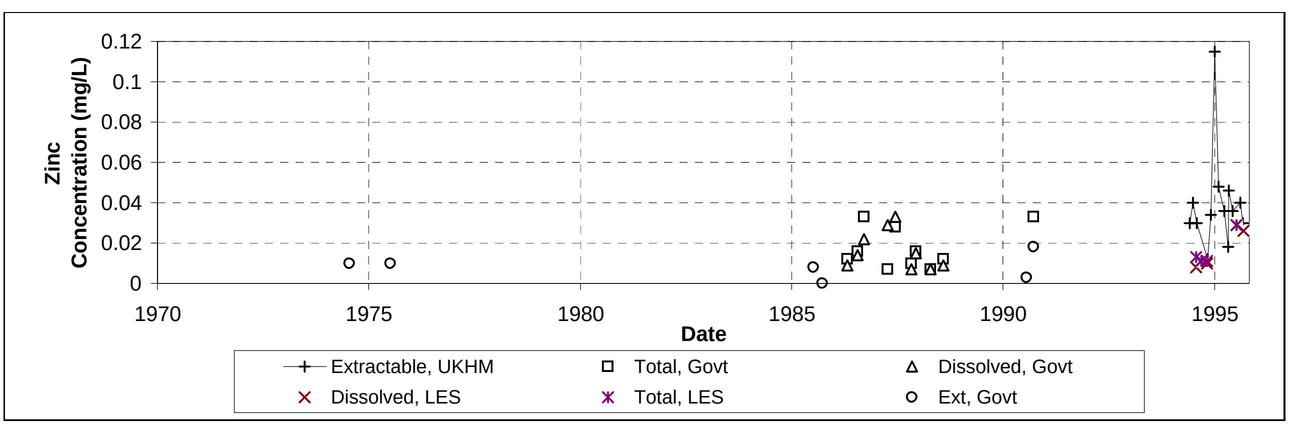


S. McQuesten River
Upstream from Christal Creek
(LES 1)









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The upstream station shows alkaline waters ranging from 70 to 160 mg/L $CaCO_3$ eq., and pH values around 8. Sulphate concentrations average about 50 mg/L - somewhat higher than may be anticipated in natural waters, but explicable considering the amount of Earn Group black phyllite upstream.

The concentrations of most metals are less than detection, with a few notable exceptions:

- total and extractable zinc concentrations range over the 20 year monitoring period from <0.002 to 0.033 mg/L;
- dissolved zinc values of 0.03 mg/L have also been recorded;
- copper concentrations of up to 0.01 mg/L;
- calcium and magnesium values are generally about 40 mg/L and 11 mg/L respectively.

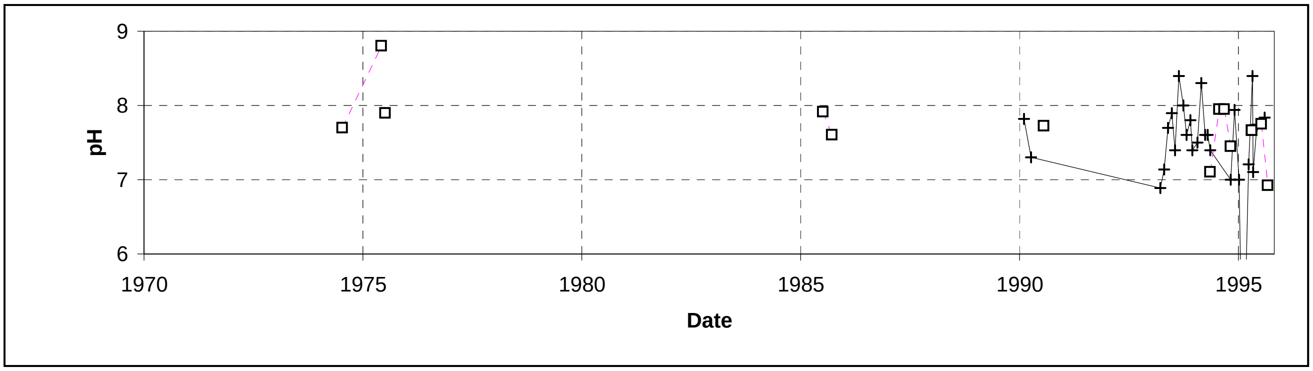
While these concentrations may seem relatively low, they can represent a large load due to the volume of flow in the South McQuesten River and are therefore a significant consideration. In addition, the external laboratories more frequently have appropriate detection limits for comparison of receiving water chemistry to CCREM guidelines. It is for these reasons that data from external laboratories, with lower detection limits and associated QA/QC data is used preferentially to UKHM data for the load balances.

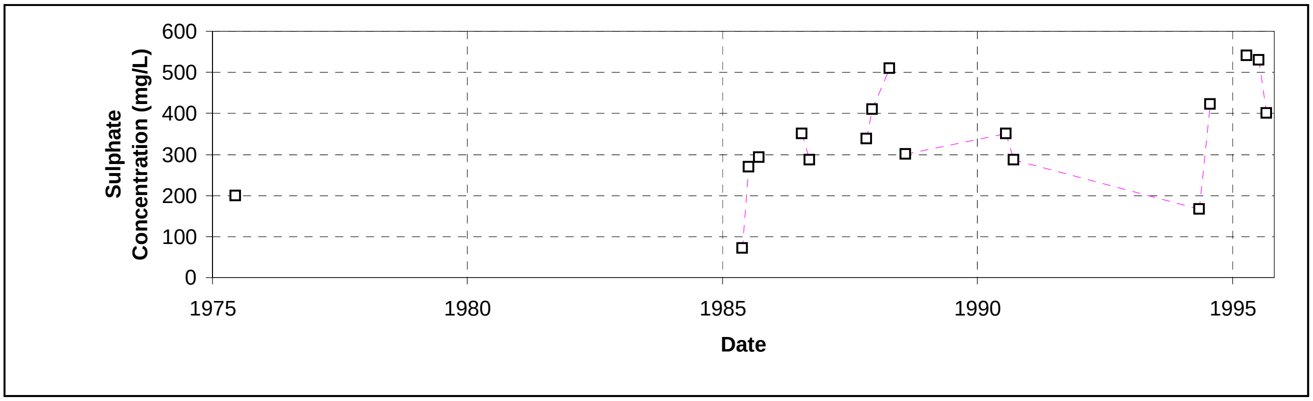
6.2.15.2 Christal Creek

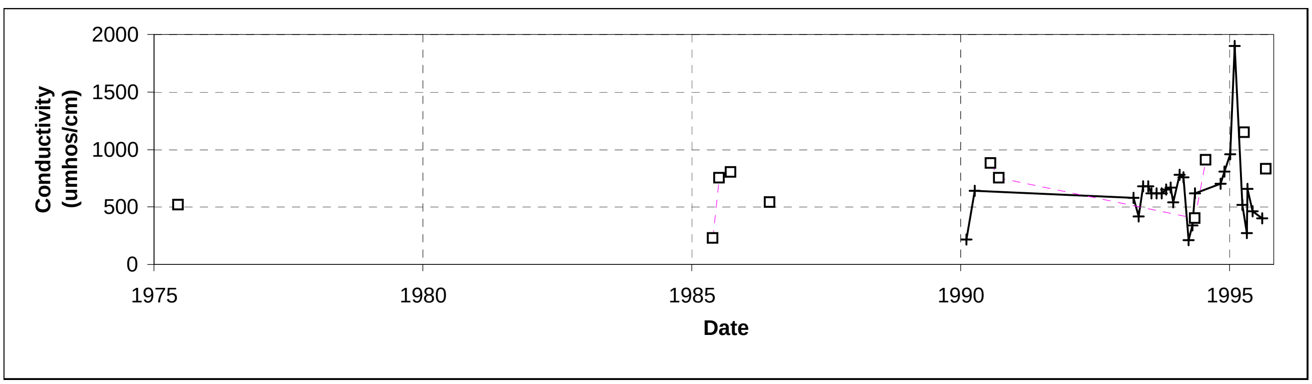
The Christal Creek drainage is of particular interest in terms of the site water chemistry for two reasons. It is primarily of interest because of the Galkeno workings located upslope from the Creek, and the concerns related to the metal loadings from the workings to the Creek and ultimately to the South McQuesten River.

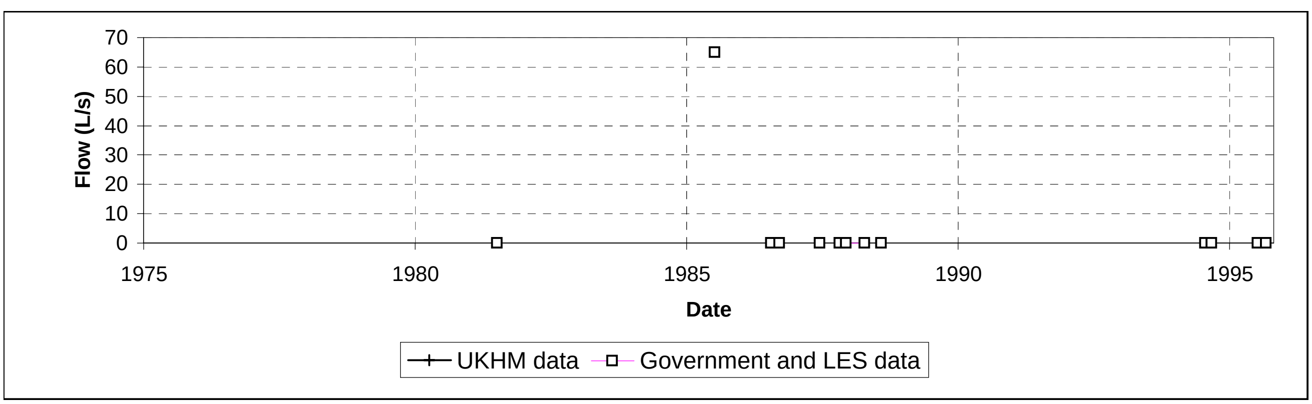
Three sampling stations have been established directly on Christal Creek, UKHM stations S-18 and S-19 which correspond to LES stations 6 and 7 respectively, and an additional station at the mouth called LES 7A. There is also a station located in Christal Lake, station 56. The stations that relate to flows into Christal Lake are 61, 62 (possibly from Onek) and 55. These are shown in Figures 6-35 through 6-40.

Christal Creek @ Elsa/Keno Road (S18)
(LES 6)

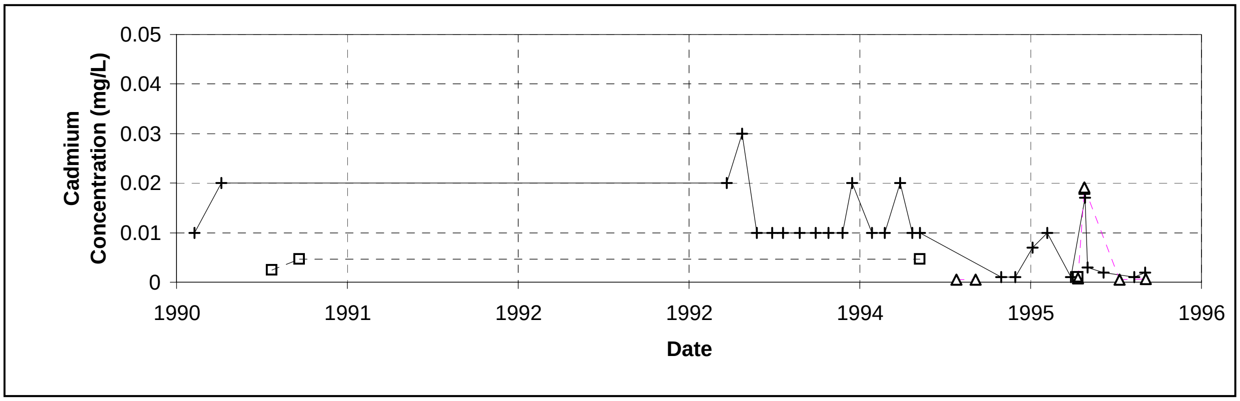


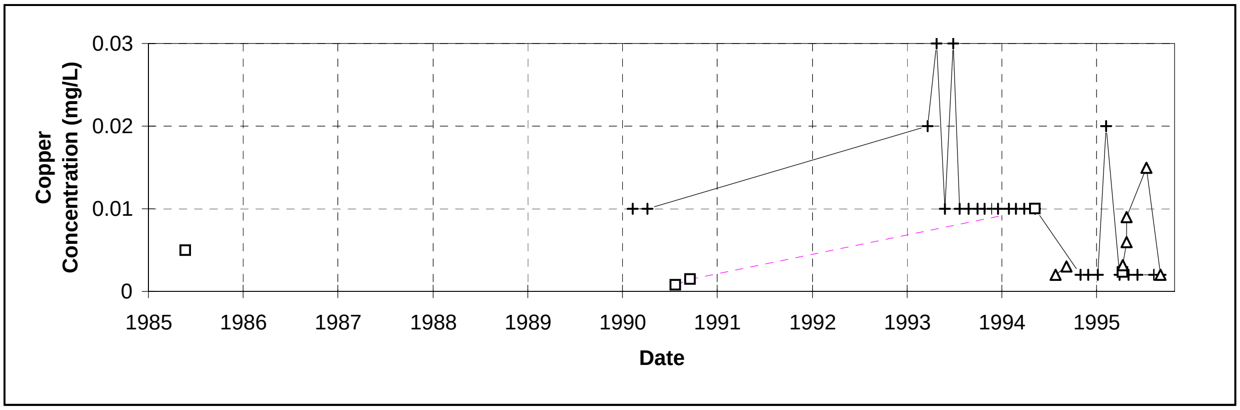


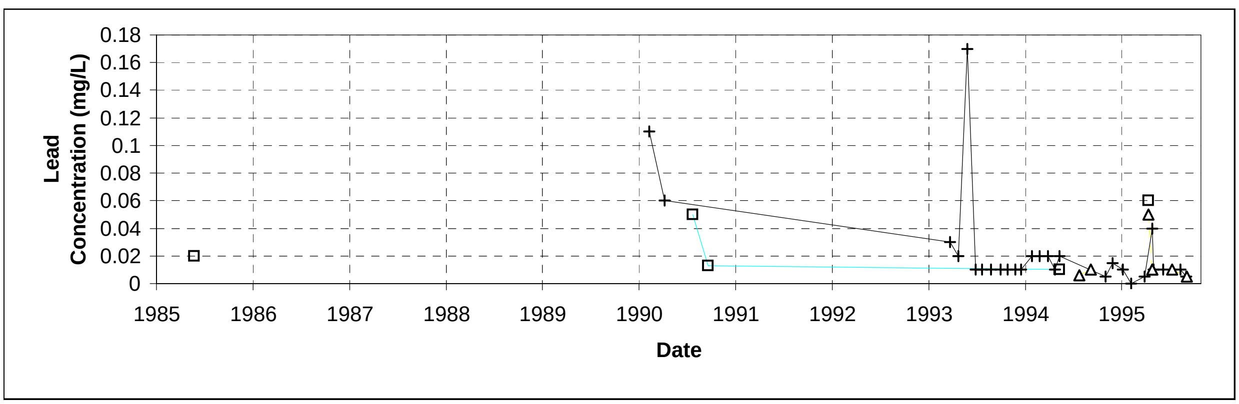


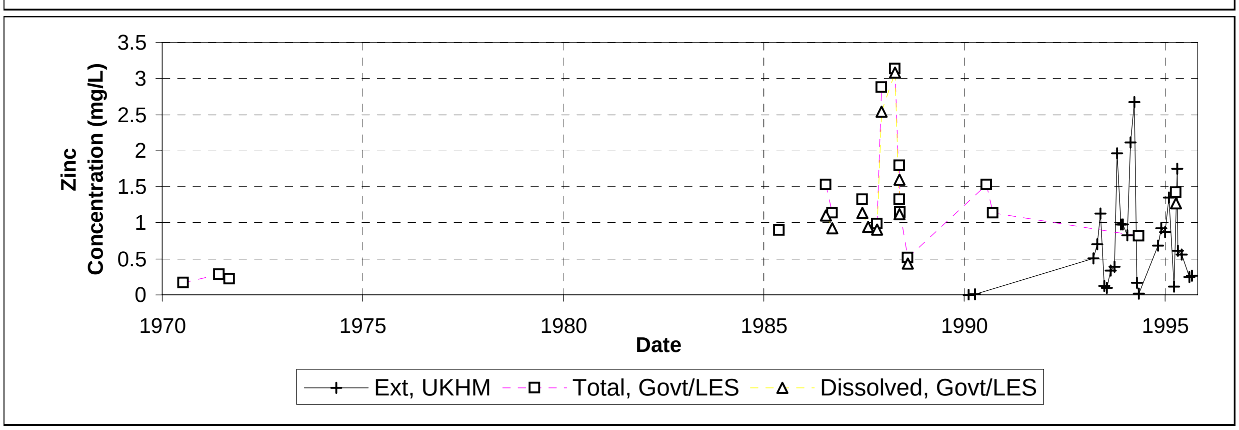


Christal Creek @ Elsa/Keno Road (S18)
(LES 6)

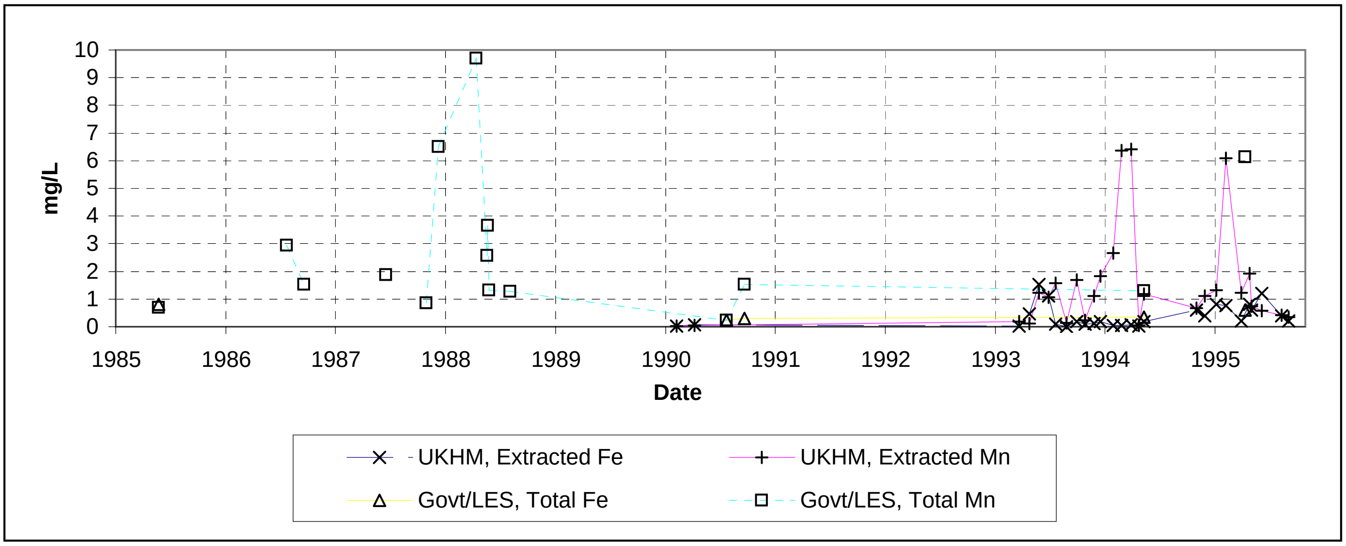


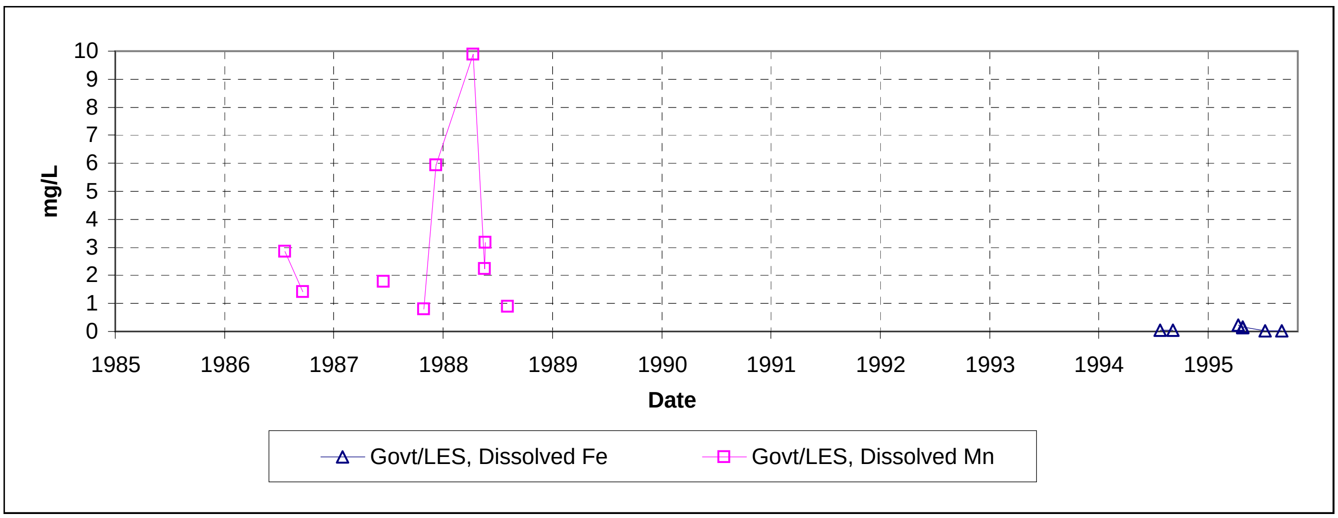




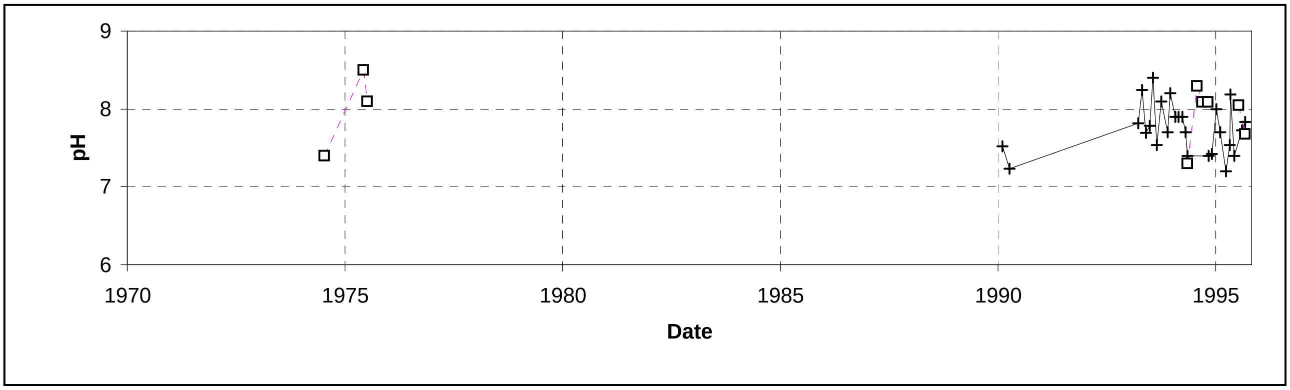


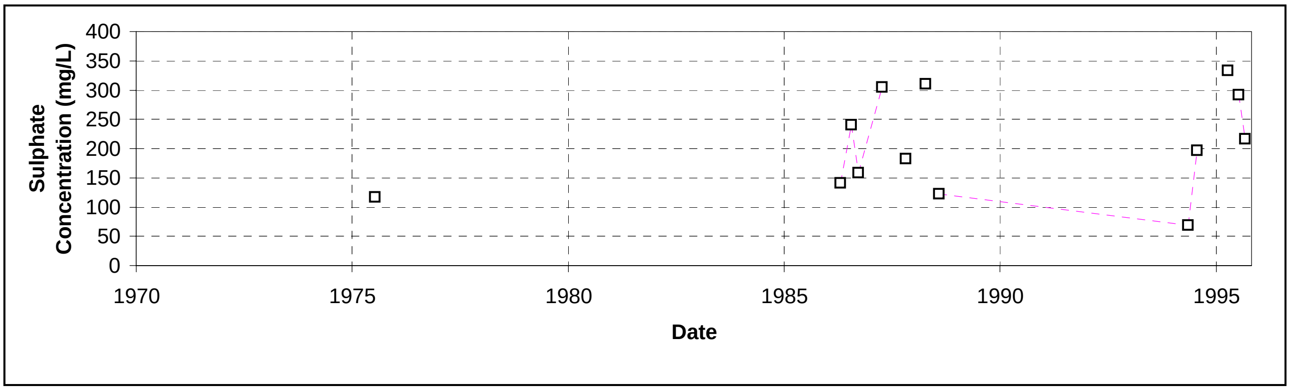
Christal Creek @ Elsa/Keno Road (S18)
(LES 6)

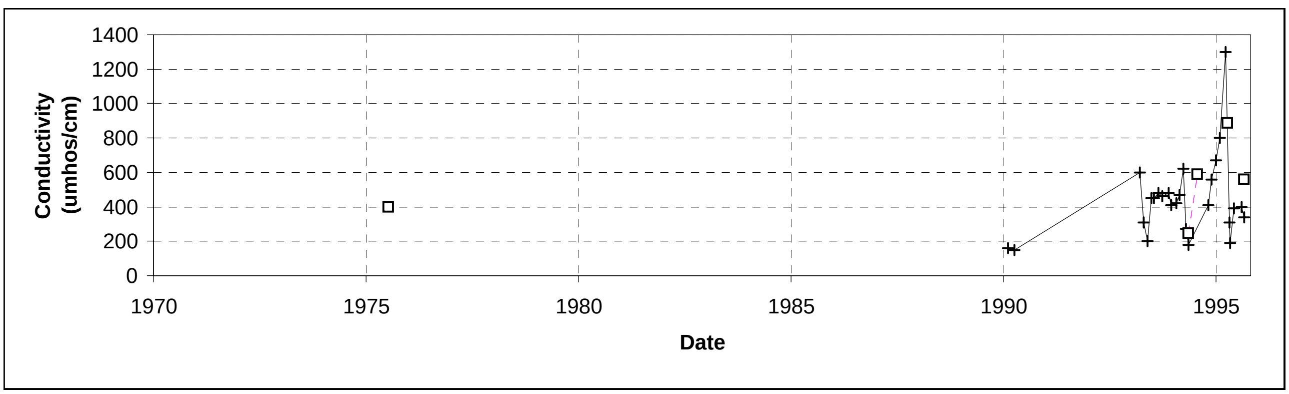


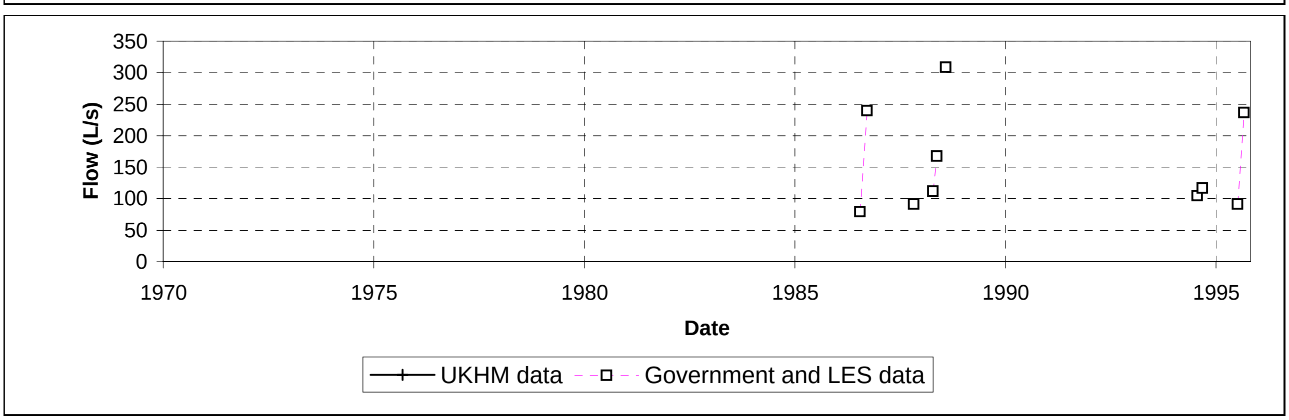


Christal Creek @ Hanson Lake Road (S19)
(LES 7)

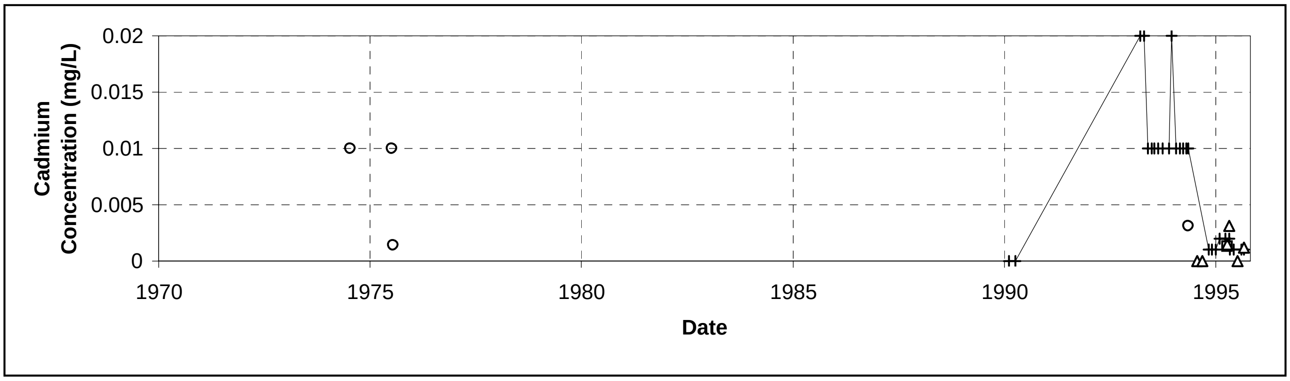


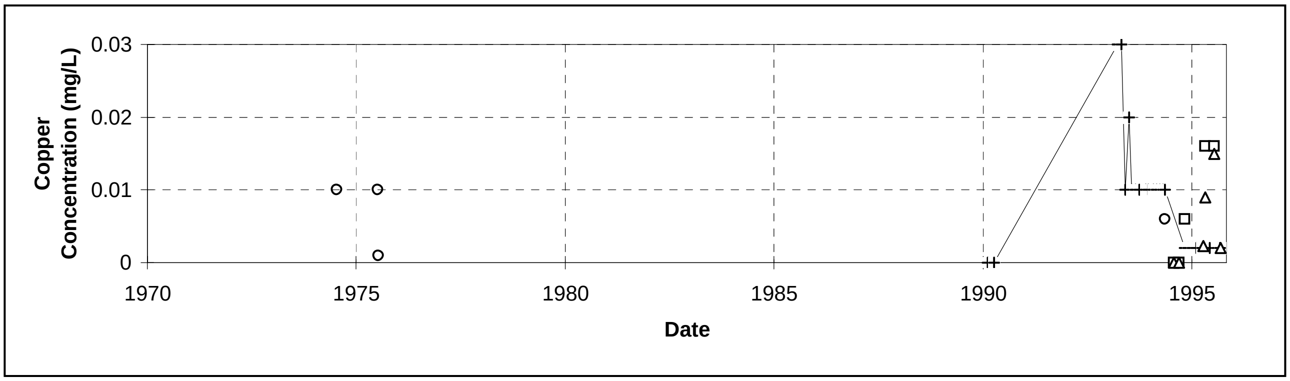


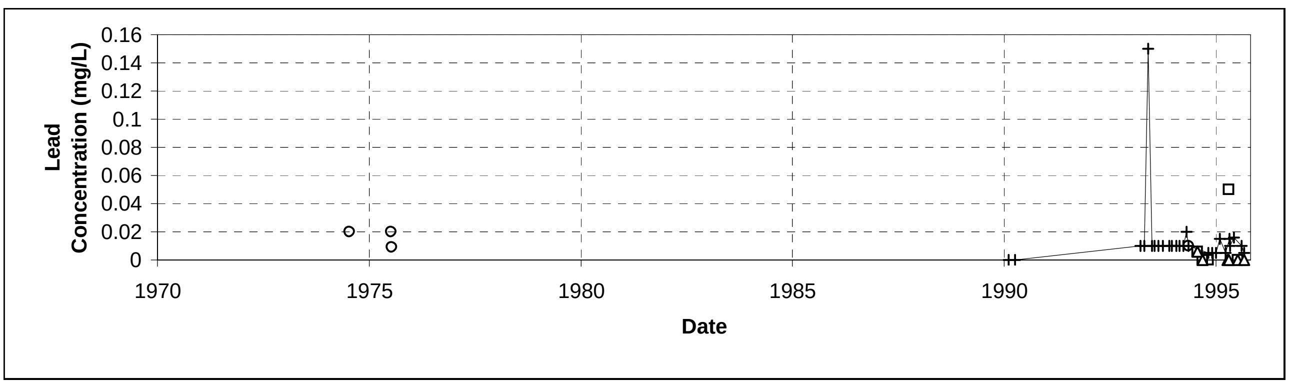


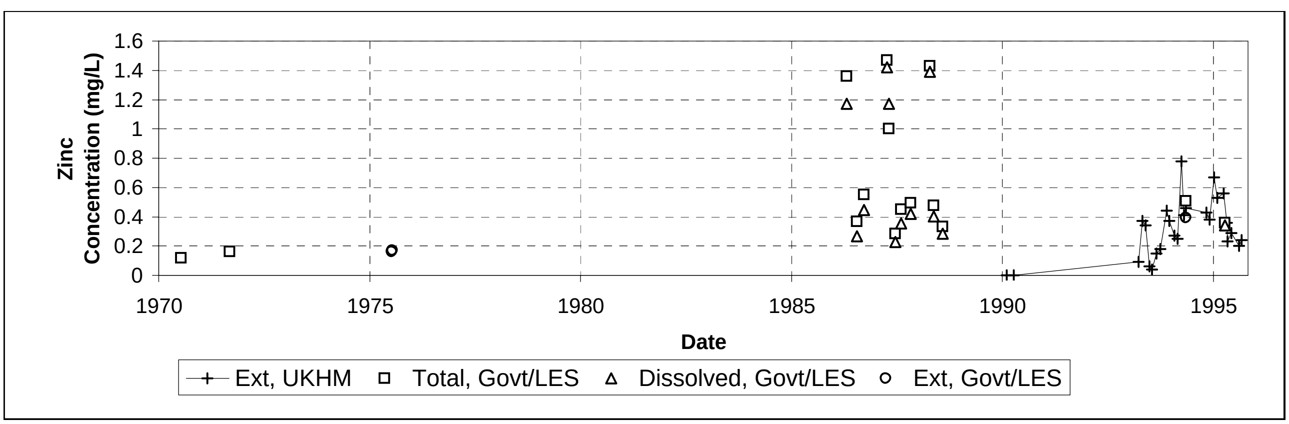


Christal Creek @ Hanson Lake Road (S19)
(LES 7)









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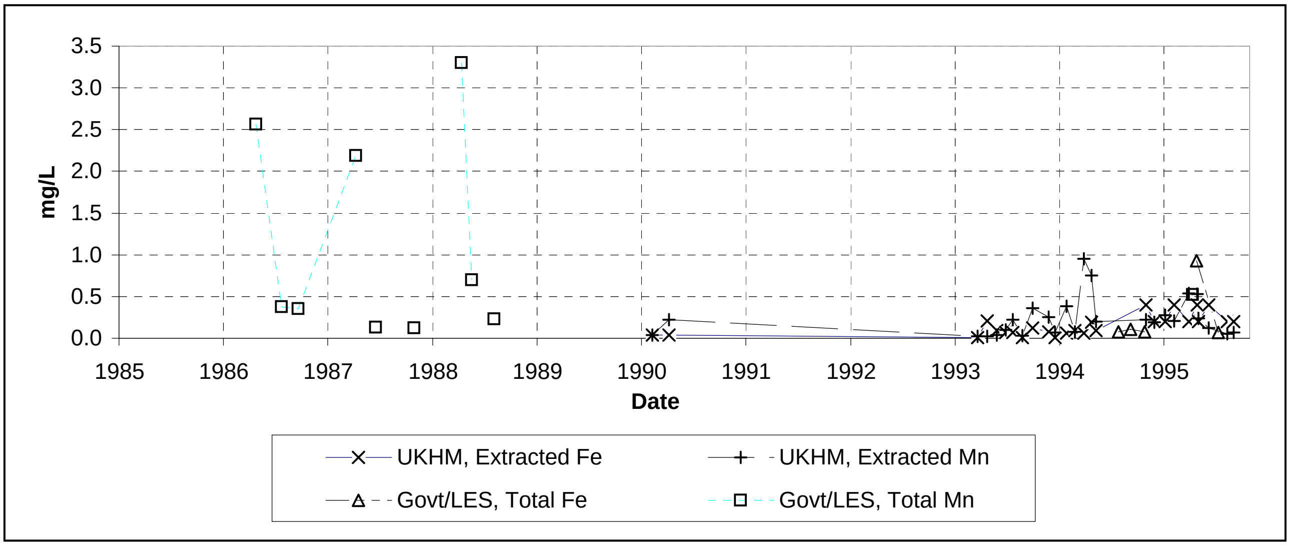
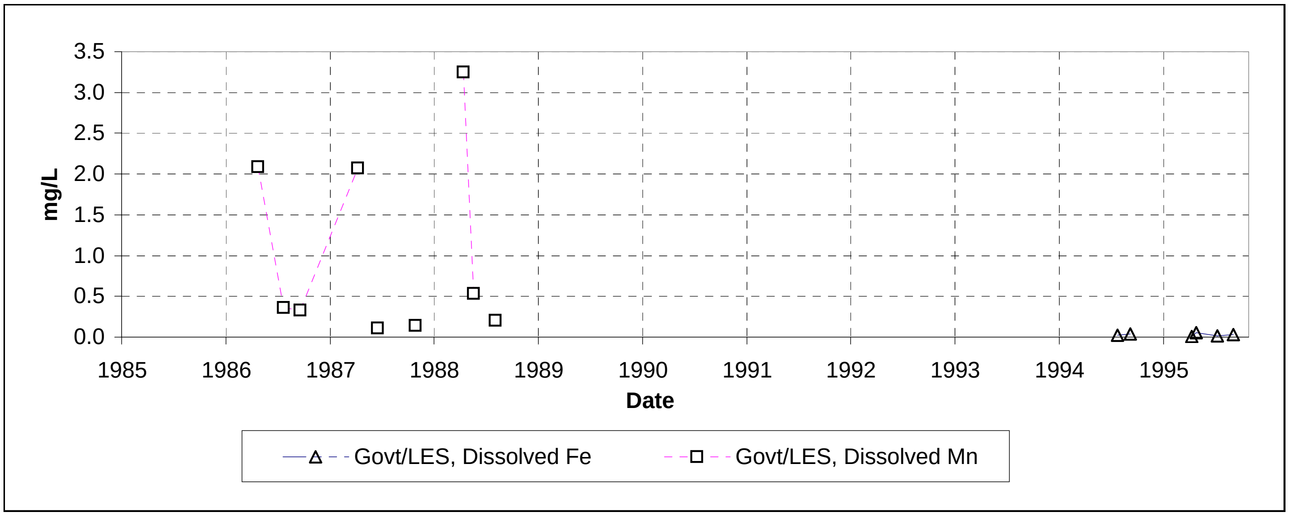
Christal Creek @ Hanson Lake Road (S19)
(LES 7)





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In addition, there are a series of stations related to the Galkeno 900 development to sample seeps and water discharge from Galkeno including the adit discharge (S-5) and LES stations 31 A through H, and 32.

The impact of these drainages on Christal Creek is evaluated in detail in the flow and loading calculations presented in Chapter 6. These data are also discussed in some detail in Appendix II and in the discussions of each mine site.

6.2.15.3 Effect of Flat Creek on the South McQuesten River

Stations LES3, S-9 (LES9), S-11 (LES4)

Flat Creek collects most of the drainage from the tailings, and the Husky, Silver King, and Elsa mines. Figures 6-41 through 6-44, 6-53 and 6-54 summarize the chemistry of this drainage. While the historic record shows considerable variability for some metals, there is no clear trend shown in the data. Seasonal variations are evident for most parameters with peak values occurring in the spring.

Interpretation of these data is difficult, given the erratic measurements of metals upstream of the confluence. However, the downstream station does not show an appreciable increase in concentrations or calculated loads for any parameters.

Figures 6-45 through 6-52 show results along the South McQuesten River.

Figure 6-41 Water Quality Profile Along Flat Creek
July 12 and 13, 1995

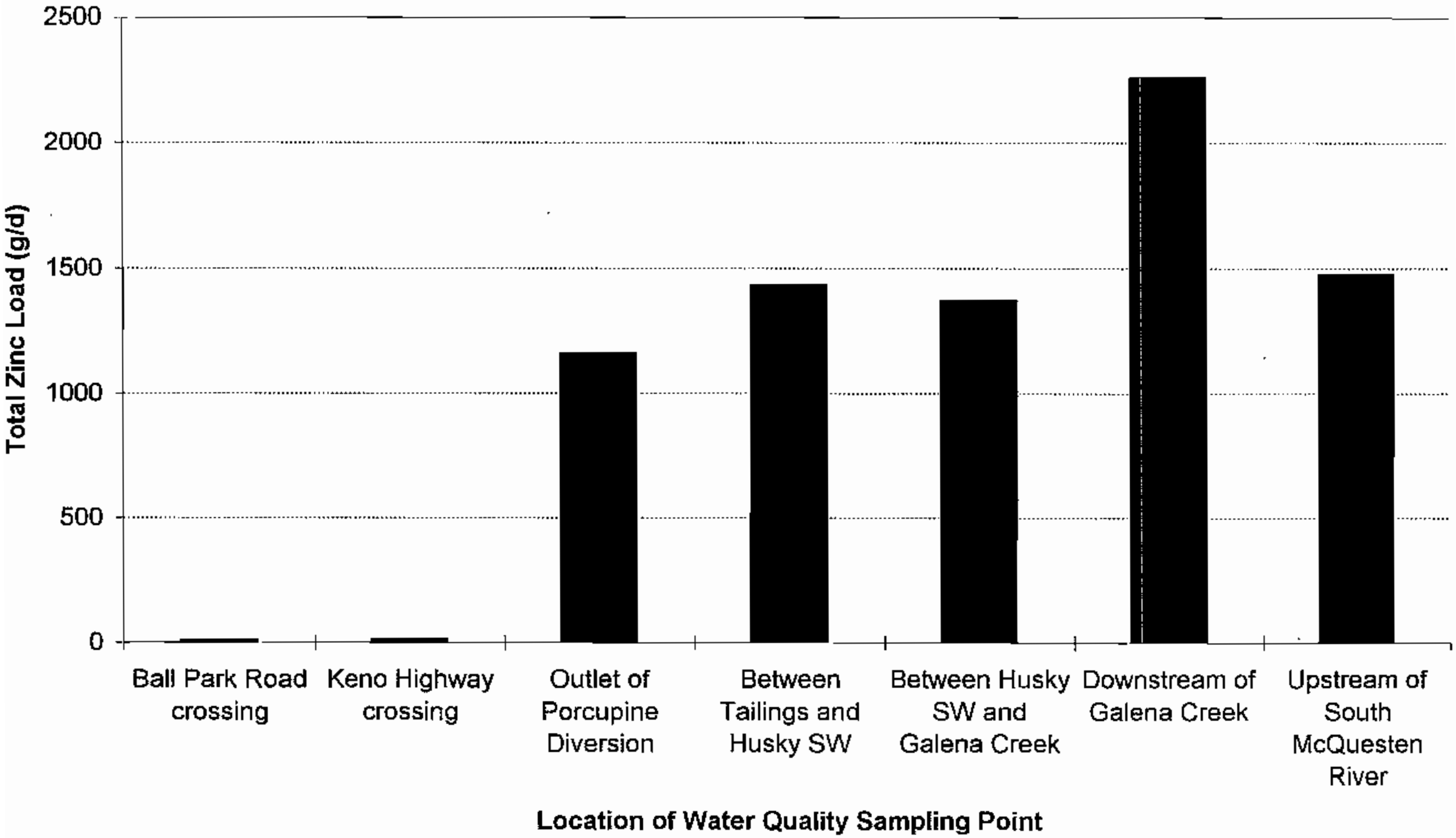


Figure 6-42 Water Quality Profile Along Flat Creek
July 12 and 13, 1995

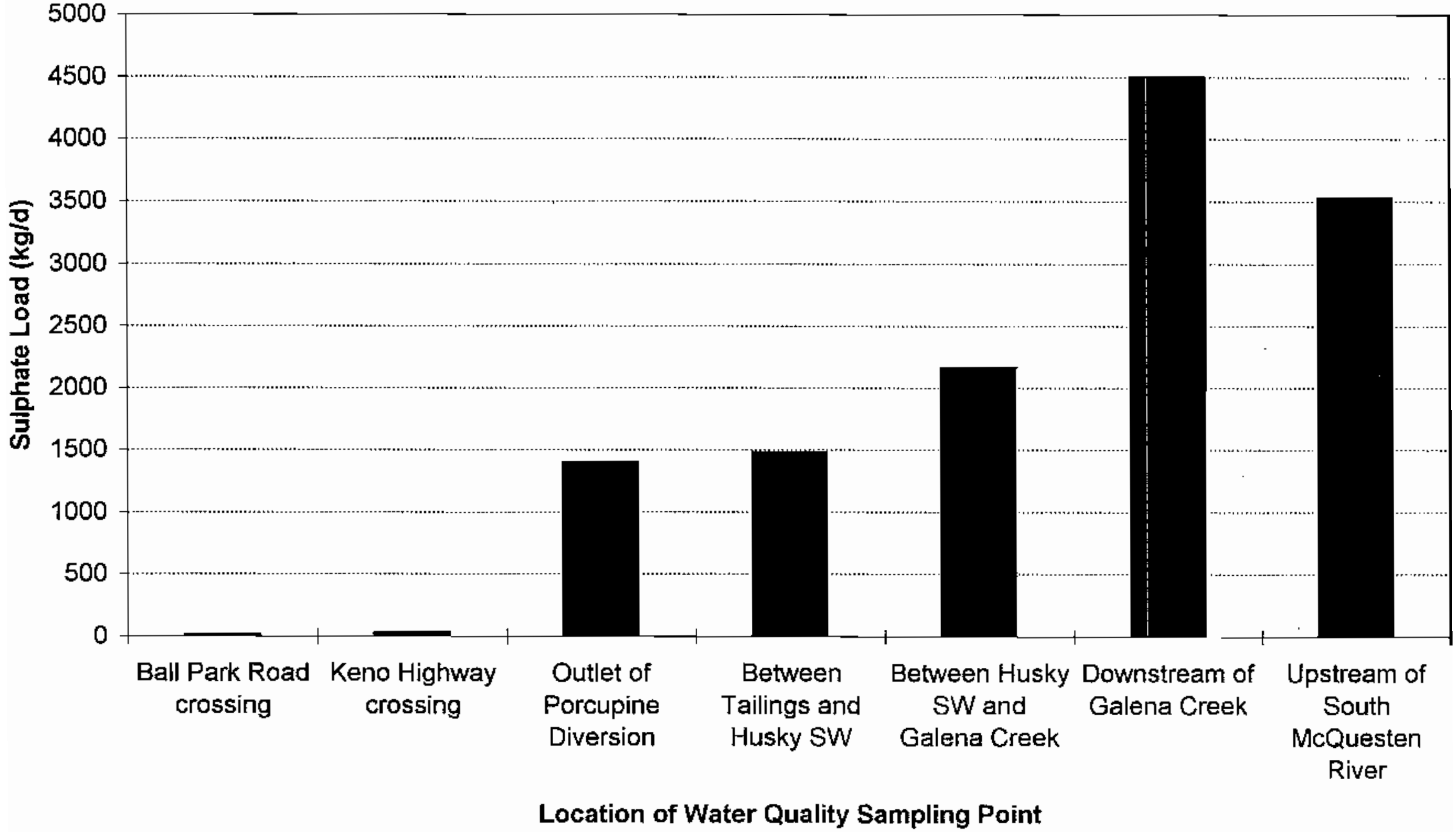


Figure 6-43 Water Quality Profile Along Flat Creek September 4 - 7, 1995

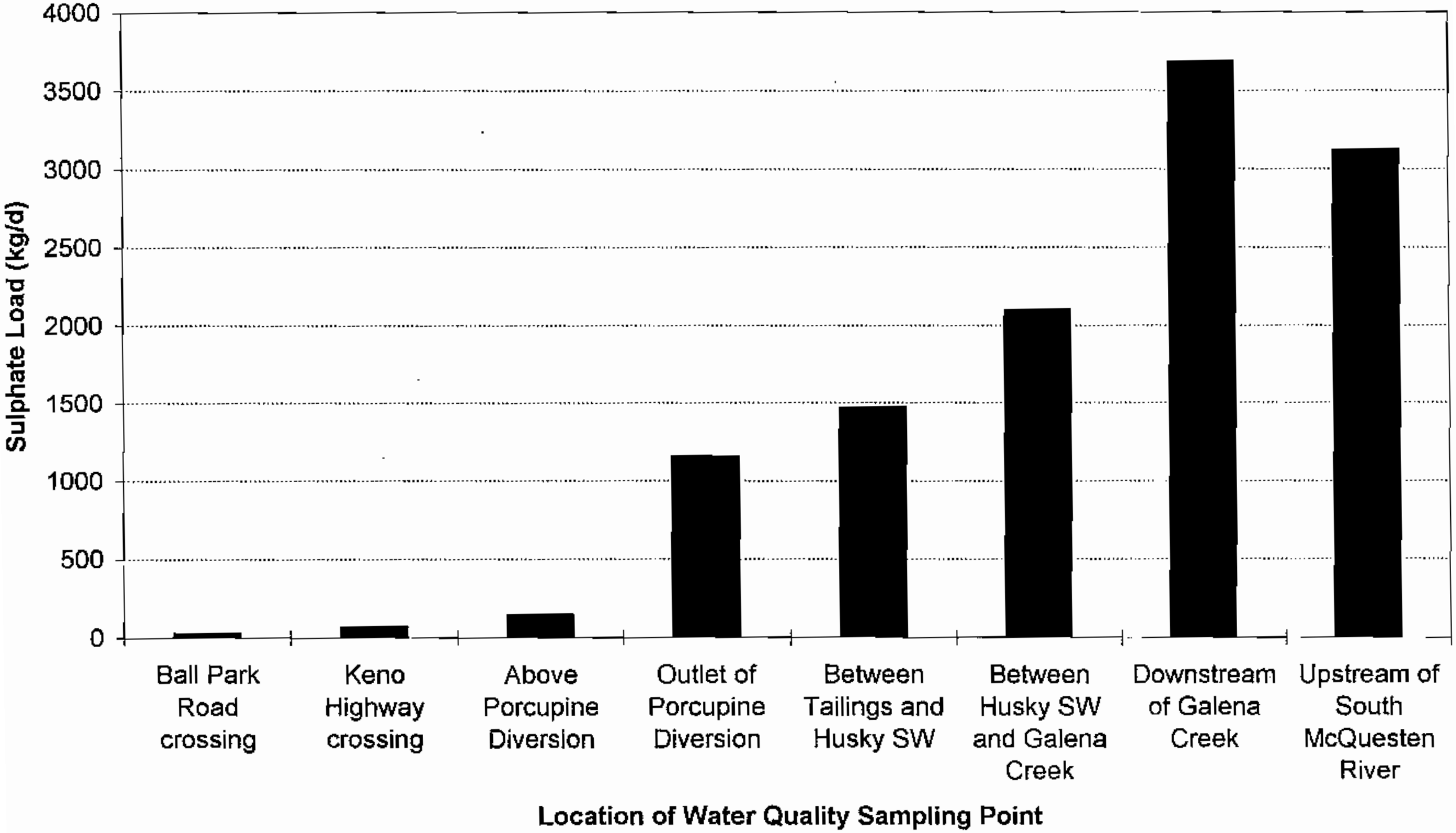


Figure 6-44 Water Quality Profile Along Flat Creek
September 4 - 7, 1995

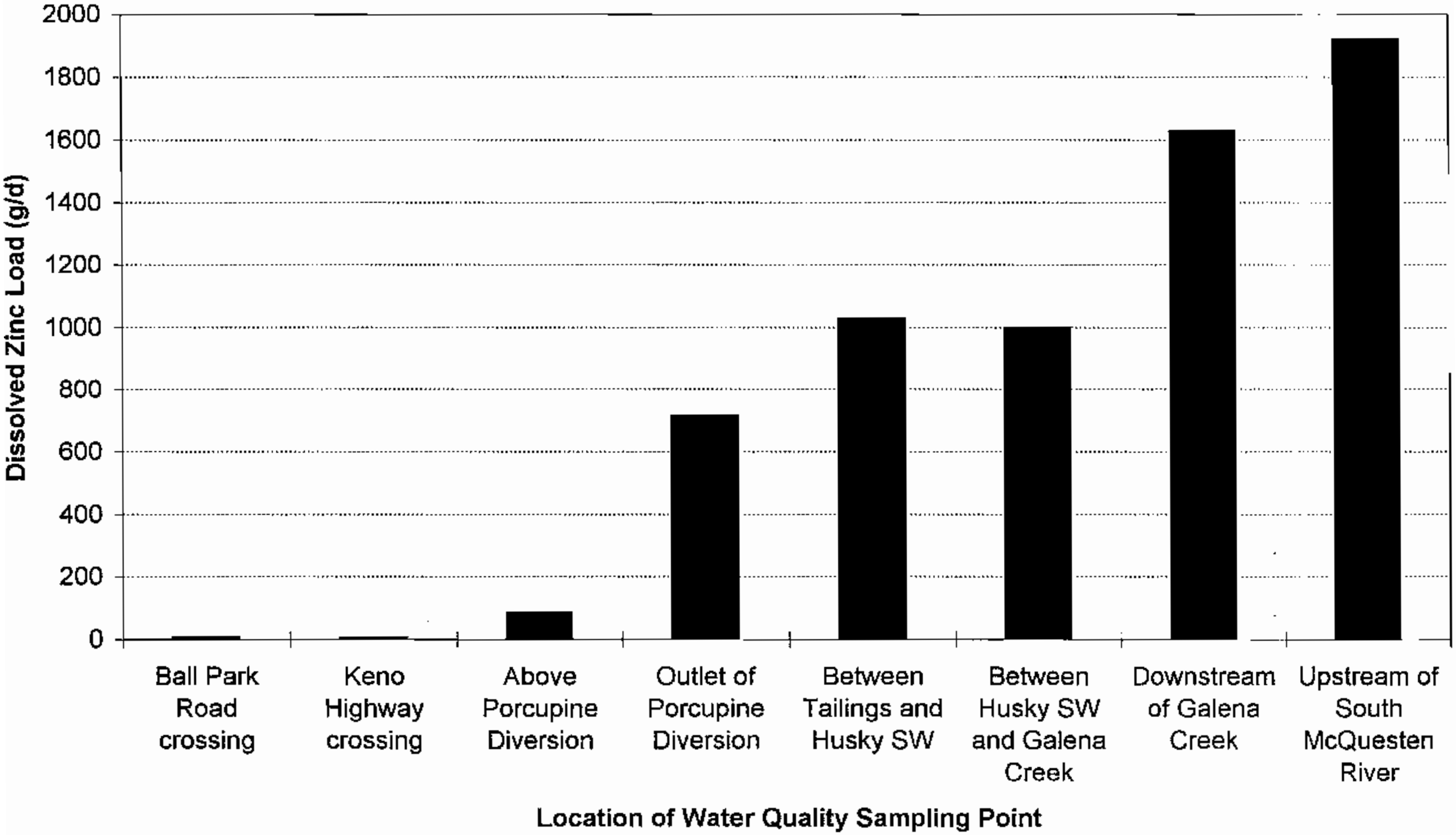


Figure 6-45 S.McQuesten River @ Pumphouse (S10)
(LES 2)

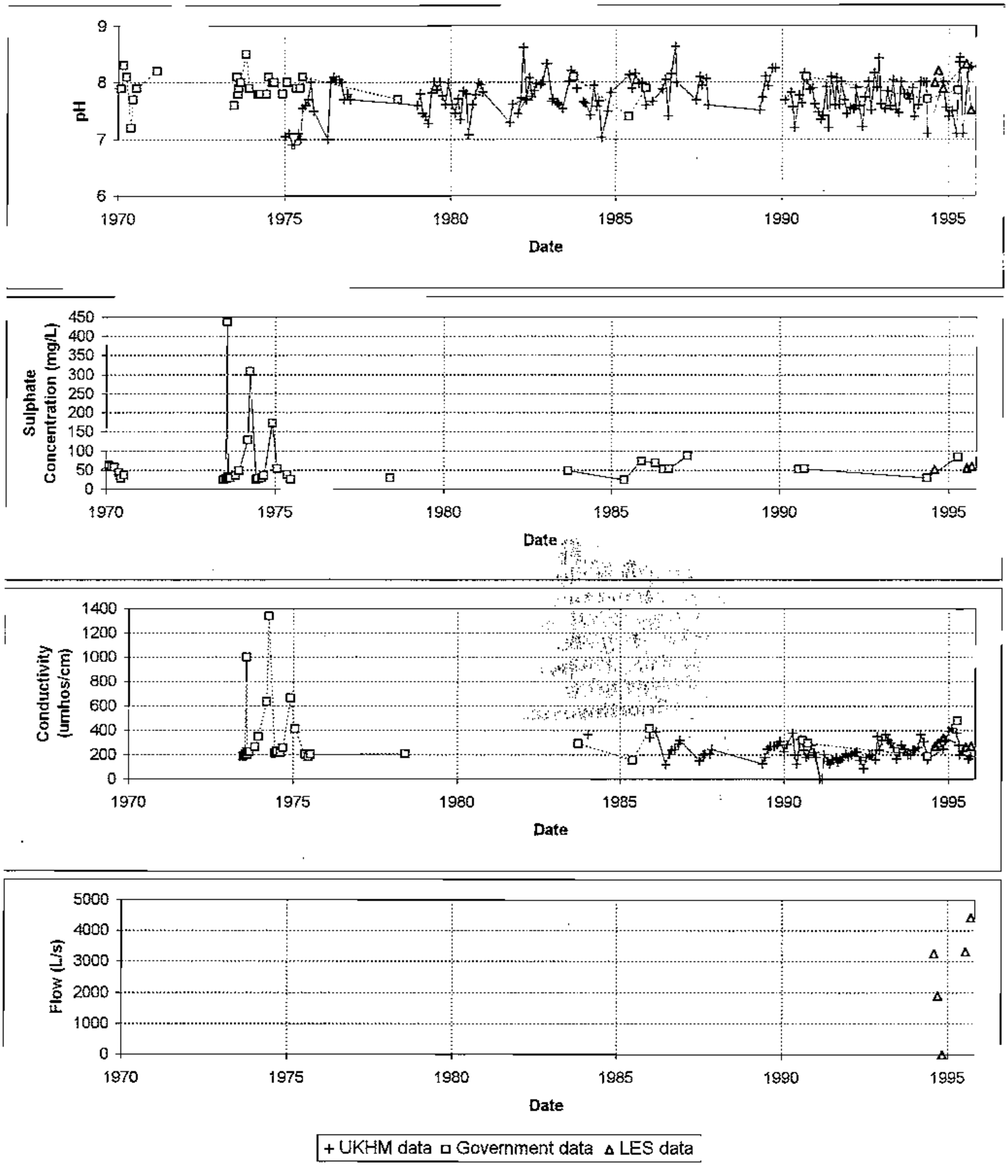


Figure 6-46

S.McQuesten River @ Pumphouse (S10)
(LES 2)

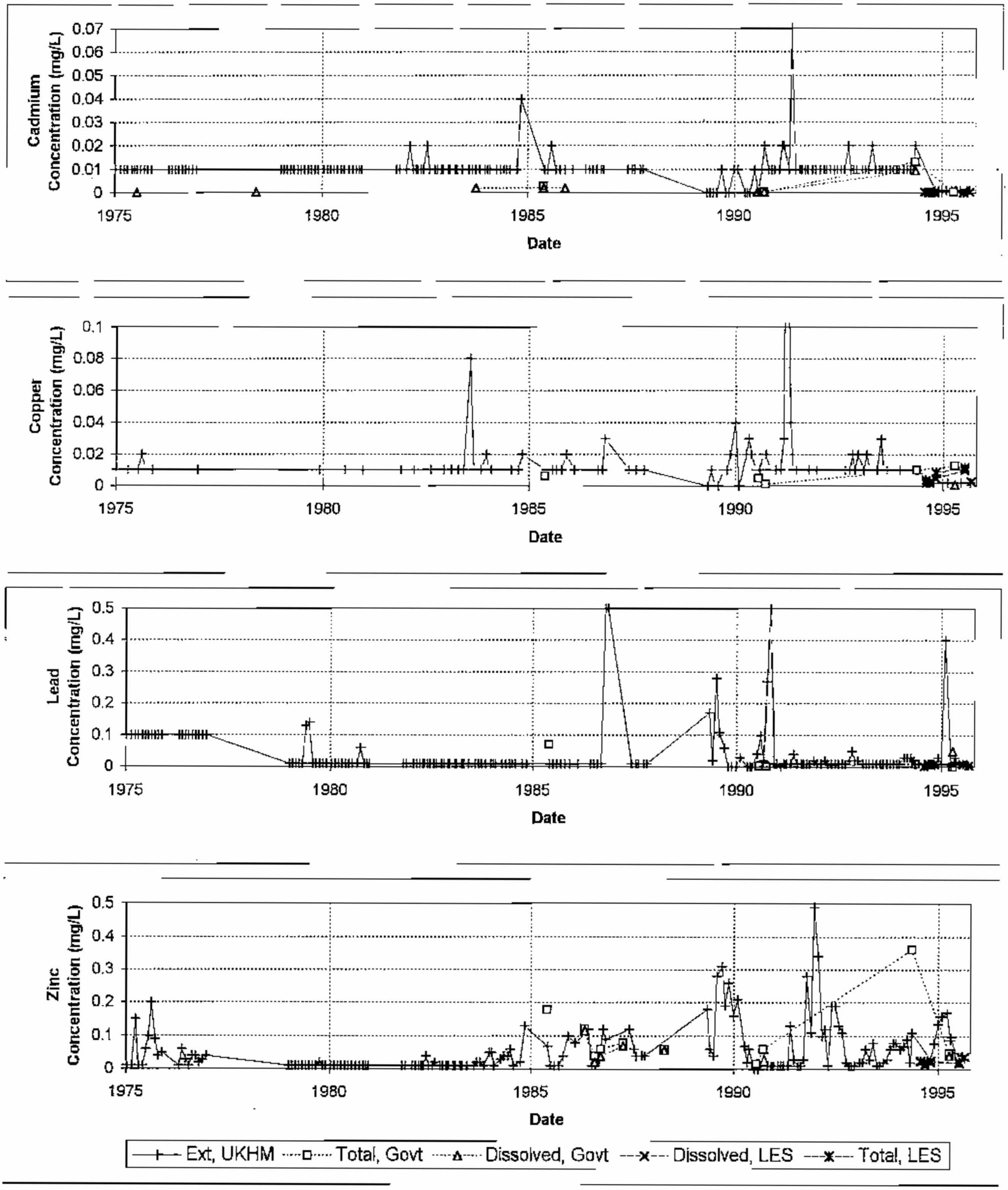
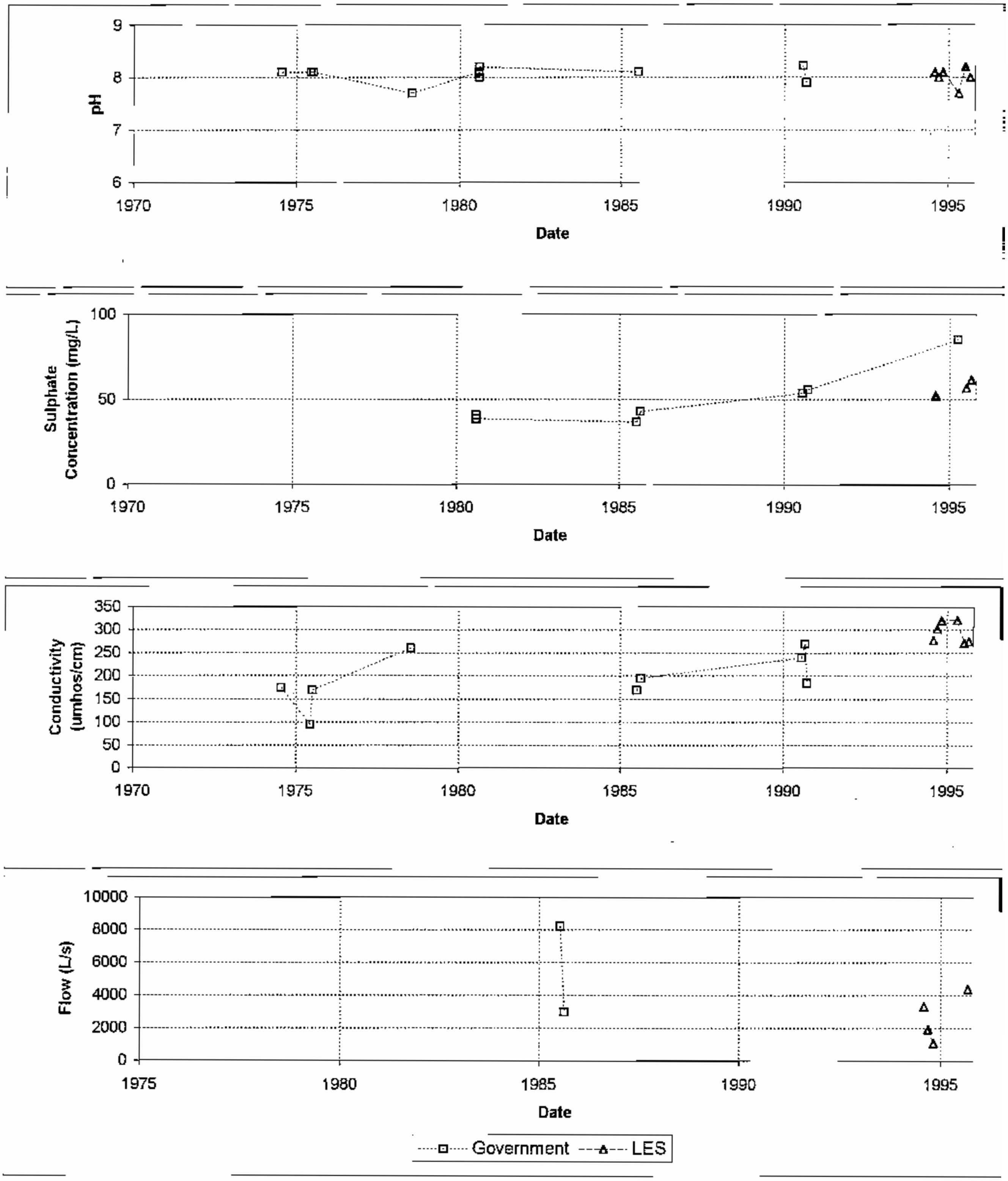
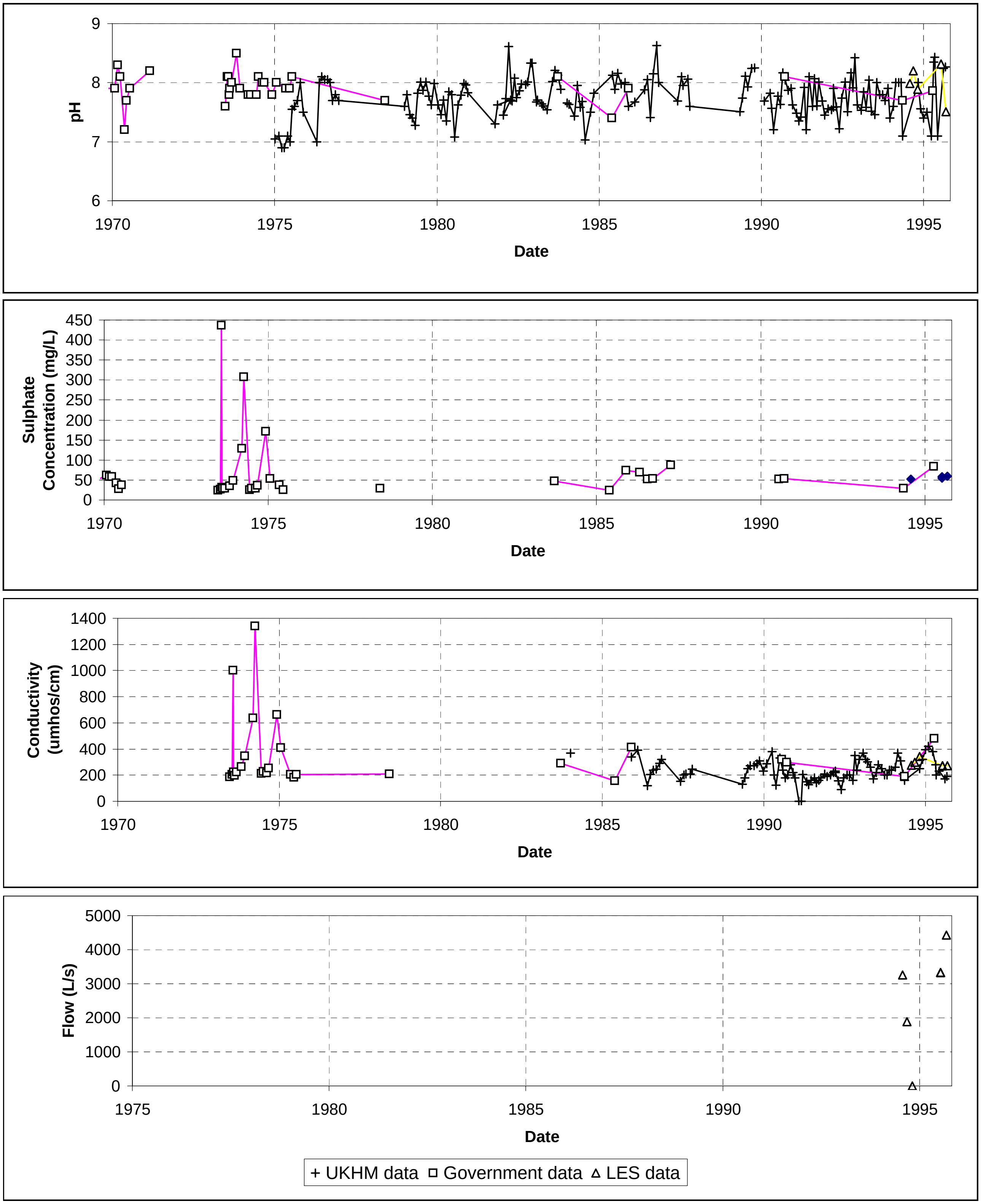


Figure 6-47

S.McQuesten River Upstream from Flat Creek (LES 3)



S.McQuesten River
@ Pumphouse



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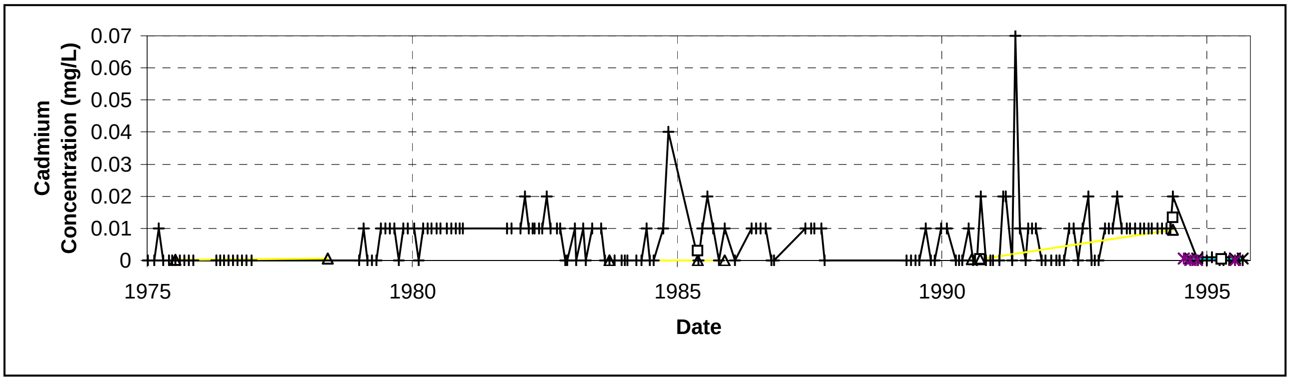
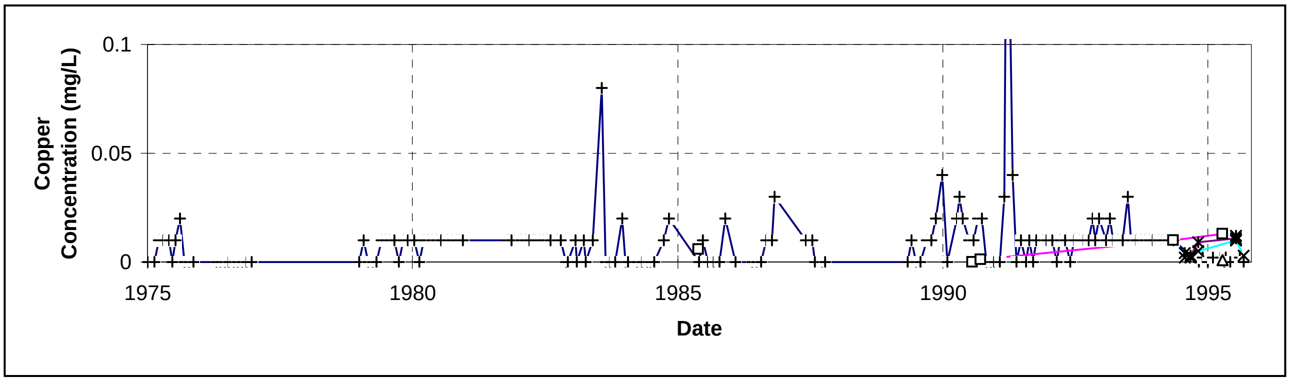
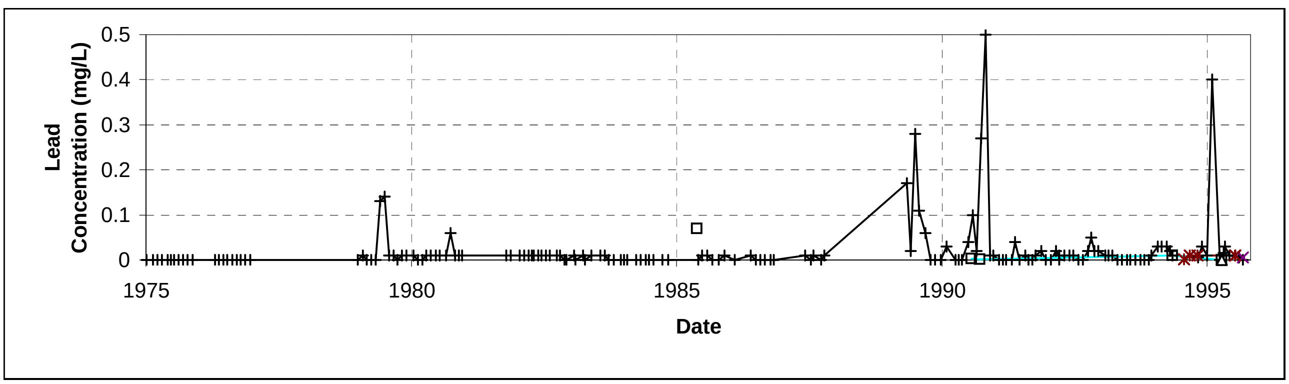
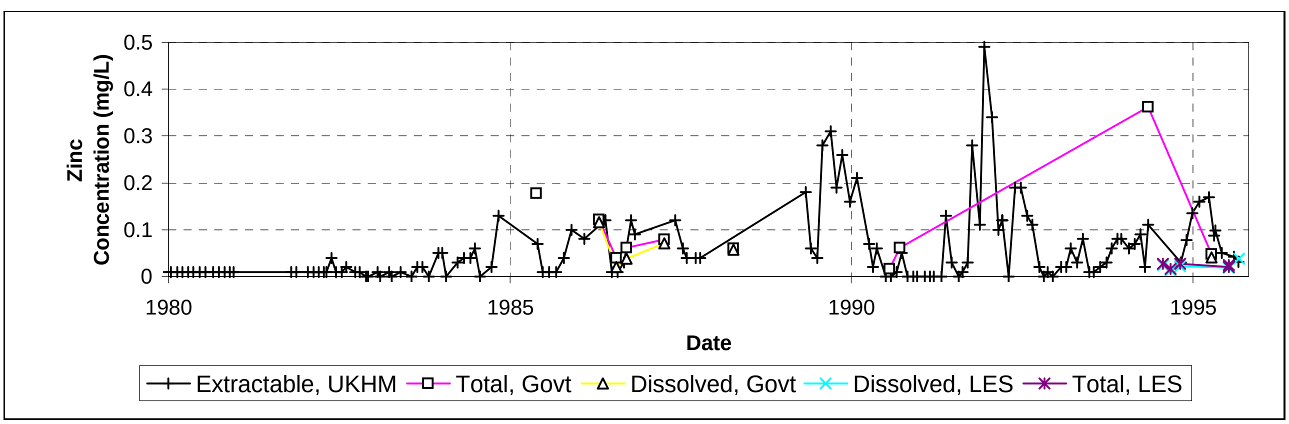
S.McQuesten River
@ Pumphouse









S.McQuesten River Upstream from Flat Creek

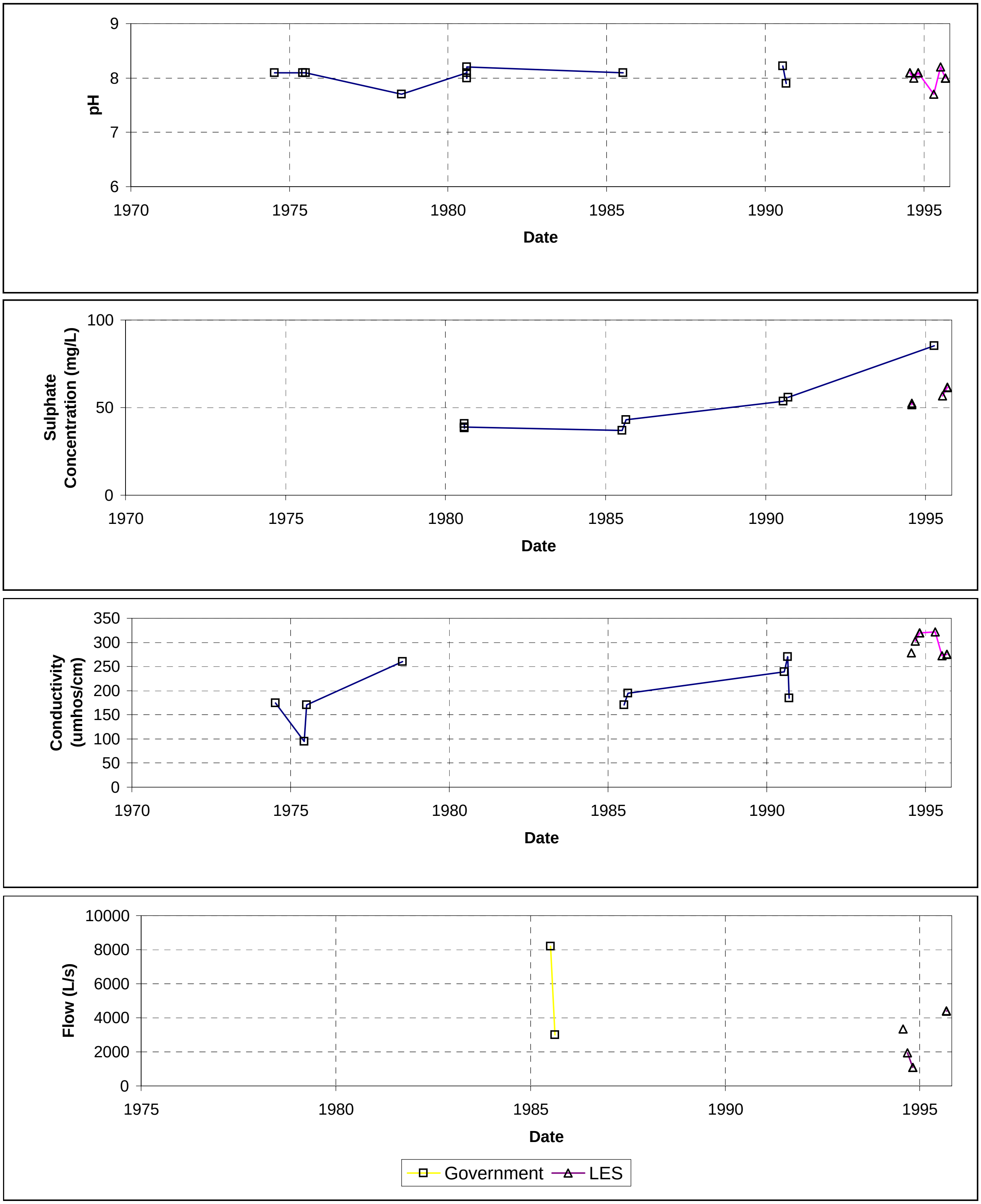


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Figure 6-48

S.McQuesten River Upstream from Flat Creek
(LES 3)

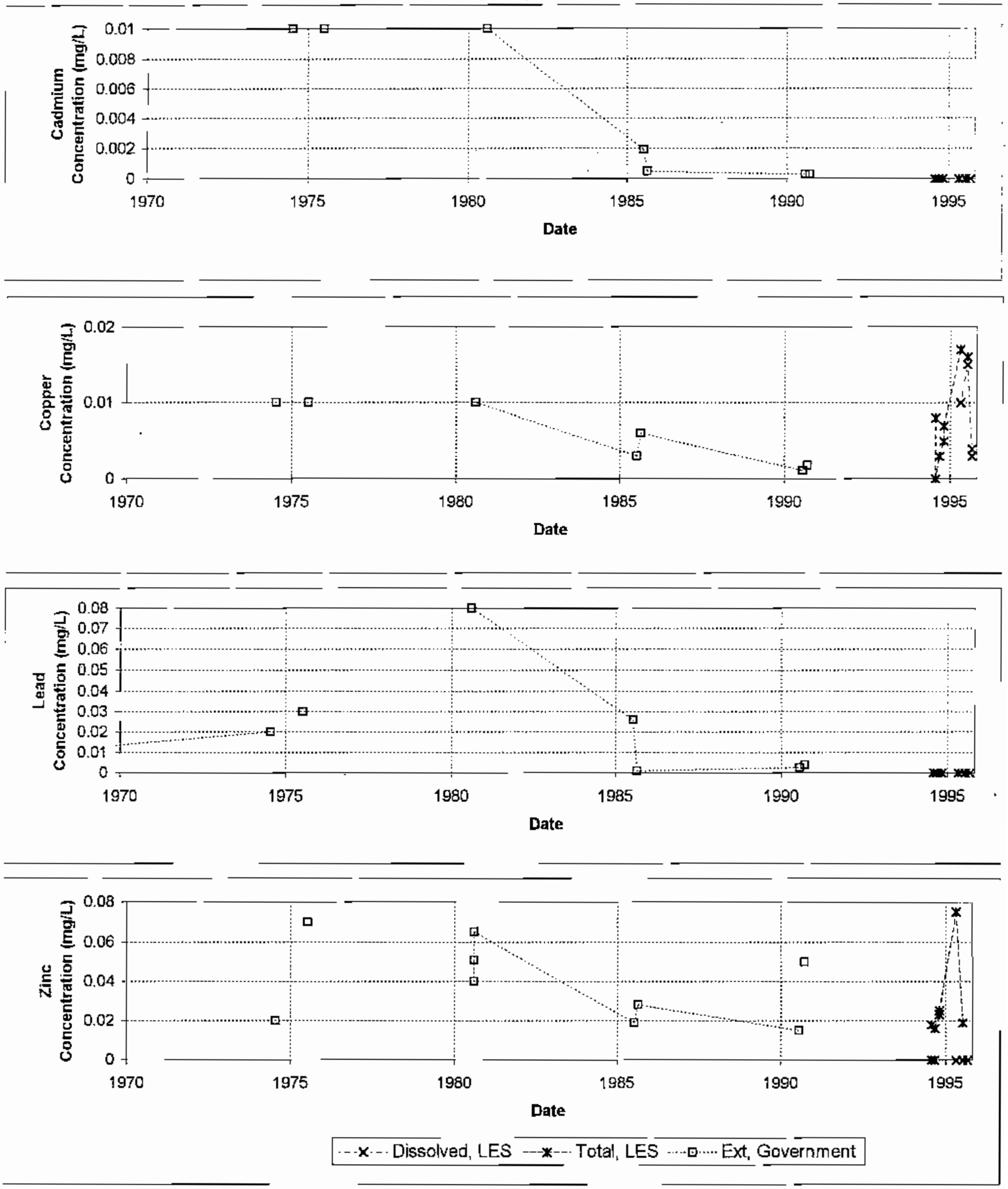


Figure 6-49

S.McQuesten River 9K Downstream from Flat Creek (LES 5)

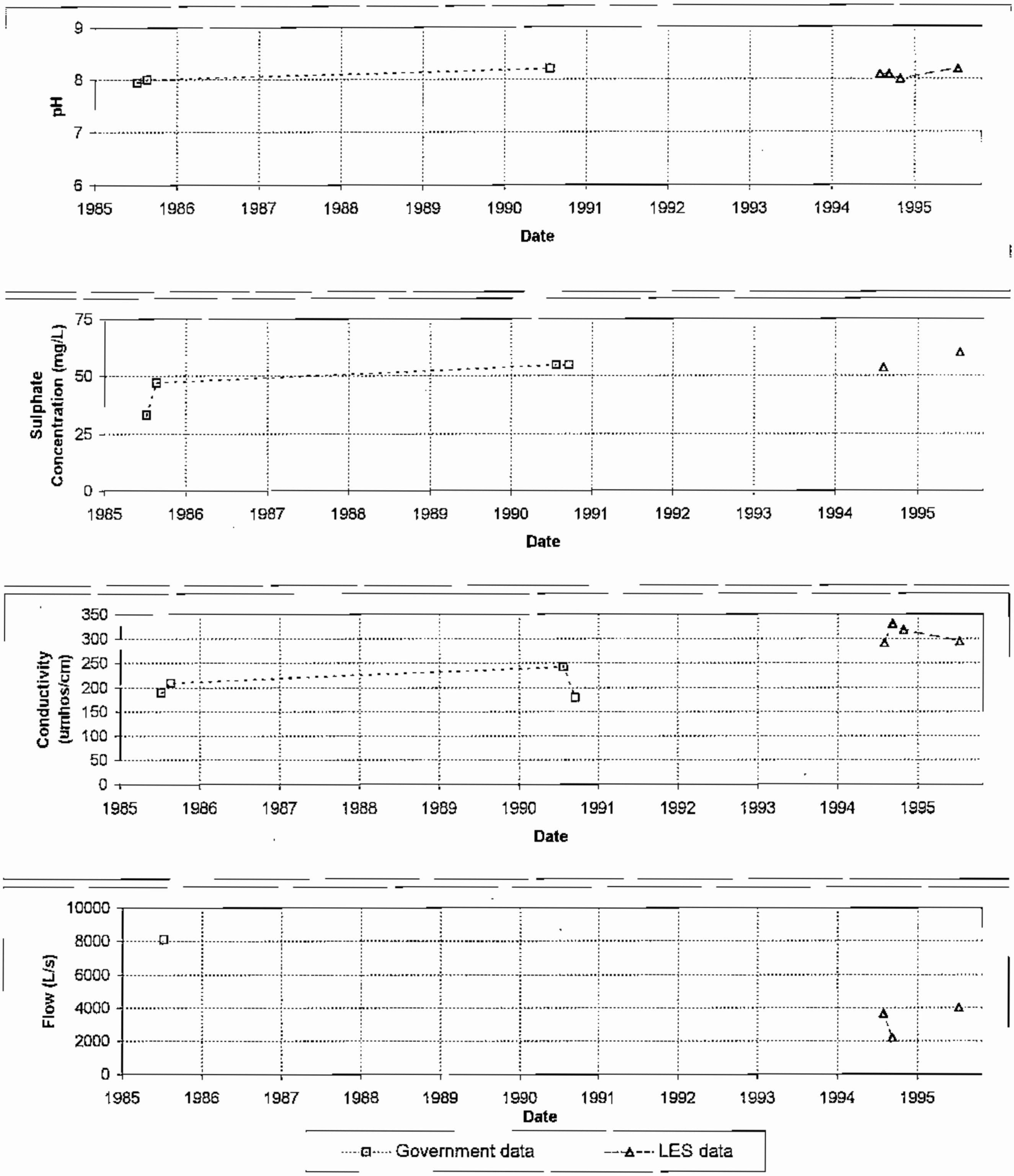


Figure 6-50

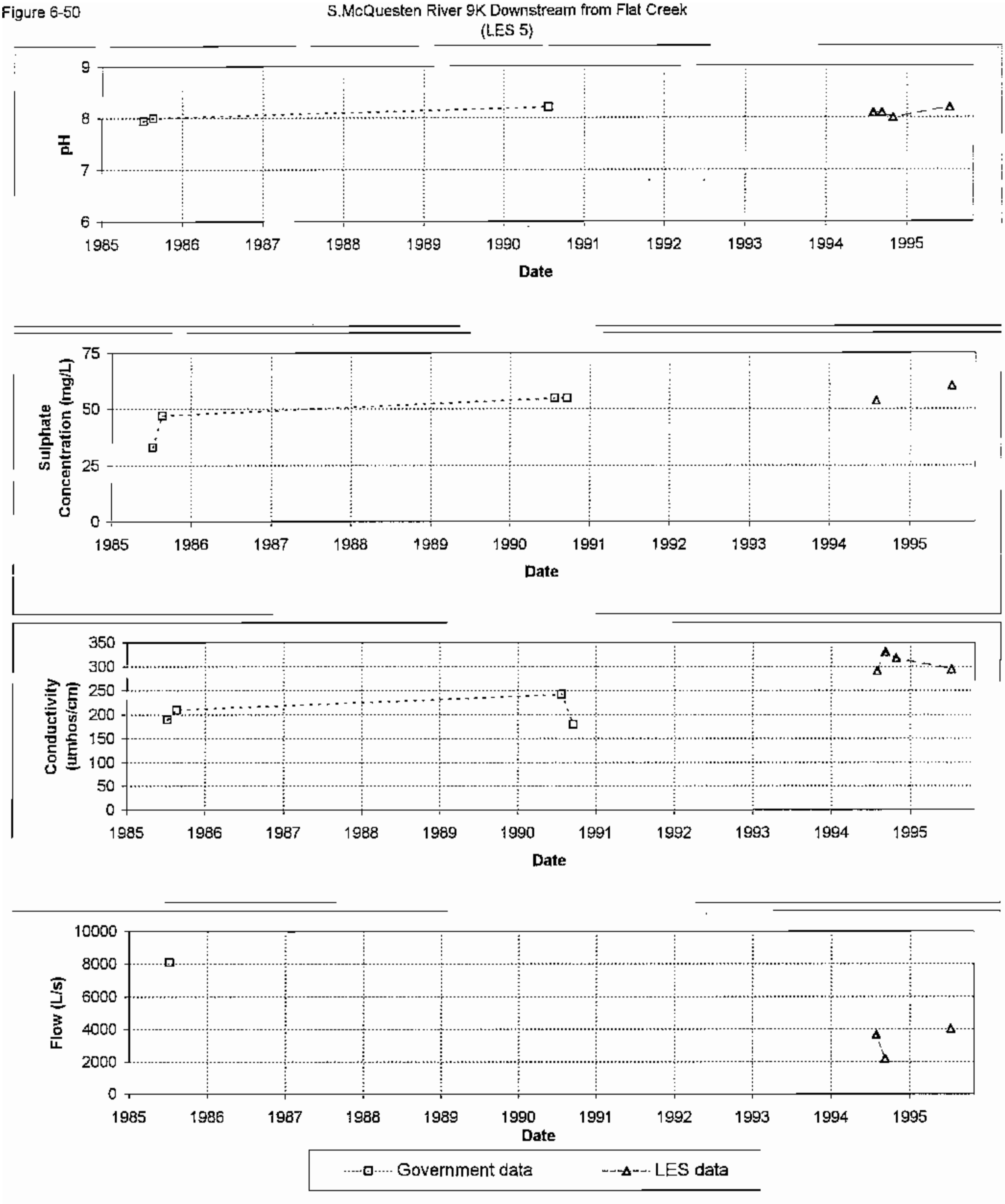

S.McQuesten River 9K Downstream from Flat Creek
(LES 5)
pH
9
8
7
6
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
Date
Sulphate Concentration (mg/L)
75
50
25
0
Date
Conductivity (umhos/cm)
350
300
250
200
150
100
50
0
Date
Flow (L/s)
10000
8000
6000
4000
2000
0
Date
Government data
LES data

Figure 6-51

S.McQuesten River Downstream from Flat Creek (S11)
(LES 4)

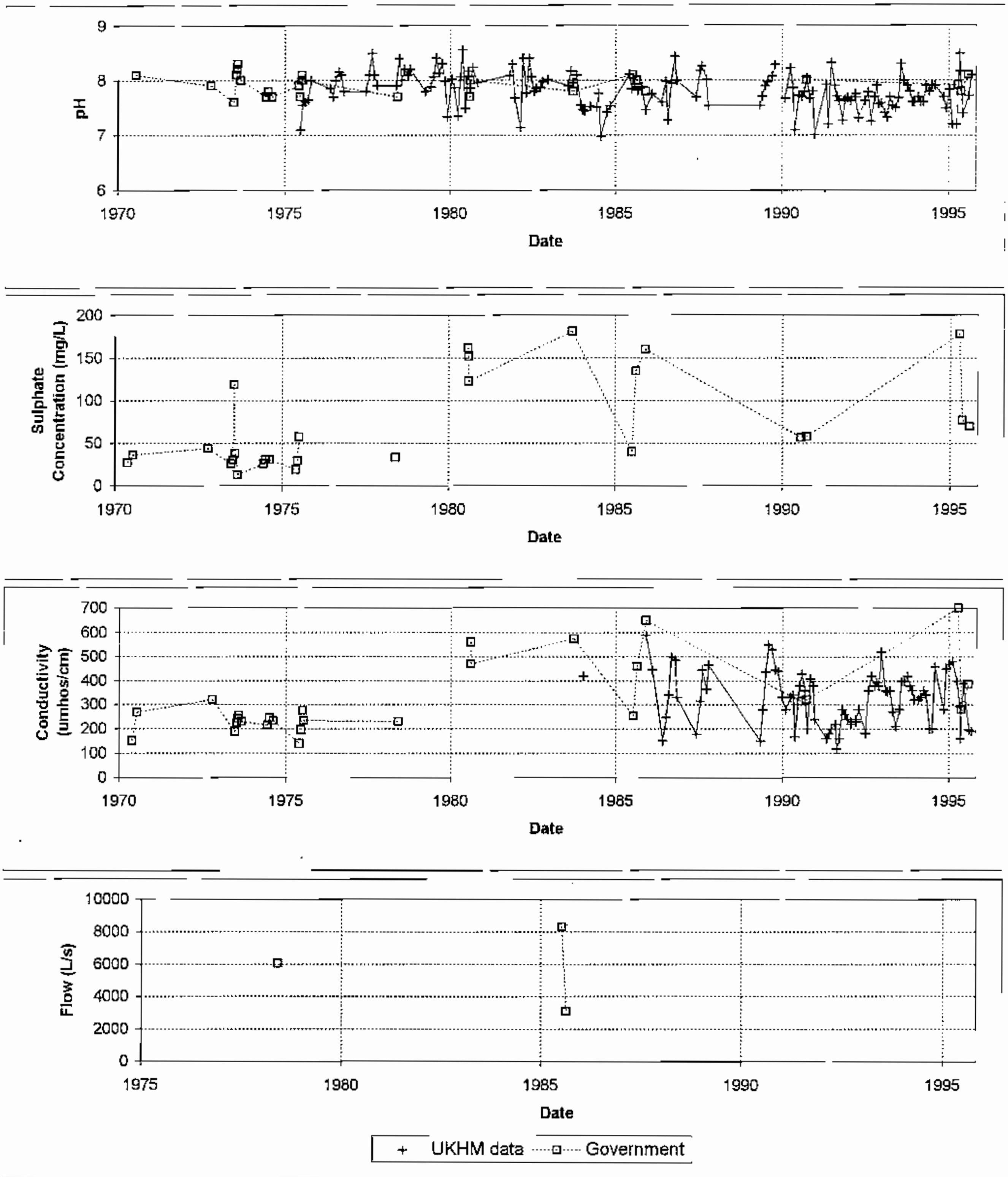


Figure 6-52

S.McQuesten River Downstream from Flat Creek (S11)
(LES 4)

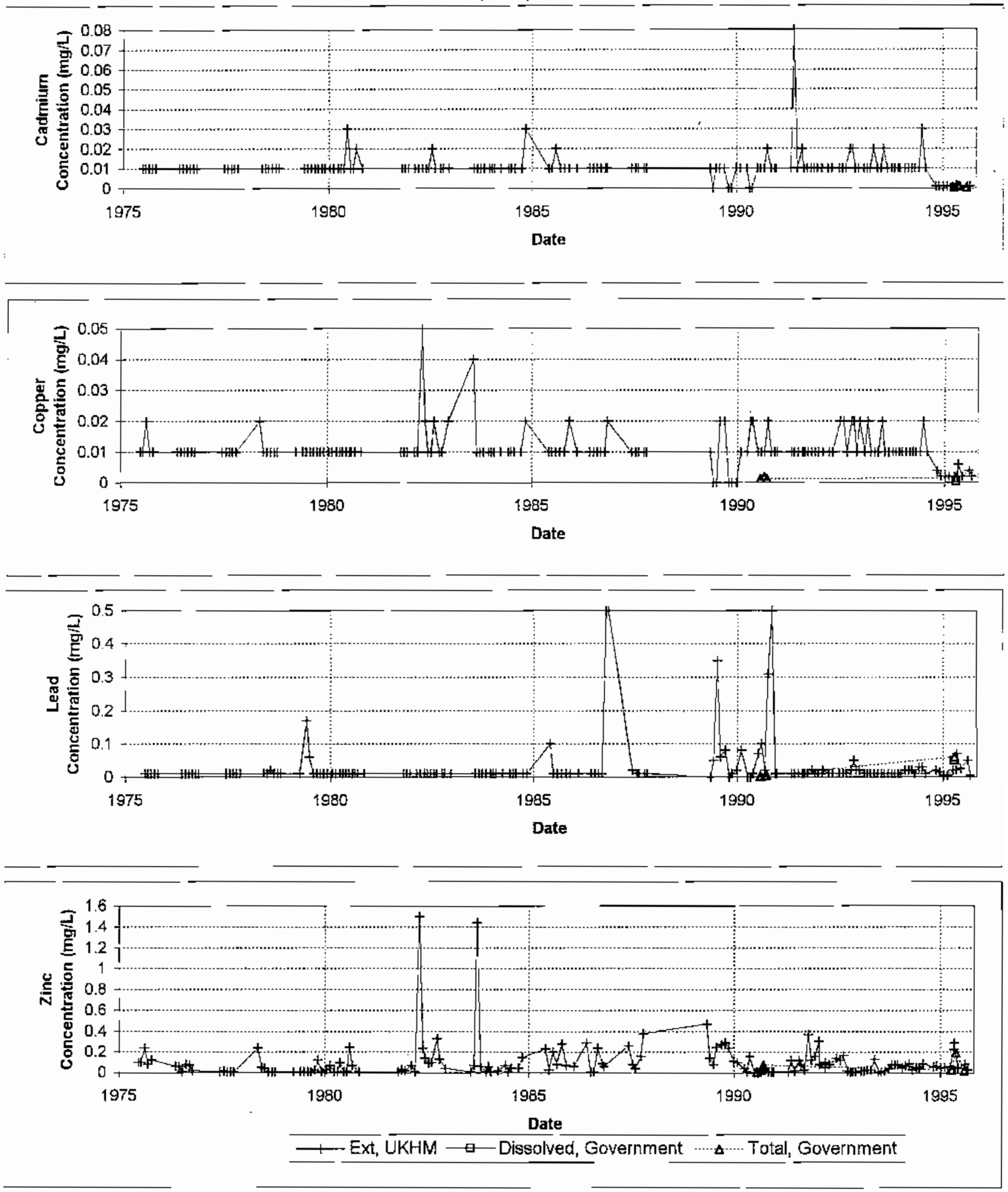


Figure 6-53

Flat Creek Upstream of S. McQuesten River (S9)
(LES 9)

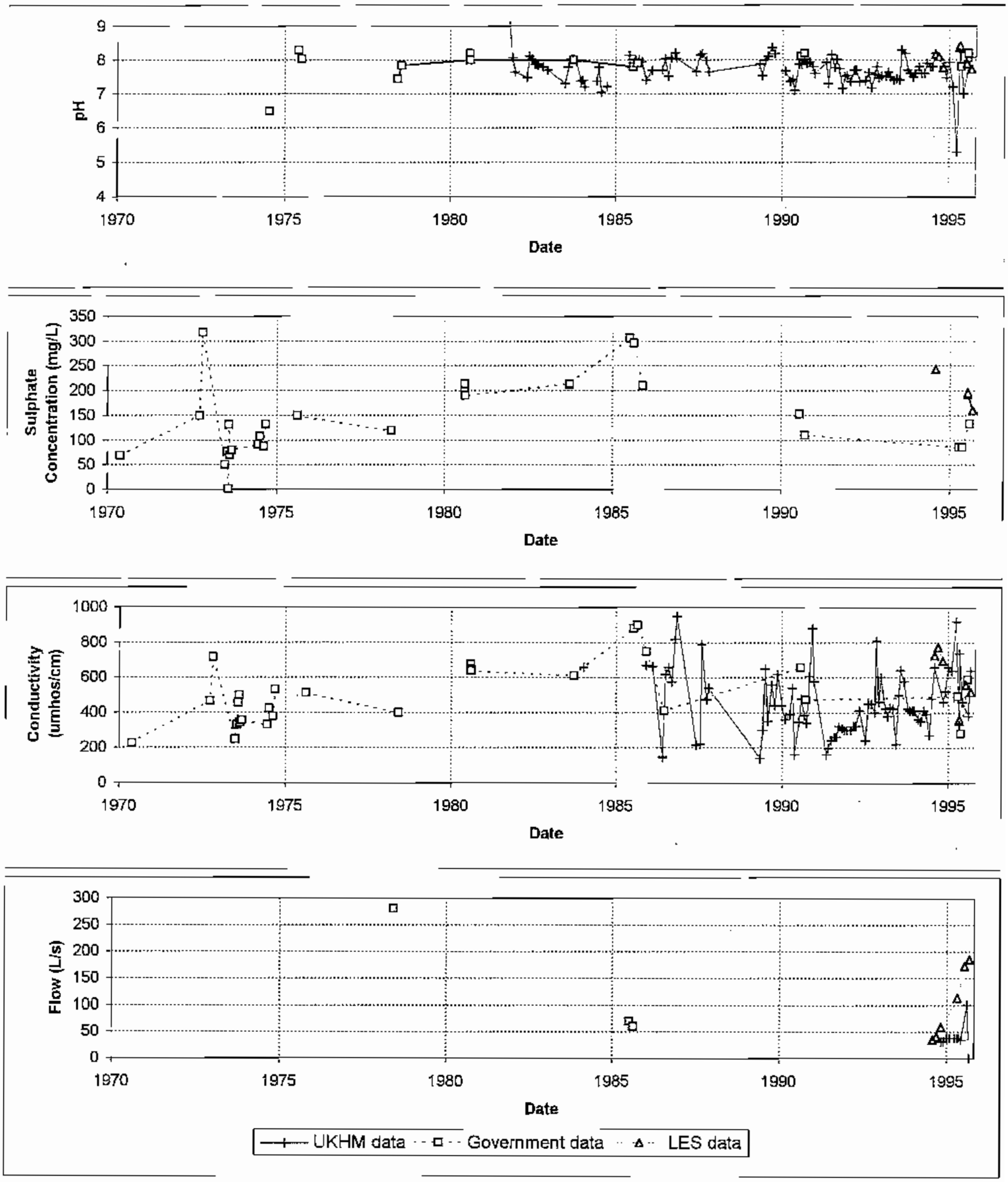
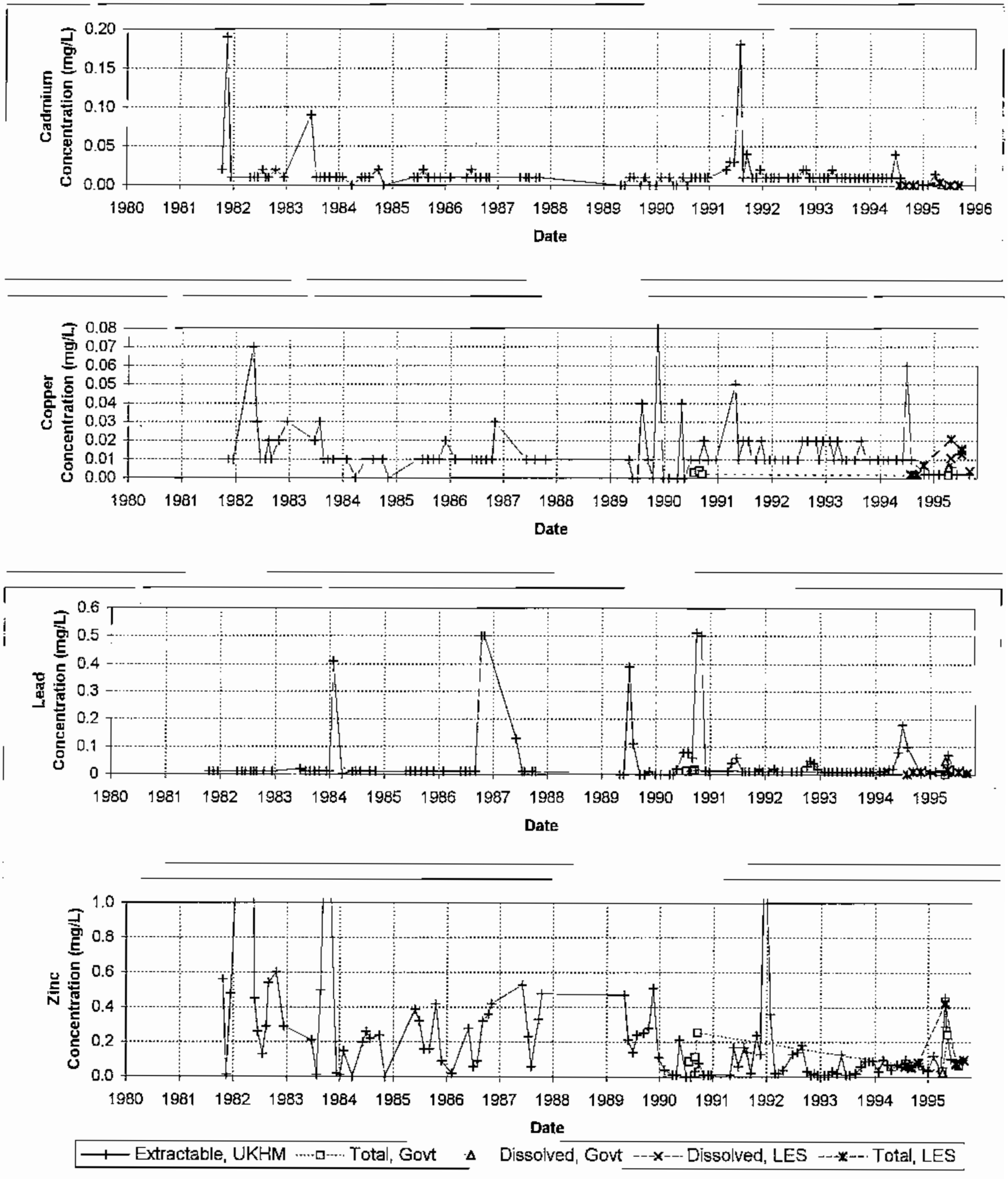
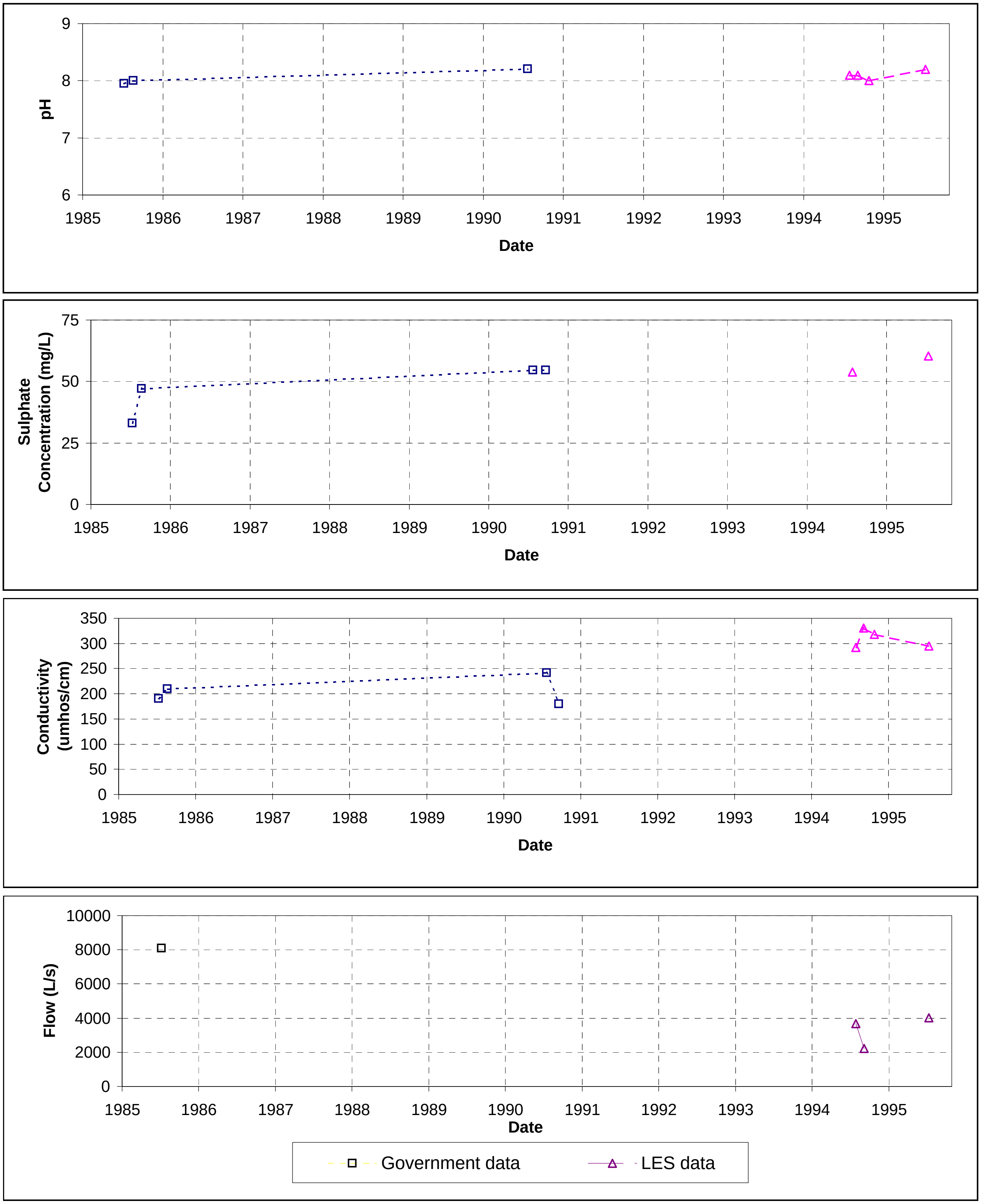


Figure 6-54

Flat Creek Upstream of S. McQuesten River (S9)
(LES 9)



S.McQuesten River 9K Downstream from Flat Creek
(LES 5)



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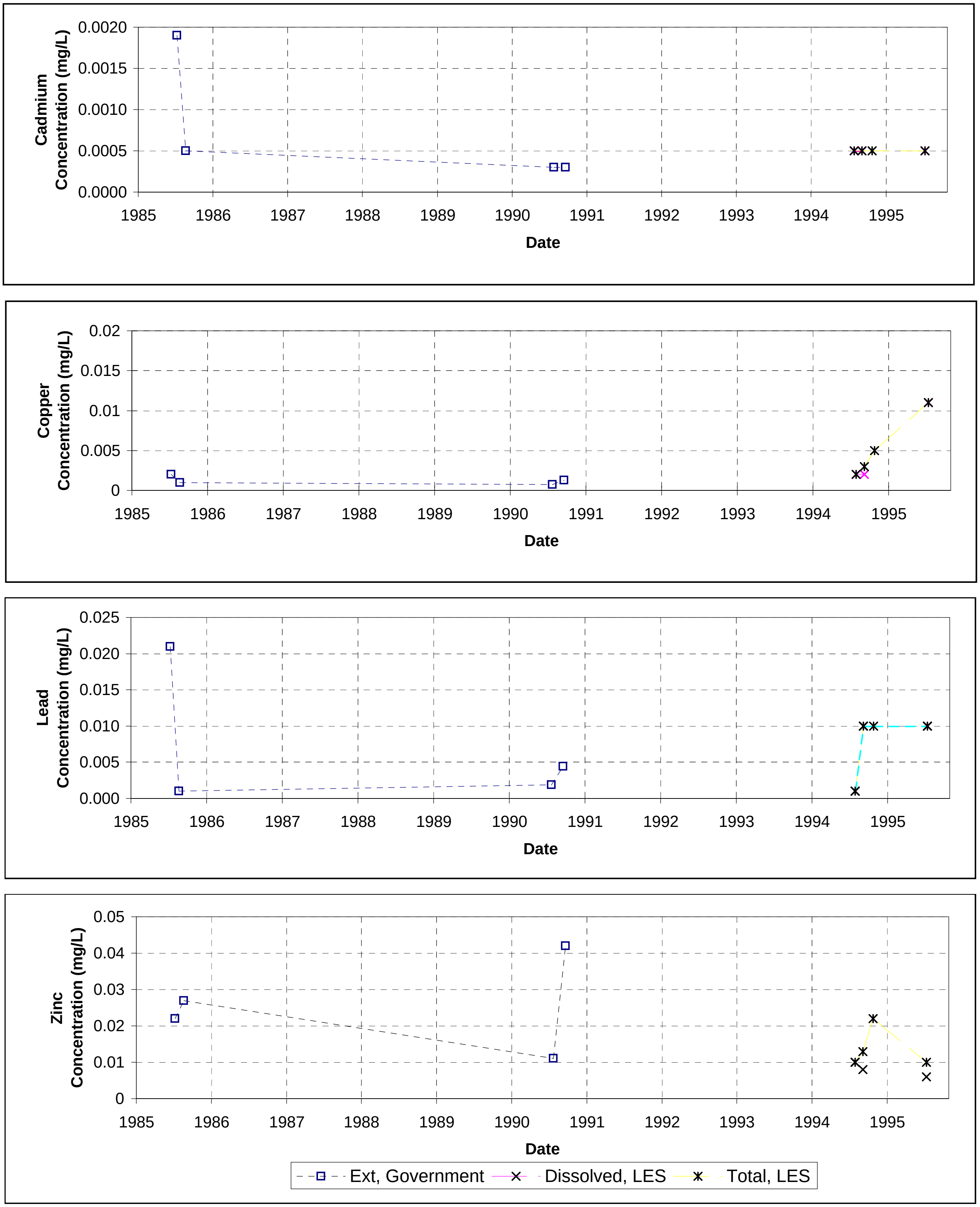
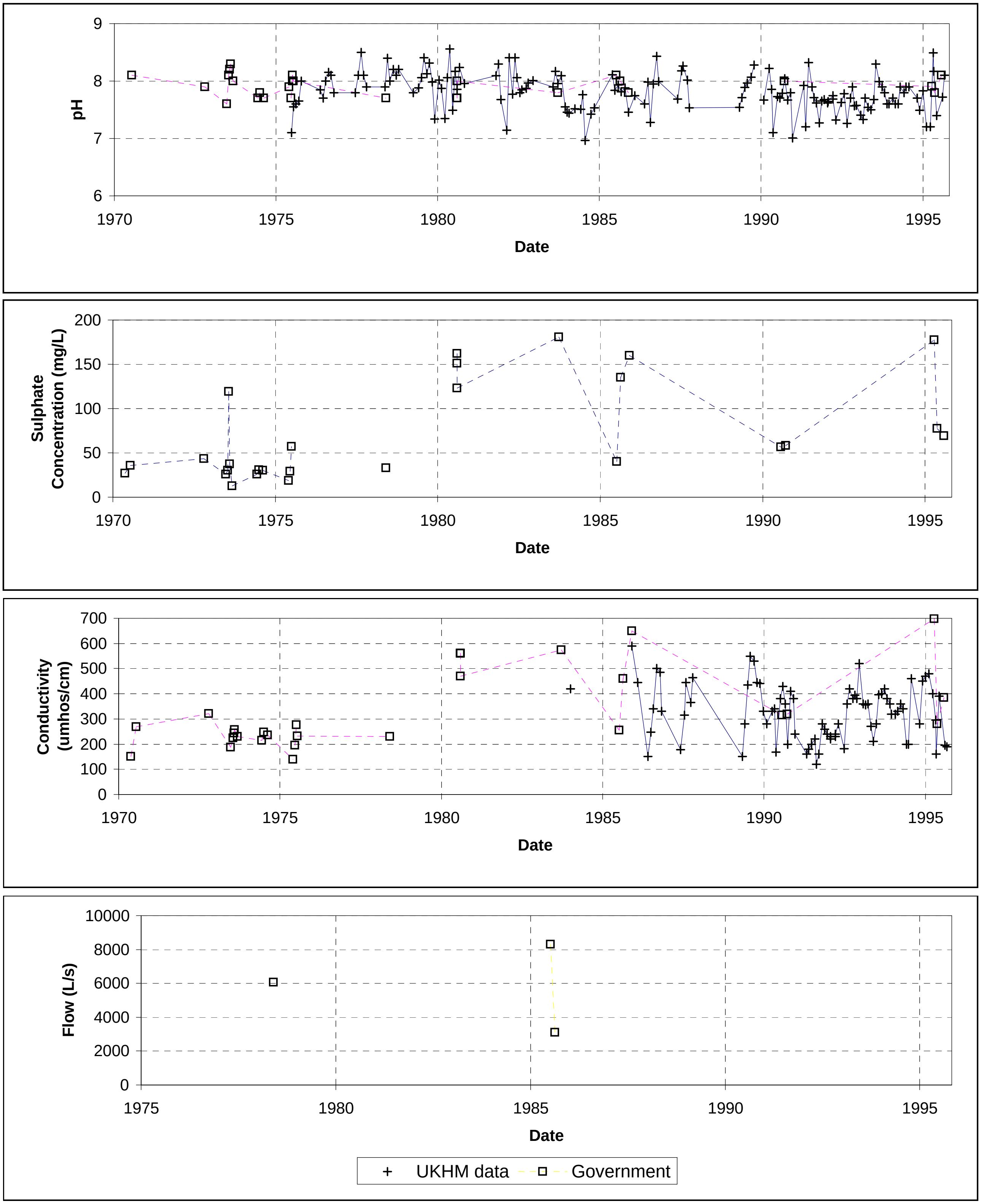
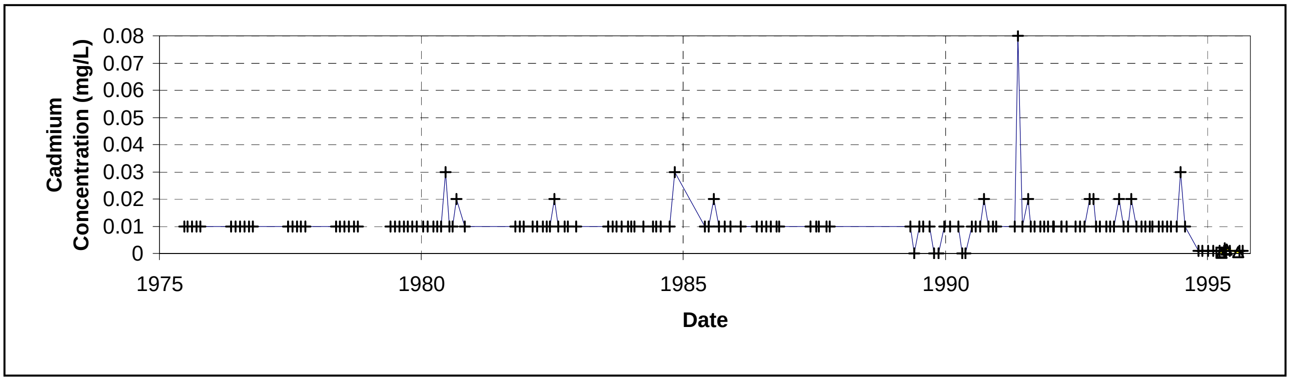
S.McQuesten River 9K Downstream from Flat Creek
(LES 5)

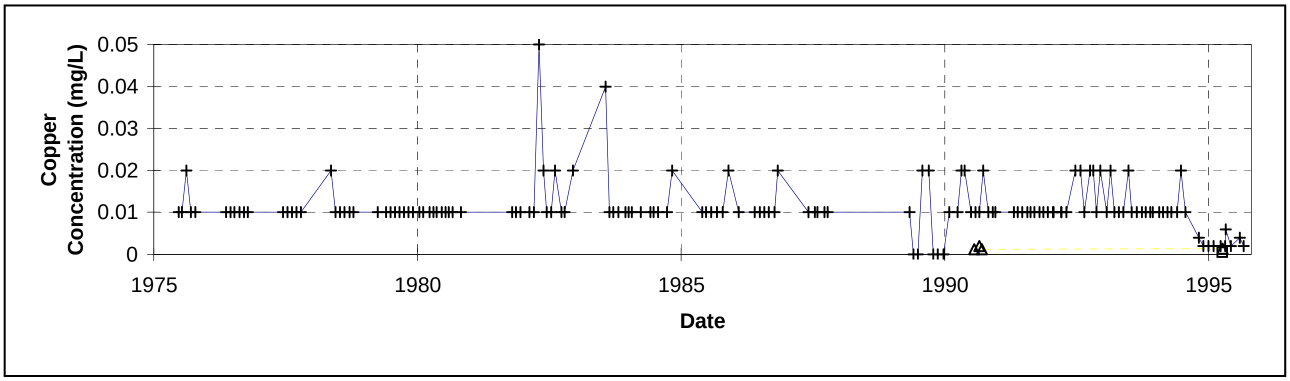


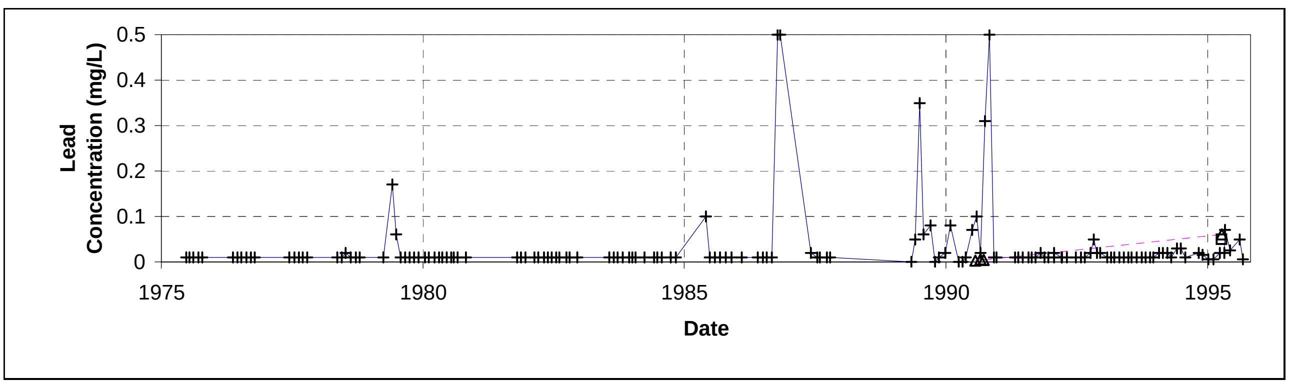
S.McQuesten River Downstream from Flat Creek (S11)
(LES 4)

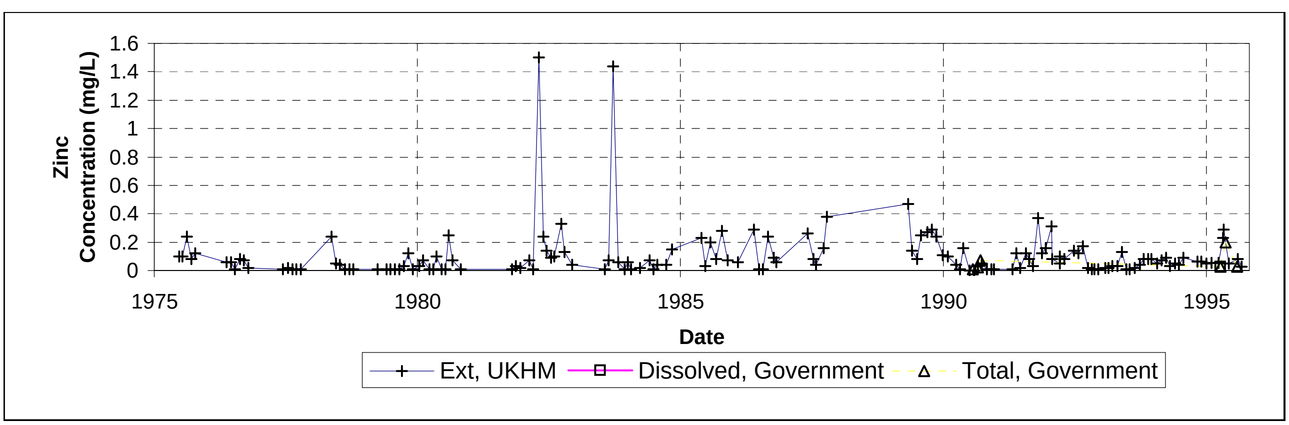


S.McQuesten River Downstream from Flat Creek (S11)
(LES 4)

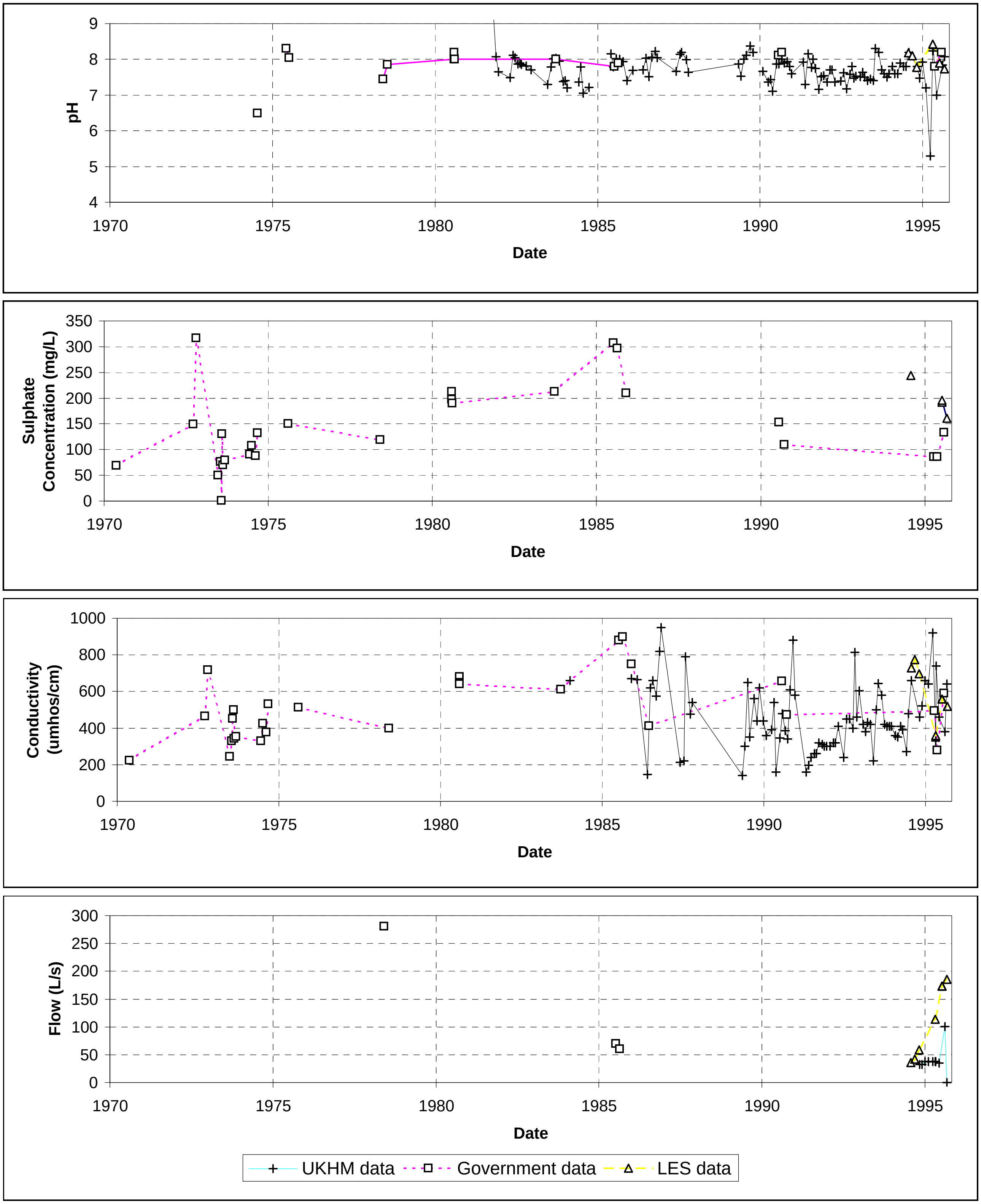








Flat Creek Upstream of S. McQuesten River (S9)
(LES 9)



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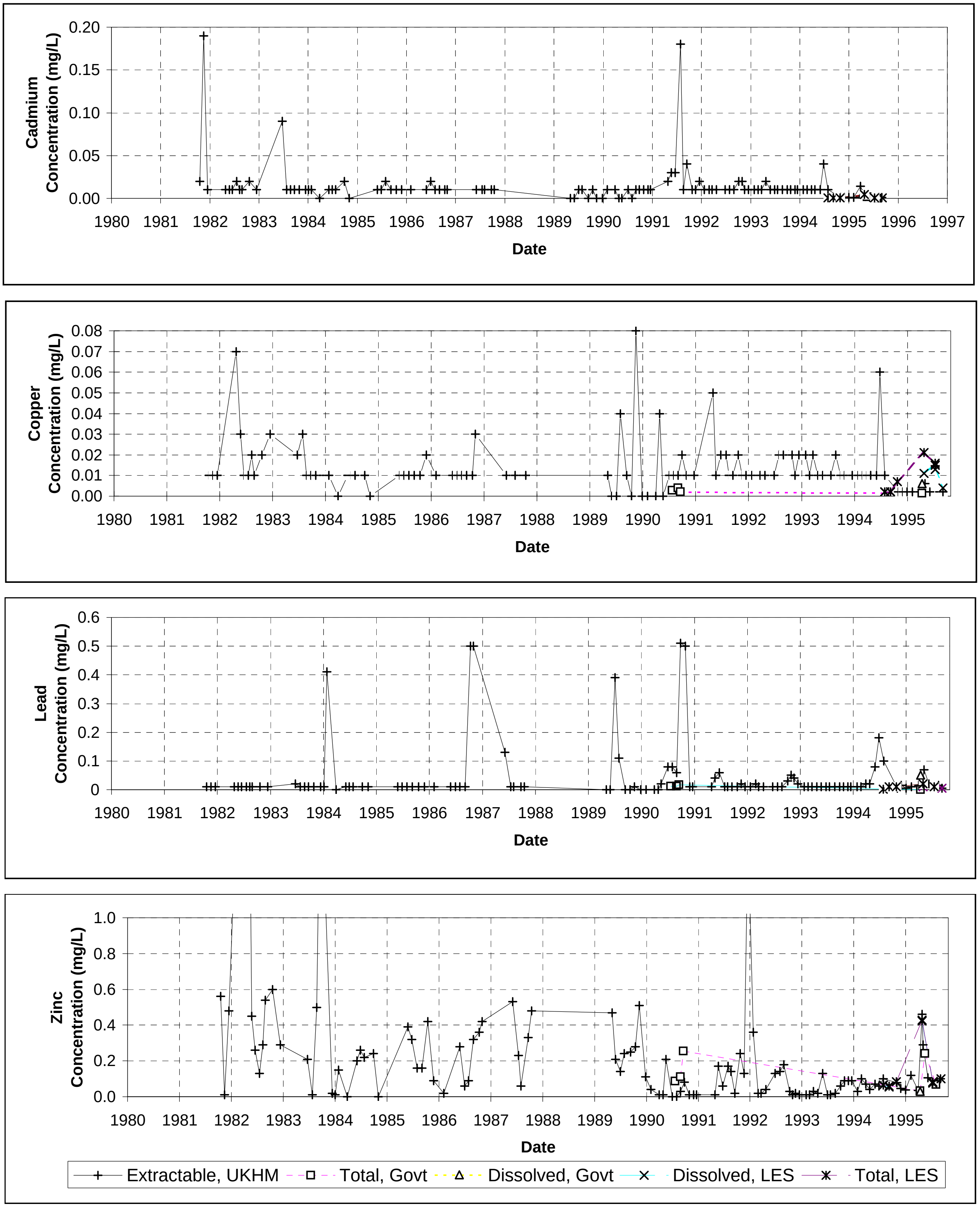
Flat Creek Upstream of S. McQuesten River (S9)
(LES 9)



7. Geochemical Testing Program

Geochemical testing programs were initiated on both tailings and waste rock samples. The objectives of the testing programs were to evaluate:

- the range of geochemical characteristics in the rocks of the different mines;
- the range of geochemical characteristics of the tailings;
- the potential for acid generation and acid rock drainage;
- the potential for metal leaching and therefore downstream adverse impacts on water quality; and,
- the extent to which oxidation, storage of soluble products, and leaching have occurred in the different rock types.

The importance of this testing is to provide a sound technical basis for prediction of long-term water quality concerns and, therefore, appropriate closure measures. However, it is very important to recognize that the most useful and representative "testing" data exists in the field; the waste dumps and tailings impoundments provide data on water chemistry after ten to 80 years of weathering. Laboratory data provide an indication of the potential for oxidation, leaching and neutralization reactions under "controlled" and sometimes enhanced weathering conditions. These data are also useful to interpret the results of field measurements.

7.1 Rock Sampling Program

Waste rock samples were collected primarily from the mines of Galena Hill, considered to be representative of the range of rock types in the district. The rock sampling locations were selected in consultation with the site geologists, to represent the geology of the site, as discussed in Section 3.2:

- the four major rock units (quartzite, schist, vein/ore, and greenstone);
- the "end-members" in terms of geochemical composition of each of these rock units;
- the vein material which was considered the most likely source of soluble metals;

- a range in spatial distribution within each of the rock units, particularly because of the understanding of changes in zinc and silver concentrations with depth; and,
- emphasis on sampling of rock types and dumps which represent the largest volume of rock and/or greatest potential concern with respect to contaminant loading.

The distribution of sampling locations is shown on the individual site plans in Chapter 5. The logs included in Appendix VIII also provide a description of the samples and the locations from which the samples were collected.

The samples were collected from both pit walls and waste dumps. The pit wall samples provide good examples of the individual rock types. The waste rock samples, in some cases were clearly individual rock types, but were also collected from excavations in the rock piles to determine weathering and soluble contaminant loads.

The sampling methods are noted on the sample logs provided in Appendix VIII. Most of the samples were collected as approximately 60 kg samples from sections of individual rock piles. Samples from the Ruby, Hector and Dixie dumps were collected from the face exposed in a dump or pile by excavation of a slot or trench with a backhoe.

Each of the sample locations was photographed. Particle size distributions of both the source rock pile, and of the sample at the laboratory, are evaluated as part of the kinetic testing program for calculations of surface area and contaminant loading.

7.2 Waste Rock Testing

The testing program includes:

- static testing to determine the geochemical characteristics of the different rock types;

  short-term extraction testing to quantify the soluble metal load and provide a basis for selecting samples for kinetic testing; and,

- kinetic testing of selected samples to compare leaching and flushing characteristics.

The static testing has been completed as have the short term leach extraction tests. The kinetic testing is in progress. The test results are provided in detail in Appendix VIII and summarized below.

7.3 Waste Rock Geochemistry

The waste rock samples are grouped according to two descriptors; the rock type and a colour or mineralogy description. The four rock types are based on the geologic descriptions in Chapter 3, are quartzite, schist, vein material and greenstone. In addition, there were samples collected of mixed quartzite and schist. The descriptions used were in terms of colour (buff, grey, and “rust” coloured weathering, primarily referring to the quartzites) and “pyritic” for samples with visible pyrite. The solid geochemistry for each of the rock types is also discussed in Chapter 3.

Static and short-term extraction tests are particularly meaningful for this site as the waste dumps are generally at least 20 years old, up to 80 years, representing a better “kinetic” test than any laboratory simulation. Field paste pH and conductivity measurements are similarly useful in understanding oxidation and neutralization over time in the field.

The metal contents of the solids are used primarily to interpret the extraction and kinetic testing. They are also useful to identify potential contaminants of concern with respect to water chemistry, and to interpret the sources of contaminants from receiving water monitoring. With the extensive water chemistry database, the solids analyses will be most useful once the longer term kinetic testing results are available.

For acid base accounting on waste rock samples it is generally considered that a sample is acid consuming if the ratio of neutralization potential to acid potential (expressed as NP/AP in the data tables) is 3:1 or greater. A sample is considered potentially acid consuming if the ratio is 1:1 or less. Between the 3:1 and 1:1 range, field data or kinetic testing are required to determine if net acidic drainage would result from oxidation of the sample.

Field testing of paste pH and paste conductivity (or total dissolved solids) was used to assist in sample selection. A range of samples of each rock type, from several different mines, was field tested. The samples for laboratory testing were then selected to represent the range of these values, with emphasis on samples with low pH and/or high conductivity, i.e. most likely to contribute contaminants.

7.3.1 Quartzite

Quartzite represents the majority of the waste rock on site and therefore sampling emphasized this rock type. Fresh quartzite ranges in colour from white through to dark grey. The majority of the quartzite on site weathers to a buff colour, with variations being a reddish “rusty” surface weathering or grey quartzite. Some of the quartzite samples contained visible pyrite.

The majority of the quartzite in the rock piles is coarse, competent rock with generally 80% in the plus 2” fraction. These estimates are based on field sampling and laboratory screen analysis of selected samples. Samples with more fines generally have higher sulphide and metals contents.

7.3.1.1 Quartzite - buff and “rusty” weathering

The buff quartzite and the rusty weathering variation represent the majority of the waste rock on site, particularly on Galena Hill. Certainly the open pit dumps are primarily quartzite. The largest dumps, the Berminhgam waste rock dumps, are estimated to be at least 95% buff quartzite.

The results of the acid base accounting and ICP analysis on the solids are presented in detail in Appendix VIII, and summarized in Tables 7-1 and 7-2.

Table 7-1 Galena & Keno Hill Rock Acid Base Accounting

LOCATION	SAMPLE ID	PASTE pH	S (tot.) %	S (SO_4) %	AP kg $CaCO_3$/tonne	NP kg $CaCO_3$/tonne	NET NP kg $CaCO_3$/t	NP/AP
DIXIE	95UKHDD01	4.14	0.35	0.28	2.19	0.00	-2.2	<0.1
adit dump	95UKHDD02	4.44	0.51	0.34	5.31	2.25	-3.1	0.4
	95UKHDD03	5.55	0.47	0.42	1.56	13.56	12.0	8.7
Average		4.71	0.44	0.35	3.02	5.27		
Std. Dev.		0.74	0.08	0.07	2.01	7.27		
Median		4.44	0.47	0.34	2.19	2.25		
Count		3	3	3	3	3		
BERMINGHAM	95UKHBP01	7.05	0.09	0.09	0.00	1.50	1.5	---
pit wall	95UKHBP02	7.09	0.07	0.07	0.00	1.75	1.8	---
	95UKHBP03	6.94	0.21	0.20	0.31	0.00	-0.3	<0.1
	95UKHBP04	6.89	0.04	0.03	0.31	0.25	-0.1	0.8
	95UKHBP05	6.87	0.07	0.06	0.31	1.56	1.3	5.0
	95UKHBP06	8.03	0.95	0.27	21.3	70.1	48.9	3.3
	95UKHBP07	8.68	0.19	0.16	0.94	9.63	8.7	10.3
BERMINGHAM	95UKHBD01	7.34	0.30	0.30	0.00	6.00	6.0	---
pit dump	95UKHBD02	7.20	0.32	0.31	0.31	7.19	6.9	23.0
	95UKHBD03	6.62	1.94	0.69	39.1	155.6	116.6	4.0
	95UKHBD04	7.24	0.49	0.21	8.75	14.13	5.4	1.6
	95UKHBD05	7.56	2.50	0.54	61.3	144.4	83.1	2.4
	95UKHBD06	7.32	0.07	0.07	0.00	0.00	0.0	---
Average		7.29	0.56	0.23	10.19	31.7		
Std. Dev.		0.55	0.79	0.20	19.27	55.8		
Median		7.20	0.21	0.20	0.31	6		
Maximum		8.68	2.50	0.69	61.25	155.6		
Minimum		6.62	0.04	0.03	0.00	0		
Count		13	13	13	13	13		
RUBY	95UKHRD01	7.82	1.06	0.43	19.69	36.25	16.6	1.8
adit dump	95UKHRD02	7.83	0.72	0.28	13.75	51.13	37.4	3.7
	95UKHRD03	7.02	0.66	0.32	10.63	15.00	4.4	1.4
Average		7.56	0.81	0.34	14.69	34.125		
Std. Dev.		0.46	0.22	0.08	4.60	18.156		
Median		7.82	0.72	0.32	13.75	36.25		
Count		3	3	3	3	3		

Table 7-1 Galena & Keno Hill Rock Acid Base Accounting

LOCATION	SAMPLE ID	PASTE pH	S (tot.) %	S (SO_4) %	AP kg $CaCO_3$/tonne	NP kg $CaCO_3$/tonne	NET NP kg $CaCO_3$/t	NP/AP
CALUMET	95UKHCD01	6.55	0.05	0.05	0.00	0.63	0.6	---
1-14 pit dump	95UKHCD02	5.54	0.41	0.41	0.00	0.00	0.0	---
CALUMET	95UKHCP01	5.75	0.09	0.06	0.94	0.25	-0.7	0.3
1-15 pit wall	95UKHCP02	6.83	0.04	0.04	0.00	0.38	0.4	---
CALUMET	95UKHCD04	6.82	0.01	0.01	0.00	0.63	0.6	---
1-15 pit dump	95UKHCD03	6.34	0.12	0.11	0.31	0.87	0.6	2.8
Average		6.31	0.12	0.11	0.21	0.46		
Std. Dev.		0.55	0.15	0.15	0.38	0.31		
Median		6.45	0.07	0.06	0.00	0.50		
Maximum		6.83	0.41	0.41	0.94	0.87		
Minimum		5.54	0.01	0.01	0.00	0		
Count		6	6	6	6	6		
HECTOR	95UKHHD01	6.01	2.10	0.48	50.63	0	-50.6	<0.10
adit dump	95UKHHD02	6.35	1.92	0.31	50.31	47.75	-2.6	0.9
	95UKHHD03	6.94	0.84	0.26	18.13	32.38	14.3	1.8
Average		6.43	1.62	0.35	39.69	26.708		
Std. Dev.		0.47	0.68	0.12	18.68	24.374		
Median		6.35	1.92	0.31	50.31	32.375		
Count		3	3	3	3	3		
SIME 6	95UKHSP01	6.15	0.09	0.07	0.63	1.75	1.1	2.8
pit wall	95UKHSP02	6.49	0.03	0.03	0.00	0.75	0.8	---
SIME 4 pit wall	95UKHSP03	6.57	<0.01	<0.01	0.00	0.81	0.8	---
SIME 35	95UKHSP04	6.47	0.11	0.11	0.00	2.50	2.5	---
pit wall	95UKHSP05	7.08	0.02	0.01	0.31	0.00	-0.3	<0.10
SIME 4 & 6 pit dump	95UKHSD01	7.08	0.04	<0.01	1.09	1.38	0.3	1.3
Average		6.64	0.05	0.04	0.34	1.20		
Std. Dev.		0.37	0.04	0.04	0.45	0.87		
Median		6.53	0.04	0.02	0.16	1.09		
Maximum		7.08	0.11	0.11	1.09	2.50		
Minimum		6.15	<0.01	<0.01	0.00	0.00		
Count		6	6	6	6	6		

Table 7-1 Galena & Keno Hill Rock Acid Base Accounting

LOCATION	SAMPLE ID	PASTE pH	S (tot.) %	S (SO_4) %	AP kg $CaCO_3$/tonne	NP kg $CaCO_3$/tonne	NET NP kg $CaCO_3$/t	NP/AP
ONEK pit	95UKHOP02	8.49	0.16	0.08	2.50	0.00	-2.5	<0.10
ONEK	95UKHOD01	8.08	0.13	0.12	0.31	0.00	-0.3	<0.10
pit dump	95UKHOD02	7.62	0.01	<0.01	0.16	1.63	1.5	10.2
	95UKHOD03	8.16	0.23	0.17	1.88	52.25	50.4	27.9
Average		8.09	0.13	0.10	1.21	13.469		
Std. Dev.		0.36	0.09	0.07	1.16	25.866		
Median		8.12	0.15	0.10	1.09	0.81		
Count		4	4	4	4	4		
KENO 700	95UKHKD01	8.03	1.03	0.16	27.19	47.00	19.8	1.7
adit dump	95UKHKD02	8.22	0.45	0.16	9.06	10.94	1.9	1.2
UN adit dump	95UKHUD01	7.69	0.08	0.06	0.63	1.56	0.9	2.5
TOWNSITE	95UKHTD01	6.33	1.16	0.11	32.81	0.00	-32.8	<0.10
adit dump	95UKHTD02	6.78	0.33	0.26	2.19	0.00	-2.2	<0.10
HUSKY S.W. shaft dump	95UKHWD01	3.72	0.96	0.28	21.25	0.00	-21.3	<0.10
HUSKY shaft dump	95UKHYD01	3.69	7.76	0.09	239.69	0.00	-239.7	<0.10
MILLER pit dump	95UKHMD01	6.43	0.03	0.02	0.31	0.38	0.1	1.2
BELLEKENO adit dump	95UKHLD01	8.05	0.50	0.22	8.75	130.00	121.3	14.9
SILVER KING pit dump	95UKHVD01	7.36	0.06	0.03	0.94	0.00	-0.9	<0.10

Table 7-2 Galena & Keno Hill Rock Sampling ICP Data

LOCATION	SAMPLE ID	As ppm	Ca %	Cd ppm	Co ppm	Cr ppm	Cu ppm	Fe %	Mn ppm	Pb ppm	Sb ppm	Zn ppm
QUARTZITE SAMPLES												
CALUMET	95UKHCD03	189	0.03	6.8	4	47	192	2.53	2193	>10000	168	805
CALUMET	95UKHCP02	25	0.11	0.3	1	55	6	0.55	30	380	4	99
DIXIE	95UKHDD01	1	0.38	0.1	4	95	13	1.59	470	176	15	336
DIXIE	95UKHDD03	1	1.03	0.1	5	90	13	1.17	257	65	3	186
HECTOR	95UKHHD01	1	0.79	>100	16	1	162	10.42	>10000	2768	114	>10000
HECTOR	95UKHHD02	1	1.07	>100	12	1	32	8.76	>10000	852	51	>10000
KENO 700	95UKHKD01	1	2.03	>100	7	41	51	2.66	6094	2473	53	>10000
MILLER	95UKHMD01	1	0.06	11.3	3	41	13	1.55	5094	462	5	902
RUBY	95UKHRD01	1	1.92	0.1	13	49	25	2.14	3450	162	5	439
RUBY	95UKHRD02	1	2.19	10.4	5	62	54	1.6	1810	1339	46	646
RUBY	95UKHRD03	1	1.13	0.1	16	43	77	2.72	1192	559	8	460
SILVER KING	95UKHVD01	39	0.07	0.1	2	62	11	0.61	22	28	2	20
SIME 4	95UKHSP03	62	0.01	2	1	48	5	0.2	13	205	6	36
BERMINGHAM	95UKHBD06	1	0.05	5.7	2	53	17	0.68	993	778	15	218
BERMINGHAM	95UKHBP03	126	0.08	0.6	16	8	18	9.98	7175	1097	1	2237
BERMINGHAM	95UKHBP05	1	0.05	4.6	1	29	10	0.81	2068	352	2	313
CALUMET	95UKHCD01	44	0.01	0.1	3	59	97	1.35	520	>10000	51	376
CALUMET	95UKHCD02	114	0.03	1.5	12	1	575	10.52	>10000	>10000	360	3516
ONEK	95UKHOD02	66	0.05	0.1	1	45	34	0.46	69	198	2	96
SIME 4 & 6	95UKHSD01	1	0.08	8.6	2	44	6	0.47	927	126	3	334
SIME 6	95UKHSP02	1	0.02	0.1	2	51	13	0.89	43	874	7	106
TOWNSITE	95UKHTD01	1	0.4	94.6	7	37	37	2.57	5781	1213	23	5632
BERMINGHAM	95UKHBP01	1	0.21	0.1	9	82	48	2.32	620	186	4	311
BERMINGHAM	95UKHBP02	1	0.23	21.6	6	46	20	1.79	2172	84	12	595
BELLEKENO	95UKHLD01	81	5.47	0.1	3	68	6	0.61	129	123	3	31
HUSKY	95UKHYD01	226	0.03	0.1	10	52	15	5.49	81	129	1	94
HUSKY S.W.	95UKHWD01	1	0.19	0.1	10	66	23	2.16	438	400	8	62
Average		36.6	0.66	17.4	6.41	47.3	58.3	2.837	2653	1668	36	1772.2
Median		1	0.11	0.6	5	48	20	1.6	993	400	7	336
Maximum		226	5.47	>100	16	95	575	10.52	>10000	>10000	360	>10000
Minimum		1	0.01	0.1	1	1	5	0.2	13	28	1	20
Count		27	27	27	27	27	27	27	27	27	27	27

Table 7-2 Galena & Keno Hill Rock Sampling ICP Data

LOCATION	SAMPLE ID	As ppm	Ca %	Cd ppm	Co ppm	Cr ppm	Cu ppm	Fe %	Mn ppm	Pb ppm	Sb ppm	Zn ppm
SCHIST SAMPLES												
BERMINGHAM	95UKHBP07	1	0.51	0.1	8	49	23	2.27	335	49	1	78
BERMINGHAM	95UKHBD04	1	0.2	>100	9	5	105	5.35	>10000	>10000	110	3468
BERMINGHAM	95UKHBP06	1	2.38	0.1	9	67	20	1.67	549	19	1	77
CALUMET	95UKHCP01	1	0.03	0.1	4	53	45	3	28	534	5	483
HECTOR	95UKHHD03	1	1.07	50.6	8	60	48	2.93	9328	1000	50	4054
KENO 700	95UKHKD02	1	0.73	9.8	13	48	108	2.45	3415	808	9	1460
ONEK	95UKHOD03	1	2.47	0.1	10	44	23	2.45	200	40	1	85
SIME 6	95UKHSP01	15	0.29	1.3	4	42	45	2.5	258	1160	15	747
Average		2.75	0.96	20.3	8.13	46	52.1	2.83	3014.1	1701.3	24	1306.5
Std. Dev.		4.95	0.96	36.6	3	18.5	35.4	1.10	4251.3	3383.4	38	1592.3
Median		1	0.62	0.7	8.5	48.5	45	2.48	442	671	7	615
Maximum		15	2.47	>100	13	67	108	5.35	>10000	>10000	110	4054
Minimum		1	0.03	0.1	4	5	20	1.67	28	19	1	77
Count		8	8	8	8	8	8	8	8	8	8	8
VEIN SAMPLES												
BERMINGHAM	95UKHBD01	1	0.2	>100	11	1	146	8.23	>10000	6503	164	2103
BERMINGHAM	95UKHBD02	1	0.4	65.2	11	1	78	5.43	>10000	3864	76	1324
BERMINGHAM	95UKHBD03	1	0.98	>100	25	1	156	>15.00	>10000	>10000	180	>10000
BERMINGHAM	95UKHBD05	1	3.02	>100	30	1	123	13.02	>10000	3073	77	8800
CALUMET	95UKHCD04	1	0.06	25.3	2	30	14	0.73	1512	357	9	643
Average		1	0.93	78.1	15.8	6.8	103	8.48	8302	4759	101	4574
Std. Dev.		0	1.22	33.1	11.4	13	58.3	5.76	3796	3658	70	4455.9
Median		1	0.4	>100	11	1	123	8.23	>10000	3864	77	2103
Maximum		1	3.02	>100	30	30	156	15	>10000	>10000	180	>10000
Minimum		1	0.06	25.3	2	1	14	0.73	1512	357	9	643
Count		5	5	5	5	5	5	5	5	5	5	5

Table 7-2 Galena & Keno Hill Rock Sampling ICP Data

LOCATION	SAMPLE ID	As	Ca	Cd	Co	Cr	Cu	Fe	Mn	Pb	Sb	Zn
		ppm	%	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm
MIXED SCHIST AND QUARTZITE												
BERMINGHAM	95UKHBP04	1	0.03	0.1	3	57	6	0.81	235	45	3	83
DIXIE	95UKHDD02	1	0.27	5.8	4	72	24	1.93	4454	567	18	771
ONEK pit	95UKHOP02	15	1.4	0.1	6	63	9	0.93	410	20	1	498
TOWNSITE	95UKHTD02	79	0.18	53.8	6	50	339	3.61	2681	>10000	571	1882
UN adit dump	95UKHUD01	1	0.14	0.1	4	35	48	1.94	55	660	11	220
Average		19.4	0.4	12	4.6	55.4	85.2	1.84	1567	2258	121	690.8
Std. Dev.		33.9	0.56	23.5	1.34	14	143	1.12	1935	4338	252	716.53
Median		1	0.18	0.1	4	57	24	1.93	410	567	11	498
Maximum		79	1.4	53.8	6	72	339	3.61	4454	>10000	571	1882
Minimum		1	0.03	0.1	3	35	6	0.81	55	20	1	83
Count		5	5	5	5	5	5	5	5	5	5	5
GREENSTONE SAMPLE												
ONEK	95UKHOD01	1	0.93	0.1	23	99	129	3.26	568	14	1	190
SIME 35	95UKHSP04	1	0.32	0.1	8	51	36	3.62	324	1380	8	676
SIME 35	95UKHSP05	22	0.03	0.1	1	53	4	0.41	60	15	3	93

Field measurements of paste pH and conductivity on these dumps are consistent across the site with neutral to alkaline paste pH values and conductivity values generally less than 100 μS/cm. These suggest that the rocks are relatively inert in terms of both oxidation and leaching potential, as would be expected for material which is primarily quartz.

The eleven buff/rusty weathering quartzite samples are considered typical of quartzite:

- essentially inert rocks being almost entirely quartz;
- very low sulphur, primarily occurring as sulphate minerals, with a median value of 0.07% total sulphur and 0.06% sulphate sulphur (eleven samples);
- very low carbonate content; and,
- the two samples with higher sulphur contents (above 0.1%) are a Calumet and a Townsite sample, both of which may have contained some pyritic quartzite or vein material.

ICP analyses on the solids show:

- generally low metals in the solids;
- higher metals in two samples, one each of the Calumet and Townsite, in which zinc, iron, manganese, and lead were elevated compared to the other quartzite samples; and,
- elevated zinc, manganese, lead, arsenic and iron in one Bermingham sample, probably contributed by the graphitic schist mixed with the quartzite.

Short term extraction tests were done on six of the buff and rusty weathering quartzite samples, selected to represent both the larger dumps with a high percentage of this rock type, and to represent the range of metal concentrations in the solids. The results are summarized in Table 7-3 and show:

- the sulphate in the solids is contained in relatively insoluble minerals in all samples, with the exception of the Townsite sample;
- the only significant leaching was seen from the Townsite sample with zinc and manganese being the two metals of note in the leachate; and,
- this Townsite sample also showed the highest alkalinity at 159 mg/L $CaCO_3$ eq, indicating that net acidic conditions have not developed.

Insert table 7-3 page 1

Table 7-3 Galena & Keno Hill Waste Rock Extraction Test Results

LOCATION	SAMPLE ID	PASTE	S (tot.)	Rock	Descrip.	Concentrations mg/L										
		pH	%	Type		pH	SO4	Al	As	Cd	Ca	Co	Fe	Pb	Mn	Zn
CALUMET 1-15 pit dump	95UKHCD04	6.82	0.01	1	10	5.7	4	<0.20	<0.20	<0.010	0.55	<0.015	<0.030	<0.050	0.03	0.031
DIXIE adit dump	95UKHDD03	5.55	0.47	1	10	2.9	1504	37.7	<0.20	0.741	338	0.159	25.8	<0.050	18.6	52.1
HECTOR adit dump	95UKHHD01	6.01	2.10	1	10	2.3	1845	42.5	3.58	0.017	18.9	0.137	520	0.557	2.84	1.25
HECTOR adit dump	95UKHHD02	6.35	1.92	1	10	6.9	883	<0.20	<0.20	0.323	259	<0.015	<0.030	<0.050	1.15	6.68
KENO 700 adit dump	95UKHKD01	8.03	1.03	1	10	7.0	92	<0.20	<0.20	0.217	35.6	<0.015	<0.030	0.078	0.029	6.65
RUBY adit dump	95UKHRD01	7.82	1.06	1	10	7.7	1540	<0.20	<0.20	<0.010	384	<0.015	<0.030	<0.050	0.033	0.047
RUBY adit dump	95UKHRD02	7.83	0.72	1	10	6.5	691	<0.20	<0.20	0.38	233	<0.015	<0.030	0.279	2.32	7.3
SIME 4 pit wall	95UKHSP03	6.57	<0.01	1	10	5.8	<3	<0.20	<0.20	<0.010	0.48	<0.015	<0.030	<0.050	0.025	0.01
SILVER KING pit dump	95UKHVD01	7.36	0.06	1	10	6.0	131	<0.20	<0.20	<0.010	34.5	<0.015	<0.030	<0.050	0.373	0.013
BERMINGHAM pit wall	95UKHBP05	6.87	0.07	1	11	6.5	5	<0.20	<0.20	<0.010	1.08	<0.015	<0.030	<0.050	0.422	0.039
CALUMET 1-14 pit dump	95UKHCD01	6.55	0.05	1	11	5.2	<3	<0.20	<0.20	<0.010	1.65	<0.015	<0.030	8.89	0.1	0.167
ONEK pit dump	95UKHOD02	7.62	0.01	1	11	6.2	<3	<0.20	<0.20	<0.010	0.35	<0.015	<0.030	<0.050	0.021	0.045
SIME 4 & 6 pit dump	95UKHSD01	7.08	0.04	1	11	6.2	<3	<0.20	<0.20	0.064	1.12	<0.015	<0.030	<0.050	<0.005	0.316
SIME	95UKHSP02	6.49	0.03	1	11	5.9	<3	<0.20	<0.20	<0.010	0.37	<0.015	<0.030	<0.050	0.033	0.013
TOWNSITE adit dump	95UKHTD01	6.33	1.16	1	11	5.3	370	<0.20	<0.20	2.01	26.3	0.1	<0.030	0.384	100	81.4
BERMINGHAM pit wall	95UKHBP02	7.09	0.07	1	12	6.8	5	<0.20	<0.20	<0.010	1.86	<0.015	<0.030	<0.050	<0.005	0.008
BELLEKENO adit dump	95UKHLD01	8.05	0.50	1	15	7.1	23	<0.20	<0.20	<0.010	21.3	<0.015	<0.030	<0.050	0.1	0.017

The buff and rusty weathering quartzite is essentially inert with neither acid generation nor neutralization potential. The soluble metals fraction is insignificant for the most part, unless vein material is mixed with the quartzite.

7.3.1.2 Quartzite - grey and pyritic

The grey and pyritic quartzite represent a small portion of the total waste rock on the site, and of most of the dumps. The exceptions are the Dixie, Galkeno, Hector and Keno 700 adit dumps which can have from 10 to 40% grey quartzite (based on visual estimates).

The field paste pH values consistently ranged from 6 to 8 for the majority of the dumps tested; therefore, a selection of samples were collected to represent different dumps. Acidic paste pH values were only seen in a few locations at some dumps but were not widespread at any dump or pit wall. The acidic material was sampled for laboratory testing.

The grey and the pyritic quartzite samples show a similar range of sulphide and metal contents, with no clear distinction between the two. Acid base account tests show:

- total sulphur contents ranging from <0.01 to 7.76%, with a median value of 0.7%;
- sulphide sulphur ranging from 0 to 7.7% and a median value of 0.3%;
- sulphate sulphur represents from 15 to 100% of the total sulphur;
- NP/AP ratios ranging up to 8.7:1;
- generally neutral paste pH values indicating that carbonates are the primary buffering minerals and that the rate of oxidation and acid generation is less than the rate of neutralization;
- only two of the samples indicate potential acid generation with NP:AP ratios of less than 1.5 to 1, and acidic paste pH's; and,
- acidic conditions are seen only in samples where NP has been depleted or was not present.

These paste pH measurements are useful for understanding the kinetics of oxidation and neutralization of grey pyritic quartzite, particularly given that some of these samples were collected from dumps dating back to the 1930's. Despite a long period of oxidation the grey pyritic quartzite material is not acidic in the dumps. The acidic Dixie adit dump samples are depleted in NP but also have little remaining acid potential.

The samples of potential concern with respect to oxidation and possible acid generation are the higher sulphide samples from Husky and Husky S.W. These samples were not typical of the material in the open pit dumps, but rather of the grey quartzite that may be exposed underground in the wall rock near the veins. The Husky S.W. sample was from a low grade stockpile.

The results of the metal analyses by ICP on these samples are similar to other quartzite samples, with the exception of higher calcium values. This is reflected in the higher NP values found in the grey and pyritic quartzite samples. Arsenic concentrations in some of the samples were also higher than in any of the other rock types.

The short-term extraction tests on the samples indicate that the grey pyritic quartzite can be a source of soluble metal loading. Short-term extraction tests showed extractions of sulphate, manganese and zinc, and to a lesser extent cadmium, arsenic, and nickel in some samples. It is important to note though that not all of the contained metal or sulphate is soluble under these conditions; extractions were generally less than 25% of the total contained in the solid sample. For example, in the Husky S.W. shaft dump sample the extractions were about 8% of the total zinc in the sample, and 14% of the sulphate. This is because of the occurrence of sulphate minerals of relatively low solubility, as shown in Appendix I.

There are no obvious and consistent correlations between the concentrations in the extraction solution and either the metal content in the solids or the degree of oxidation, as seen in the figures in Appendix VIII. However, in general, samples with acidic paste pH values (up to pH 6) and sulphate content above 0.2% did show metal leaching, whereas samples with pH values around 7 and low sulphate did not leach appreciable metal (e.g. Silver King).

Kinetic testing is in progress on quartzite samples. While the tests are continuing, the preliminary results show that there is the expected initial flush of metals and particulates from the samples due to the disturbance from both sampling and loading into the columns. The buff quartzite sample initial loadings is minor and primarily as particulate rather than dissolved metal, and drainage water quality quickly improves. The grey quartzite samples however show much higher loadings which have continued for several cycles of testing. More time is required in the testing however to use these data for field water quality predictions.

7.3.1.3 Summary - Quartzite

The above test results indicate that net acid generation and “acid rock drainage” is not a concern from the quartzite which comprises the bulk of the waste rock. There are however a range of sulphide contents in the quartzite and, in some dumps, there will be local areas of oxidation and metal leaching potential.

The extraction tests, designed to extract the soluble component from the sample, suggest that the majority of the quartzite material would not contribute significant loading to the drainage water from the dumps under *in-situ* conditions. However, disturbance of the grey and pyritic quartzite material (such as the Dixie material) could lead to a significant short-term release of metals and sulphate.

Drainage from underground workings with very pyritic quartzite may contain acidity, zinc and possibly arsenic, particularly from the Husky and Husky S.W. workings.

7.3.2 Schist

A total of eight schist samples were collected from the waste dumps and pit walls. It is estimated that about 20% of the total waste rock on the site is schist, being most evident at Hector, Dixie (mixed with quartzite), and Keno 700. The two main types of schist found on the dumps are the sericitic and graphitic schists.

Schist is generally less competent than the quartzite, particularly the graphitic schist material.

Acid base accounting on the eight schist samples suggests that the sericitic and graphitic schists are similar in terms of sulphide, sulphate and alkali content, as shown in Table 7-1. While the median sulphide sulphur content is 0.2%, there is generally sufficient neutralization potential that the samples are neutral to alkaline in pH, ranging as high as pH 8.7. One sample, from the Calumet pit wall, is slightly acidic at pH 5.8, although there is essentially no acid potential (total sulphur of 0.09% with sulphate of 0.06%).

The ICP analyses on the head samples show that the concentrations of metals of interest for the site are, on average, similar in the schist and grey/pyritic quartzite samples. However, the schist samples are consistently higher in metals, as shown by comparison of the median values. The schist samples also tend to have more neutralization potential (carbonate minerals) as indicated by both the NP and calcium values in the solids.

Extraction tests were done on nine schist samples, as it was initially thought that the schist could be a source of contaminant loading. The results do not indicate a major soluble loading potential from the schists. One sample, a sericitic schist from the Hector adit dump, did show some soluble zinc and sulphate although the dissolution represented less than 1% of the total of each in the solid sample.

In summary, the schist material does not appear to pose either an acid generation concern, or a high soluble metal loading concern. Preliminary results suggest that there could be a short-term release of metals from these schists if the waste rock in the Hector or Dixie dumps, for example, were disturbed. However, the soluble load from the schist is lower than from the pyritic quartzite.

7.3.3 Mixed Schist and Quartzite

Schist and quartzite are often mixed within the waste dump, as a result of geologic occurrence or of dumping. Samples of the combined schist and quartzite were also collected for analysis

The quartzite associated with the schist in the pit walls tends to be the grey or pyritic quartzite. Buff quartzite mixed with schist appears to be the result of mixing during or subsequent to dumping.

The geochemical characteristics of the samples reflect those of the individual rock types, and the dumps from which each was collected, e.g. the Dixie mixed samples reflects the acidic paste pH, sulphide, NP and metal contents of the Dixie quartzite sample.

Extraction tests were done on the Onek pit and UN dump samples with low metal dissolution, low sulphate concentrations and alkaline pH values as seen in the individual rock type samples.

7.3.4 Vein/Ore Material

As discussed in Section 3.2.2, ore in the Galena Hill and Keno Hill camp occurs in irregular shoots within vein systems developed along the vein faults. There is significant oxidation within these veins.

Five samples of vein material were collected for analysis. There are very few areas where a distinct pile of vein material can be found in a dump although a skim of vein material is visible on some. This is probably vein material remaining from temporary stockpiles. Some vein material is evident mixed in with quartzite and schist at, for example Dixie, Townsite and Bermingham. Vein material is evident in the pit wall at Bermingham.

The vein material shows sulphur contents ranging up to 2.5%. In three of the five samples, this sulphur was entirely as sulphate. There is neutralization potential associated with the vein material, resulting in NP:AP ratios of 2.4:1 or greater. Despite the extent of oxidation of these samples, paste pH values are consistently near neutral. Thus the vein samples are partially to completely oxidized, and contain sufficient neutralization potential to neutralize acidity. All vein samples showed near neutral pH values in the laboratory testing and in field measurements. Only one acidic pH was found in the field; on a single hand sample with visible sulphides.

Vein sample ICP analyses on the solids tend to show higher metal contents than in the other rock types for the metals of interest; zinc, sulphate, manganese, lead, and iron. The arsenic and calcium content of the vein material however is lower than in other samples.

Extraction tests on the vein samples support the assumption that the vein material can be a major contributor to dissolved metal loading on the property. Vein samples may release sulphate, cadmium, copper, manganese, lead or zinc, depending on the mineral composition of the vein.

7.4 Waste Rock Drainage

These results support the field observations that the primary source of metal loading to the surface waters is in drainage from underground workings. This is due to both geochemical and mining constraints, and due to hydrology. In terms of geochemistry, since mining followed the vein structure as much as possible, the highest surface area of vein material exposed would be in the underground workings.

In general, the waste rock dumps would contain relatively little vein material as most of the vein material extracted would have been milled. The waste rock dumps associated with the open pits would be expected to have the lowest percentage of vein material, which can be readily differentiated from the quartzite and schist by observation, and selectively mined. Open pit dumps also tend to contain abundant rock far from the vein stripped to gain access to the vein. The waste rock dumps at the adits can be expected to have higher proportions of vein material and to be particularly rich in weakly mineralized rocks near the veins (e.g. the acidic Dixie quartzite sample).

The second generalization that can be made from this testing is that amount of pyritic quartzite and of vein would directly affect the contaminant loadings from the dump, particularly if there is any disturbance of the waste rock. Not all of the pyritic quartzite is a source of soluble metals however. The geology of the district indicates that metals do occur as oxides and/or sulphate, not just as sulphides. This is supported by the presence of “insoluble” sulphate minerals in the extraction tests.

While the kinetic testing must continue for some weeks before detailed water quality predictions can be made (and field groundwater samples are required for calibration), the testing to date and field observations are sufficient to identify potential issues for metal release in the longer term from these waste rock dumps:

- the infiltration through the dumps is relatively low given the dry climate during the summer months and lack of seepage from the dumps, resulting in storage of soluble products in the dump;
- the storage of soluble contaminants within the waste rock in dumps of this age suggests that there is limited infiltration and flushing of the rock. Given the period of time that many of these dumps have been in place, it would appear that the rate of soluble metal production (i.e. oxidation reactions) is low and/or flushing rates are low;
- this suggests that while there may be isolated seeps with elevated metals, the most important issue in terms of closure is to minimize disturbance of the waste rock and, as required, minimize run-on to the dumps (i.e. by ditching).
- the amount of soluble contaminants cannot be directly predicted from metal or sulphate analyses of the solids. It is recognized that there are "insoluble" sulphate minerals that occur as primary minerals in the rocks; and
- zinc provides a good indication of metal leaching as zinc is consistently elevated in water samples with any of the other leachable metals, and thus is a useful monitoring parameter.

Thus, while there is no reason to anticipate any changes in oxidation, metal production or release from the waste rock dumps, it can be expected that some dumps will have seepage with elevated metals. Field observations and monitoring of receiving water have not identified a metal loading problem from any of the waste dumps. Groundwater monitoring results from the piezometers installed in 1995 will be required to support this observation, in conjunction with the kinetic testing data.

With respect to acid generation potential, and the oxidation profile over time, the results of the static testing and field measurements support the observations that:

- oxidation and neutralization have been occurring over time and there are no indications that the geochemistry with "suddenly" change over time, i.e. the waste rock is generally near neutral with carbonate minerals the main source of alkalinity, and there are few samples with NP:AP ratios less than 2:1 and acidic pH's;
- net acid generation (i.e. "ARD") is not a concern for this site as indicated by both static testing and field sampling and observations of alkaline to slightly acidic conditions.
- XRD analyses of the kinetic testing samples does not show any siderite, with calcite the main neutralizing mineral;
- the majority of the waste rock is inert, containing negligible sulphide sulphur;
- there are some materials which may be net acid generating, depending on the sulphide content but sufficient in quantity to lead only to isolated zones of acidity;
- there are soluble metals associated with the waste rock as a result of both oxidation over time since deposition in the rock pile, and as primary minerals, in the grey pyritic quartzite and vein material.

The general conclusions from these results are that the majority of the waste rock is non-acid generating (chemically inert) or is acid consuming. "Acid rock drainage" as such is not a concern from this site; the waste rock dumps are not going to generate net acidity in the classic ARD sense. However, there is a small portion of the waste which is potentially acid generating (as seen in field water chemistry and laboratory and field paste pH measurements) and may generate local low pH zones. The more significant issue is that of metal leaching potential, with or without net acid generation.

7.5 Tailings History

A review of the milling records and metallurgical testing by the metallurgical consultant for the pre-feasibility study (UKHM, 1996) indicated some characteristics of the ore and milling process of interest in the assessment of leaching and oxidation potential:

- the mill produced two concentrates, a silver/lead concentrate and periodically a zinc concentrate;

- prior to 1970, the majority of the ore was produced from underground operations. During this time, the lead and zinc minerals were primarily sulphides;
- when open pit production became the major source of ore to the mill in the 1970's, the proportion of "non-sulphide" lead and zinc increased substantially as indicated by changes in the milling characteristics and by analysis;
- tailings assays in the 1950's were approximately 0.6% Pb and 0.8% Zn;
- in the 1970's the lead and zinc grades in feed to the mill decreased, as did the tailings grades with typically 0.5% Pb and 0.3% Zn;
- mineralogy studies at the time indicated lead to be present as cerrusite (lead carbonate) and anglesite (lead sulphate), both of which contained silver;
- in the 1980's zinc in the feed decreased below 1% and a zinc concentrate was no longer recovered. However it is also reported that spalerite and zinc were no longer being depressed into the tailings;
- in the last year of operation, the tailings assayed 1.2% Pb, 0.5% Zn, and 10.9% Fe;
- at the same time, the non-sulphide lead assayed 0.7% with sulphide lead of 0.5%. This is an increase in non-sulphide Pb from 10% in the 1970's to 25%;
- Pb concentrations are higher in the fines fraction of the tailings, although the Zn assays are consistent for all size fractions.

7.6 Tailings Sampling Program

The Elsa tailings had been sampled over the years, prior to the investigations for this closure plan, primarily to investigate metal grades and tonnage for reprocessing evaluations. Some static testing was also done.

The objectives of this sampling and testing program were to identify:

- any differences in the geochemistry of the tailings deposits, sufficient to warrant separate closure measures for different areas;
- the mechanisms controlling dissolved metal release from the tailings;
- the future trend in contaminant release from the tailings;
- the stored contaminant load within the pore water and tailings solids, and the implications for closure.

The evaluation in this closure plan is based primarily on two sampling events were conducted in 1995 for characterization of tailings geochemistry and environmental evaluations:

- test pit sampling by hand shovel and then auger to depth, with samples collected over depth from 11 of the test pits;
- trenching and test pits using a backhoe, primarily to sample the tailings at depth and to determine the depth of the tailings.

The locations of the tailings samples are shown on Figure 5-14 and discussed in Technical Appendix IX. The sampling logs are also provided in this Appendix.

7.7 Tailings Testing

The tailings testing program includes:

- static testing to identify any differences in geochemical characteristics of the different tailings areas and ages;
- short-term extraction testing to quantify the soluble metal load; and possibly,
- kinetic testing of selected samples to quantify the oxidation and leaching potential over time.

The results of the testing completed to date are provided in detail in Appendix IX.

There is an extensive database of water quality monitoring from the tailings and this will form the basis of the closure decisions for the tailings. Thus, there does not appear to be any added benefit from laboratory kinetic testing of the tailings.

7.8 Tailings Geochemistry

In excavating the tailings test pits, observations were made of paste pH and TDS over the depth of the test pit. The test pit was demarcated in layers based on appearance and field paste pH and TDS measurements. Samples were taken from each layer both for field measurements and laboratory testing. Where possible, water samples were also collected from water seeping into the test pits, or decanted from the sample in the laboratory.

Test pits are particularly useful for tailings investigations of acid generation potential due to the nature of the oxidation processes, and the controls on oxidation. It is well understood that oxidation generally is initiated at the surface of tailings, and proceeds to depth over time. This vertical migration of the oxidation front is due both to the draining of tailings over time (saturation limits oxidation) and to the ingress and progressive consumption of oxygen from surface to depth. Thus, the depth of oxidation front(s) can indicate the extent to which oxidation and neutralization have occurred in the tailings.

Detailed results of the static testing program are provided in Appendix IX and are summarized in the following discussion. The results include the test pit logs, the static test results and the ICP analyses on the samples. In addition, the profiles of selected results over depth in each test pit are provided. The results are discussed in terms of the objectives of this sampling and testing program to evaluate requirements for closure; the potential for acid generation in the long term, the identification of any specific zones of concern with respect to acid generation, metal leaching and the need for water treatment.

Test pit No. UK/TP/01 is most indicative of the tailings immediately behind Dam No. 1, and at the edge of the seasonal pond. Field tests show that the tailings are near neutral to alkaline at depth. The tailings are not considered acid generating based on NP:AP ratios, however the TDS values indicate elevated dissolved solids in the layers near surface. Analysis of pore water samples decanted from the solids showed elevated metal concentrations from the surface samples mobilized by excavating and agitating the sample.

The saturation of the very fine tailings in this test pit, combined with the lack of iron staining and oxidation precipitates suggests that the mechanism of zinc release is one of dissolution of “soluble” metals as much as oxidation of sulphides and subsequent leaching. However, the profiles and ICP analyses of NP, calcium and zinc in the solids suggest that there has been oxidation and neutralization in the top 0.35 m of the tailings, and perhaps the top metre, reducing these concentrations in the near surface.

The weighted average NP for this hole is 14 kg $CaCO_3$/t with an AP of 3 indicating net acid consumption potential. ABA data were interpolated for layers not analyzed based on the similarity between the ICP results for the layers and layer C.

Test pit No UK/TP/02 is located within the second impoundment which is used for settling of the decant from Dam 1 and the treated tailings water. This was evident at depth in the test pit with visible lime and high NP values in these samples. Metal concentrations are slightly lower than in TP/01, however sulphur concentrations are higher at 1 to 1.5% total sulphur. The weighted average NP for this test pit is 71 kg $CaCO_3$/t, and the AP 3 kg $CaCO_3$/t indicating that net acid generation is not a concern for this area, probably mainly because of the large amounts of lime added.

Test pits 3 through 6 are located within the tailings southwest of the road and north of the Porcupine Diversion ditch (i.e. not deposited behind Dam No. 1). Seepage from these tailings was sampled in 1995 and showed neutral pH values with sulphates up to 416 mg/L, and dissolved zinc concentrations of 0.5 and 0.8 mg/L. Calcium and magnesium were also elevated above background in these samples, suggesting dissolution of some carbonate minerals.

The tailings in this area are saturated at depth, and moist to dry at surface as shown in the test pit logs. The drier tailings (test pits 03 and 04) have similar pH and TDS profiles (Figures in Appendix IX) showing slightly acidic pH values and high dissolved solids. Test pits 05 and 06 are similar, however pH values are more alkaline at depth. Distinct layers were found in each test pit, with orange stained sands and some hardpan layered with fine grey silts and sands.

The acid base account results summarized in Table 7-4 show that tailings would be expected to be acid generating with NP:AP ratios of less than 1:1. It is clear that oxidation is occurring in distinct layers within the tailings, based on the elevated dissolved solids and lower pH values in the drier samples and the observations of iron

Table 7-4 Elsa Tailings Test Pits July 1995

TEST PIT NO. UK/TP/01

Location: Upstream of Dam No. 1, at edge of ponded water, near original ground peninsula

LAYER	DEPTH (cm)	Paste pH field	TDS field	Paste pH lab	S(T) %	S(SO4) %	AP	NP	Net NP	NP/AP
Surface	0									
A	10	6.5	800	7.17	0.36	0	11.25	11	-0.25	1.0
B	20	7.5	300	7.57	0.39	0.00	12.2	13.8	1.6	1.1
C	35	8	800	7.49	0.52	0.52	0.0	8.3	8.3	<0.1
D	50	8	700							
E	75	8.8	700							
F	100	8.8	190							
G		8.4	170	7.79	0.70	0.36	10.6	25.8	15.1	2.4

TEST PIT NO. UK/TP/02

Location: on "island" in pond upstream of Dam No. 2, just below old treatment plant (decant)

LAYER	DEPTH (cm)	PASTE pH field	TDS field	Paste pH lab	S(T) %	S(SO4) %	AP	NP	Net NP	NP/AP
Surface	0									
A	10	8	260	8.18	1.35	0.30	32.8	56.3	23.4	1.7
B	35	7.6	440	7.78	1.27	0.14	35.3	22.5	-12.8	0.6
C	50	7.8	480							
D	80	7.8	260							
E	90	9.5	340	9.18	1.48	0.94	16.9	326.9	310.0	19.4

TEST PIT NO. UK/TP/03

Location: in tailings along road at power pole by 2 pipes from Husky Shaft

LAYER	DEPTH (cm)	PASTE pH field	TDS field	Paste pH lab	S(T) %	S(SO4) %	AP	NP	Net NP	NP/AP
Surface	0									
A	10	5.8	>2000	6.16	4.27	0.53	116.9	32.1	-84.8	0.3
B	15	6.1	>2000	6.40	2.57	0.53	63.8	23.1	-40.6	0.4
C	32	6.1	>2000	5.93	2.93	1.71	38.1	95.0	56.9	2.5
D	38	5.1	>2000	5.79	1.94	0.92	31.9	21.5	-10.4	0.7
E	41	5.2	1500	5.68	1.88	0.76	35.0	14.1	-20.9	0.4
F	83	5.2	>2000							
NOTE:	32 to end of hole is alternating layers of C and D									
	F is a composite of the alternating fine sand and the silt layers which are less orange									

Table 7-4 Elsa Tailings Test Pits July 1995

TEST PIT NO. UK/TP/04

Location: along channel in old tailings near Diversion

LAYER	DEPTH (cm)	PASTE pH field	TDS field	Paste pH lab	S(T) %	S(SO4) %	AP	NP	Net NP	NP/AP
Surface	0									
A	20		>2000	5.90	2.95	0.99	61.3	6.6	-54.6	0.1
B	50		>2000	6.25	3.99	0.58	106.6	18.4	-88.2	0.2
C	90		>2000	5.72	3.82	0.59	100.9	46.0	-54.9	0.5

TEST PIT NO. UK/TP/05

Location: along channel in old tailings near Diversion, further south from previous two test pits

LAYER	DEPTH (cm)	PASTE pH field	TDS field	Paste pH lab	S(T) %	S(SO4) %	AP	NP	Net NP	NP/AP
Surface	0									
A	20	7.8	>2000	4.49	3.72	1.85	58.4	7.6	-50.8	0.1
B	75		1100	5.06	3.93	0.45	108.8	11.4	-97.4	0.1
C	120	5.8	>2000	4.74	3.88	0.48	106.3	13.6	-92.6	0.1
D	150	6.2	270	7.01	0.61	0.22	12.2	35.9	23.8	2.9
seep		6.9	700							

TEST PIT NO. UK/TP/06

Location: downslope from previous test pits, near pole across from chemical storage

LAYER	DEPTH (cm)	PASTE pH field	TDS field	Paste pH lab	S(T) %	S(SO4) %	AP	NP	Net NP	NP/AP
Surface	0									
A	37	6.1	1600							
B	75	6.1	900	5.99	4.66	0.44	131.9	98.3	-33.6	0.7
C	87	8	0	6.93	3.17	0.36	87.8	28.8	-59.1	0.3

TEST PIT NO. UK/TP/07-2

Location: in old dozed test pit, on north side of road, downstream to trees

LAYER	DEPTH (cm)	PASTE pH field	TDS field	Paste pH lab	S(T) %	S(SO4) %	AP	NP	Net NP	NP/AP
Surface	0									
A	20		>2000	5.96	1.65	0.82	25.9	16.5	-9.4	0.6
B	50		>2000	5.76	1.70	0.94	23.8	7.3	-16.5	0.3
C	75		>2000	5.66	2.70	0.52	68.1	51.3	-16.9	0.8

TEST PIT NO. UK/TP/08

Location: upper part of Pond 1 - old tailings area below garbage dump and bunkhouse

Table 7-4 Elsa Tailings Test Pits July 1995

in old metallurgical bulk sample test pit location

LAYER	DEPTH (cm)	PASTE pH field	TDS field	Paste pH lab	S(T) %	S(SO4) %	AP	NP	Net NP	NP/AP
Surface	0									
A	23	7.1	700	6.84	1.05	0.27	24.4	17.3	-7.1	0.7
B	76	5.5	1480	5.87	2.16	0.67	46.6	16.0	-30.6	0.3
C	86	6.1	560	5.72	2.61	0.71	59.4	56.5	-2.9	1.0
D	150	5.2	1460							

TEST PIT NO. UK/TP/10

Location: downstream adjacent to sewage channel, but closer to trees of original ground

LAYER	DEPTH (cm)	PASTE pH field	TDS field	Paste pH lab	S(T) %	S(SO4) %	AP	NP	Net NP	NP/AP
Surface	0									
A	100		600							

TEST PIT NO. UK/TP/11

Location: downstream adjacent to sewage channel, but moving closer to road and trees

LAYER	DEPTH (cm)	PASTE pH field	TDS field	Paste pH lab	S(T) %	S(SO4) %	AP	NP	Net NP	NP/AP
Surface	0									
A	50		1100	6.80	2.23	0.39	57.5	13.4	-44.1	0.2
B	100	6.6	310	6.81	5.25	0.26	155.9	104.8	-51.2	0.7

staining and “hardpan”. Seep and pore water samples show elevated alkalinity and hardness though, indicating that there are carbonate minerals providing neutralization. These tailings samples differ from the tailings behind Dam No. 1 in that the saturated samples do not show elevated dissolved metals, and the seep samples generally have low metals compared to tailings dam decant.

Thus it appears that the tailings near the Porcupine Creek Diversion do have the potential to generate net acidity, based on static testing. It must be recognized however that oxidation of zinc sulphide minerals releases little or no acidity compared to the oxidation of iron sulphide minerals on which the AP calculations and the NP:AP criteria are based.

Field evidence suggests that the rate of acid production is such that there is sufficient NP to maintain pH values above 6. The depth of oxidized layers (hardpan) suggests that the geochemical processes are well established. The data also indicate that the soluble metal component in these tailings is relatively low. Kinetic testing with accelerated oxidation rates is required to determine if this condition will exist in the longer term.

Test pits 7 through 10 are located with the “original” tailings deposited upslope of Dam No. 1. These tailings are visually much different than the lower tailings comprising layers of fine grey sands and orange/brown “hardpan”. The grey sands generally were higher in pH and lower in TDS with higher NP and moisture content at depth.

It is clear that the oxidation and neutralization processes are well established in these tailings.

7.9 Tailings Drainage and Seepage

The different periods of tailings deposition in the valley and the changes in ore and metallurgical characteristics suggest that the solids geochemistry of the tailings would vary spatially. The tailings water chemistry has consistently shown zinc concentrations in the 1 to 4 mg/L range, although pH values remain alkaline at about 8.

The conductivity measurements done since the 1980's show a generally decreasing trend, from peaks of 1600 in 1986 and 1987, to values around 600 since 1993. Iron concentrations also show a generally decreasing trend.

Conductivity measurements are indicative of the dissolved ion content of a solution, with sulphate generally being the dominant anion in these solutions. There are three possible sources of sulphate in the tailings water:

- residual milling reagents;
- sulphate released by dissolution of soluble sulphate minerals associated with the tailings. However, the main sulphate minerals are associated with calcium, iron, lead and zinc and therefore are essentially insoluble under the pH and temperature conditions of the tailings;
- oxidation of sulphides.

The decreasing trend in conductivity and iron supports the observation that the tailings are not acidic. It also suggests that the rate of oxidation in the tailings is decreasing or remaining constant, which would not be the case if the iron sulphides in the tailings were oxidizing. Certainly there is no evidence of a developing "acid mine drainage" problem. However, it is recognized that there are probably local zones of sulphide oxidation and acid generation.

The most useful data for predicting the geochemical response of the tailings to weathering is the existing field data. These tailings are up to 30 years old; a considerable database for evaluation. Drainage from the tailings is consistently neutral, with elevated zinc concentrations averaging about 0.3 mg/L.

Test pit data support the water chemistry data. Paste pH values are neutral to alkaline, with evidence of oxidation seen only in the changes in conductivity (indicative of dissolved ion and particularly sulphate concentrations).

The interpretation of static test results for tailings is different than for waste rock because of the physical differences in terms of particle size and therefore mineral distribution and contact. It is generally accepted that at an NP/AP ratio of 1.2 or greater, the tailings sample will not generate net acidity. At ratios of less than 1, the sample may generate acidity. However, testing or field data is generally required for ratios less than 1.2 because the field potential depends to a large extent on the physical conditions in the field; notably moisture content, depth/surface area and particle size.

The static test results reflect the differences in the ore mineralogy described in the milling records, with considerable oxide ore processed in the latter years. There is clearly oxidation of the higher sulphide tailings, with either neutralization of the acidity or low acid production. These results support field observations that net acid production is not anticipated from the tailings, but that continued release of low levels of dissolved zinc can be expected. The results of the water chemistry and extraction tests are needed to refine conclusions about the tailings geochemistry.

8. Assessment of Impacts

8.1 Introduction

This section discusses the impacts of the UKHM Elsa operations on the local receiving environment, including aquatic and terrestrial resources and other resource users. The previous chapters have discussed the property history, regional setting and provided a detailed description of the individual project components. These, with the site water chemistry and geochemical testing program discussed in the preceeding two chapters provide the basis for the impact assessment.

Undertaking an impact assessment at an existing mine site presents unique challenges. The local environment was not characterized prior to commencement of mining activities as is now typically done for new mining projects. Pre-mining or baseline environmental conditions were not established and therefore the basis for comparing and assessing impacts on the surrounding environment is made more difficult. In addition, while each mine site is relatively small, the area of activity is quite large, and is influenced by other mining activities and local land usage. Multiple watersheds are affected by development activities.

The approach taken for the impact assessment has been to recognize and use the local property history, field studies and existing site information to establish the present environmental conditions. Experience at other mine sites has indicated that while terrestrial and other resources users impacts may be significant, the effects are limited to a local area, when compared to potential impacts associated with surface water quality contamination and aquatic resources. Therefore, in this assessment, emphasis was placed on understanding and assessing impacts on the aquatic resources.

Water flow and contaminant loading balances (Section 8.2) are used to quantify contaminant loads and concentrations and thus provide a basis for environmental impact assessment (Section 8.3). This section integrates the information provided in the previous chapters in an overall impact assessment. Since the loading balances, and hence the impact assessment, are done for the catchments as a whole, they include the effects of all activities within each watershed. Many of the historic, and in some cases current, activities are not controlled by UKHM - or were not operated by UKHM. Clearly, however, it is not possible to separate the impacts attributable to development by others.

8.2 Site Water and Chemical Loading Balances

8.2.1 General

One of the prime objectives of the closure plan for the UKHM Elsa site is the protection of aquatic resources which can be achieved by alleviating contaminant loadings to the receiving environment, and particularly the South McQuesten River. Given the complexity and extent of the UKHM site workings, it was essential to develop a water balance and contaminant loading balance for the study area in order to:

- identify the sources and the sinks for contaminants;
- quantify the contaminant loading from the workings and in the receiving environment; and,
- from the above, determine the potential environmental impacts and therefore set priorities for closure and remediation measures.

The subsections below describe the steps undertaken to construct the water and chemical loading balances.

8.2.2 Mine Site Water Balance

Development of the water balance essentially involved two broad steps, namely:

- to conceptualize the mine site as a system of components; and,
- to quantify the amount of flow generated by the said components.

The results of performing the first task are graphically illustrated in the water balances of Figures 8-1 and 8-2. The legend for the two figures is provided in Figure 8-3. The boxes and circles on these figures are used to symbolize the various system components. In developing the conceptual representation of the mine site, three different types of system components were identified, namely sub-catchments, point sources, and water treatment facilities. Each of these types has been assigned its own symbol on the figures. Lines and arrows are used on the figures to show the movement of water between the various system components.

DRAFT

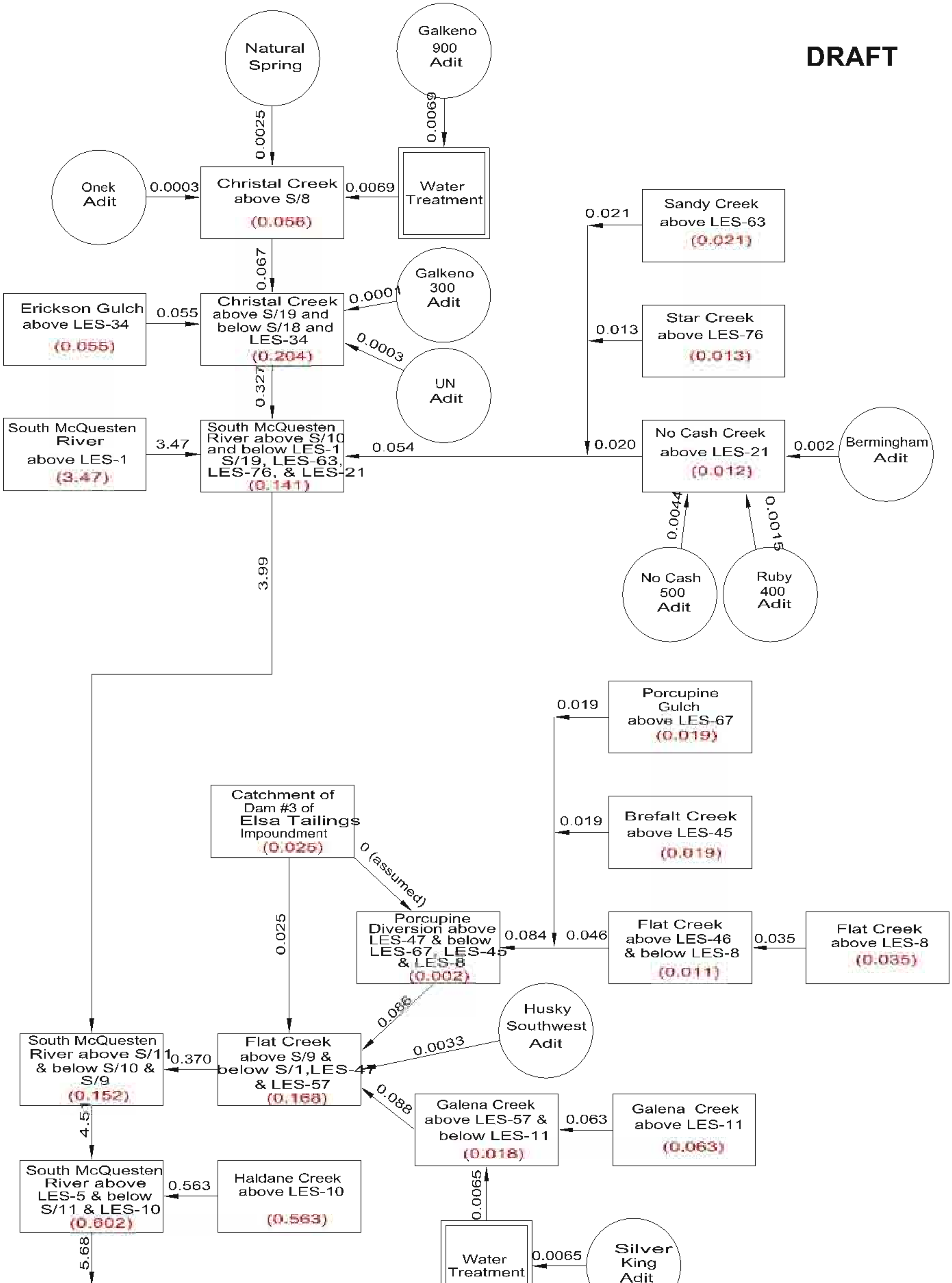
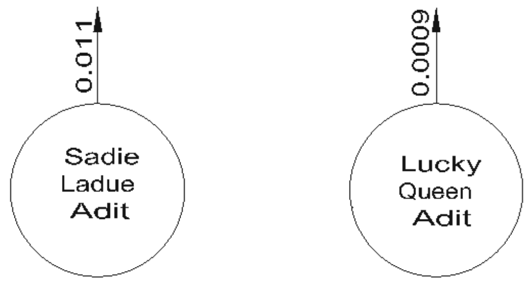


Figure 6-55a. Average Annual Water Balance - Minesite Drainages within the South McQuesten Watershed

Ladue Creek Watershed



Lightning Creek Watershed

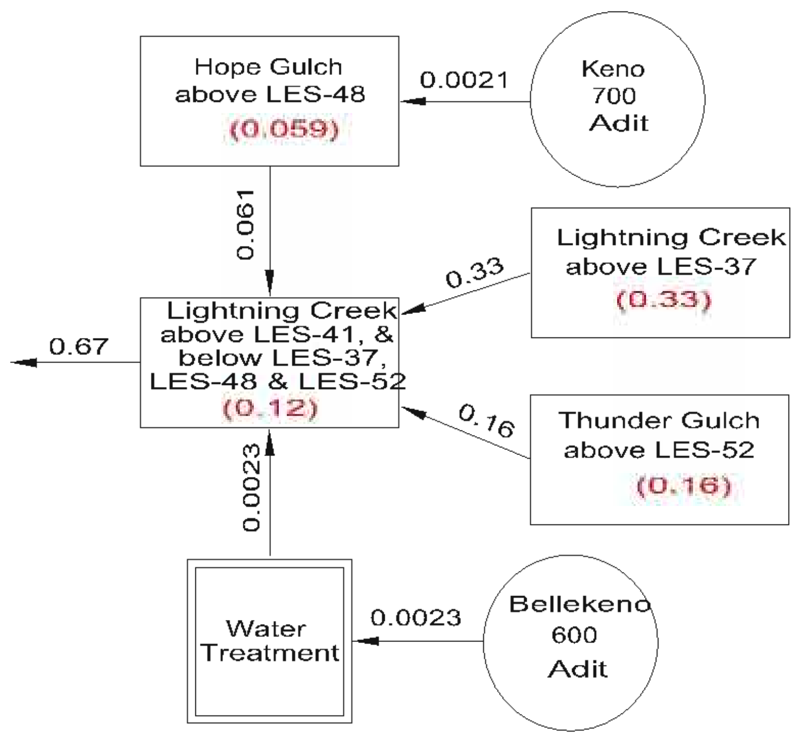


Figure 6-55b. Average Annual Water Balance Schematic - Minesite Drainages within the Ladue Creek and Lightning Creek Watersheds

LEGEND

Christal Creek above S/18 (0.058)	Catchment (bracketed number denotes estimated mean annual runoff generated by catchment in m^3/s.)
UN Adit	Point source (e.g., discharge from adit or spring.)
Water Treatment	Water treatment facility
3.47 →	Flow line (number denotes estimated average annual flow in m^3/s.)

Figure 6-55c. Legend for Minesite Water Balances

The most important type of system component is the sub-catchment. For the purpose of developing the water balance, the mine site was subdivided into a total of 24 of these, as dictated by the locations of water quality sampling points and streamflow gauging stations. The outlines of the adopted subcatchments were discussed in Chapter 3, and are shown in Figures 3-6 and 3-7.

The conceptual representation of the mine site also includes a total of 14 point sources. These comprise discharges from 13 adits and a single spring. In addition, the conceptual representation includes three water treatment facilities, one each at the portals of the Galkeno 900, Silver King, and Bellekeno 600 Adits.

Having developed a conceptual representation of the mine site, the next step in preparing the water balance was to estimate the flows generated by each of the system components. This was accomplished by using either of two approaches. The first involved using site-specific data (i.e., records of measured flows collected at points within the mine site). The second entailed using synthesized flows which were derived by a technique known as regional analysis. This technique involved making correlations between the runoff measured at regional streamflow gauging stations and the physiographic characteristics of the catchments which generated the runoff. The resulting correlations were then used to predict flows at ungauged sites. A description of the regional analysis performed for the UKHM mine site is presented in Section 3.7.

In general, the site-specific data were used to assess the average flows emanating from the point sources. Regional analysis, on the other hand, was used to estimate the average flows generated by the subcatchments. The ideal situation would have been to use site-specific data to assess the magnitude of all the water balance flows, not just those of the point sources. This situation, however, could not be met because the measured flows on the mine site streams are, as yet, too limited to accurately characterize the sub-catchment runoffs. In a few years time, this story should be different when longer streamflow records have been collected at the five streamflow gauging stations which were established at key points around the mine site during 1994 and 1995 (see Appendix III for details).

The estimated flows for the water balance are presented on Figures 8-1 and 8-2. All flows represent the long-term average discharge rate, expressed in units of cubic metres per second.

In examining Figures 8-1 and 8-2, the reader should note the following two points about the water balance.

a) The mine site straddles three drainage divides and, accordingly, its runoff may drain to any one of three watersheds (i.e., the South McQuesten River, Ladue Creek, or Lightning Creek). Figures 8-1 and 8-2 were organized to reflect this fact. The northern slopes of Keno Hill drainage directly to the Keno Ladue River. The southern slopes of both Keno Hill and Galena Hill drain to Duncan Creek, which in turn discharges to the Mayo River. The remainder of the mine development drains to the South McQuesten River, a major tributary of the McQuesten River. This latter portion of the mine site includes the northern and eastern slopes of Galena Hill and the western flank of Keno Hill. Most of the drainage from this latter portion is conveyed to the South McQuesten River by either Christal Creek or Flat Creek.

b) An effort was made to avoid, at least partially, any double accounting of the adit discharges within the water balance. This was accomplished by using only the effective drainage areas in estimating the sub-catchment runoffs (i.e., all enclosed basins which drain to the mine site open pits were excluded in the runoff calculations). The runoff which flows into the open pits is undoubtedly a significant source of the waters which discharge from many of the mine site adits.

8.2.3 Mine Site Loading Balance Calculations

This section describes the steps undertaken to establish the present-day chemical loadings generated at the UKHM mine site. Chemical loadings were obtained by the product of concentration and flow. As described in Sections 6.1, UKHM maintains an extensive network of water quality monitoring stations at the mine site. The data collected at this network were used to specify the required chemical concentrations for the load calculations. The information assembled above for the mine site water balance was used to specify the flow component of the load calculations.

Load estimates were prepared for two contaminants, namely sulphate and zinc. Sulphate was selected both because it is a relatively conservative parameter (chemically), and because it is an indicator of oxidation and reduction processes. Zinc, on the other hand, was identified as the primary contaminant released from the mine development to the receiving environment.

Earlier in this chapter the water balance for the site catchments was shown (Figures 8-1 and 8-2). This water balance is also the basis for the contaminant load balances. These loading balances are useful to identify contaminant sources and to evaluate the impact of alternative closure measures, which leads to the evaluation of environmental impact at closure.

The complete water chemistry database was used to evaluate trends in water quality, as discussed in Chapter 6.2. For the loading balances, the water quality data collected since 1990 were used as this period contains reasonably detailed data for both water flow and water chemistry. In addition, the data are reasonably consistent from year to year, and did not have any data sets which would bias the data; that is, no data showed a significant trend that would be “damped” by averaging over a three to five year period.

The loading calculations were done first on an annual average basis to understand the loadings to the environment for each of the catchments, using a spreadsheet model. The stations evaluated on an annual basis included those which were recently established, as part of the water chemistry characterization program for this study. For these stations, the record is not sufficient for seasonal analyses to be meaningful. These calculated values are presented in the schematics for each catchment described in the following section.

An examination of the data for the receiving waters and for the adit discharges revealed that there were distinct seasonal trends in both flows and water chemistry. In recognition of these seasonal trends, the load calculations were performed on a seasonal basis to improve the accuracy of the estimated annual total loadings.

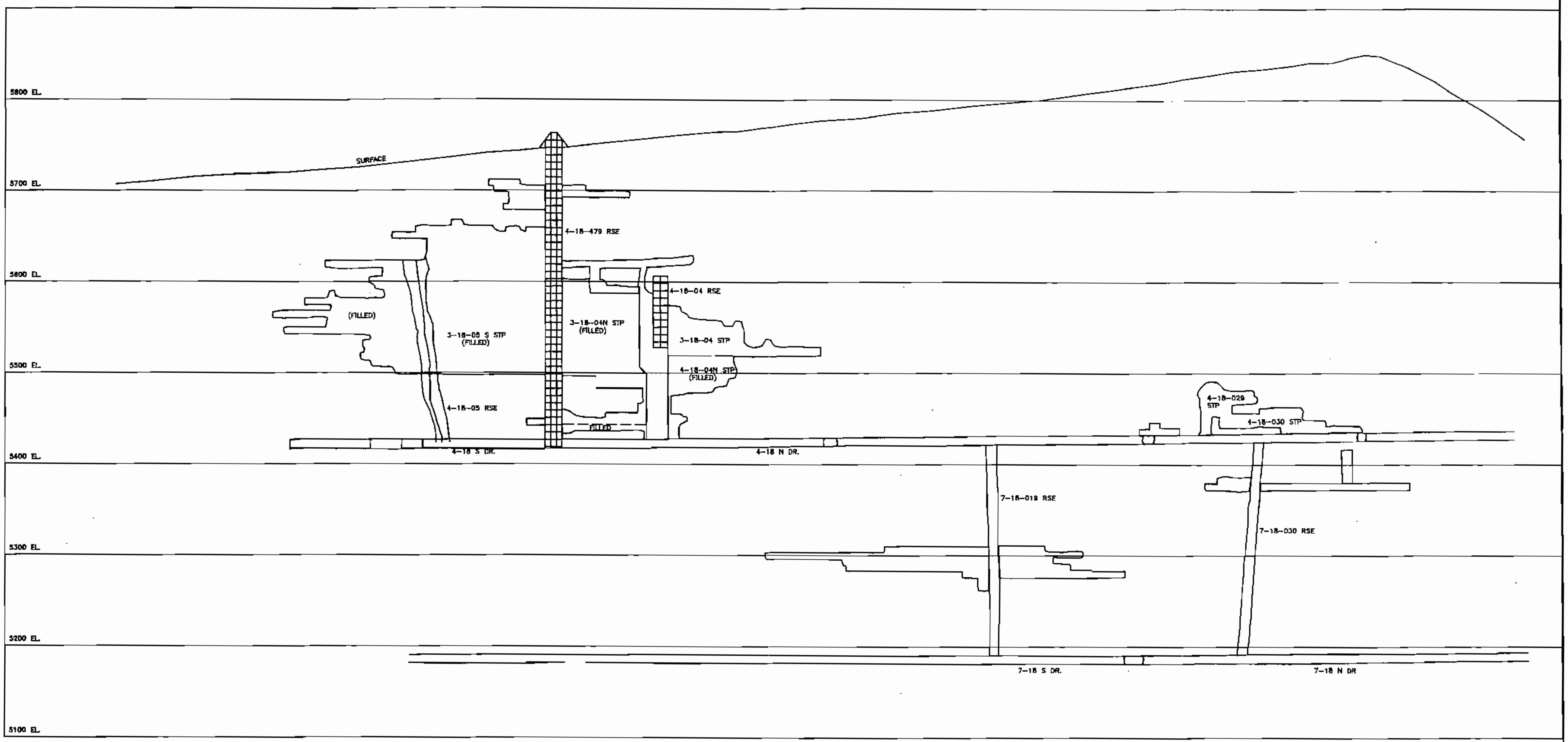
A spreadsheet model was developed to facilitate the calculation of the chemical loadings on a seasonal basis. This model was set-up to operate on quarterly periods (i.e., January to March, April to June, and so on). Figures 8-1, 8-2 and 3-6 are graphical representations which illustrate the basic structure of the spreadsheet model. As can be seen from these figures, the spreadsheet model is constructed of an interconnected network of channel elements. These elements are used to simulate the movement of water and chemical loadings throughout the mine site. Each element can receive inflows of water and loadings from a number of different sources, namely flows at the upstream end of the channel, lateral flows along the length of the channel, and point discharges (e.g. adit discharge).

The output created by the spreadsheet model is presented in Appendix X for the scenarios discussed below. This output shows:

- the basis for all water flow estimates including drainage areas and estimated unit runoffs for the subcatchments; and,
- a description of the sources of data used to characterize the water chemistry for each point of interest on the mine site drainages.

8.2.4 Discussion of Loading Balances

It has long been recognized for the UKHM Elsa site that drainage from the adits is probably the most significant source of metals released from the site. The tailings deposits in the Flat Creek valley have also been perceived as a significant source of metals and various types of water treatment have been used over the past 20 years, primarily for control of zinc in the decant. A graphical comparison of these loadings is presented in Figure 8-4. This figure is particularly useful for understanding the relative contributions of metal loads from the different sources, and for comparison with loadings within and around each catchment as shown in the subsequent detailed loading balances.



UNITED KENO HILL MINES LIMITED

MINE WORKINGS

SHAMROCK MINE, J-18 VEIN

VERTICAL LONGITUDINAL SECTION (Looking Northwest)

ACCESS MINING CONSULTANTS LTD.

SCALE: NONE	FILE: SHAMLSEC.DWG	DATE: 28/05/96

Figures 8-5 and 8-6 show the calculated sulphate loading balance for the "current conditions", based on the data since 1990. A legend for these figures is found in Figure 8-7.

While sulphate is not a water quality concern in itself at Elsa, it is often used in water and load balances at sites where sulphide oxidation and leaching is an issue, since it is considered a conservative parameter. At UKHM, sulphate is also important as the water quality data indicate that there is attenuation of metals from drainage water within the natural environment, particularly within the natural wetlands areas. The mechanism of metal removal is believed to be sulphate reduction and subsequent metal sulphide precipitation. In these models therefore, sulphate is not "conservative" but rather provides an indication of sulphate reduction in appropriate wetland areas.

Zinc has been chosen as the metal of interest for the load balances since it is the main contaminant of concern for the site, and also since it is a good indicator of other metals in solution, as discussed in Section 6.2. The zinc loading balance was evaluated for two time periods, reflecting the effects of both remediation and exploration activities on site water quality:

- the period from 1990 to fall of 1993 which is prior to the installation of the Galkeno 900 plug and water treatment to control the discharge of zinc from the adit; and,
- the period from late 1993 to present which represents "current" conditions, based on the external sampling data, i.e. not the internal UKHM monitoring data for both the Galkeno 900 and the Silver King water treatment.

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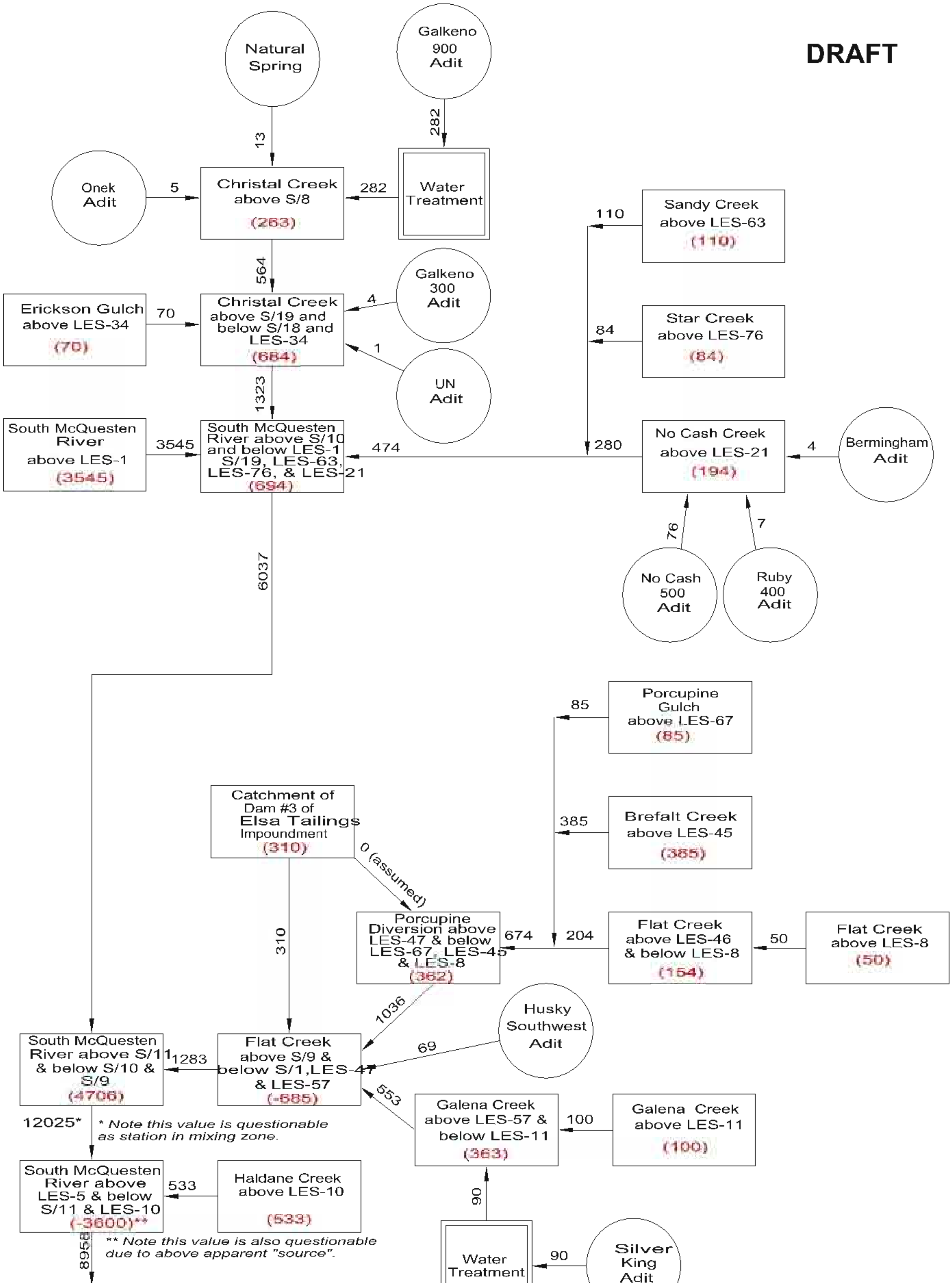
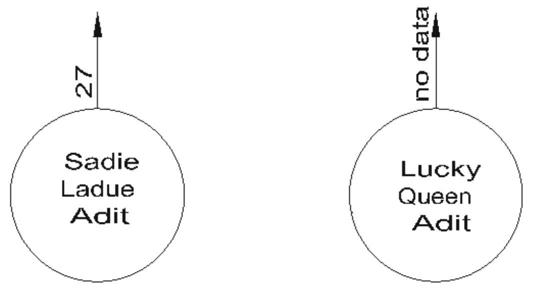


Figure 6-58a. Current Average Annual Sulphate Balance Schematic Minesite Drainages within the South McQuesten Watershed

DRAFT

Ladue Creek Watershed



Lightning Creek Watershed

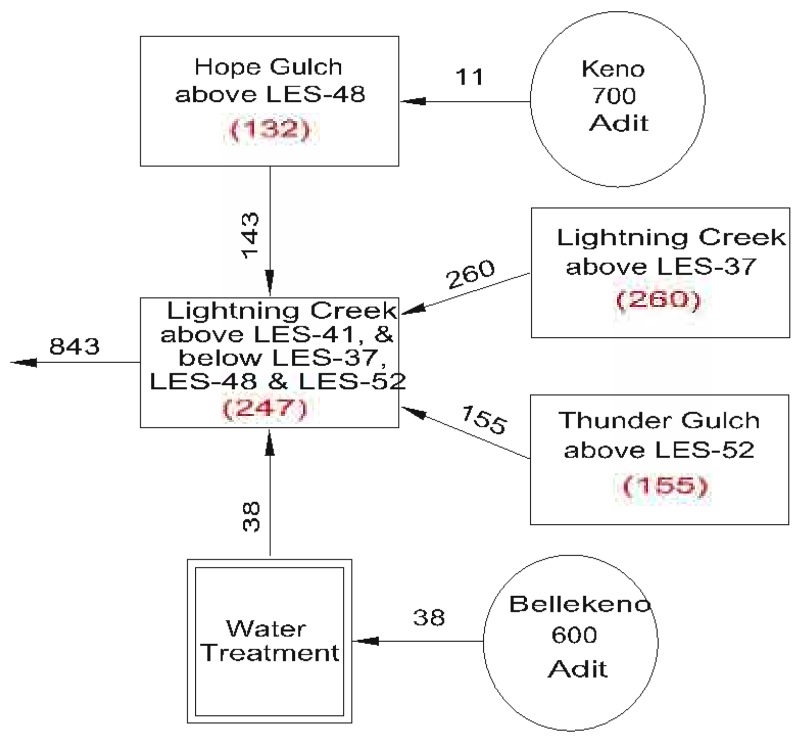


Figure 6-58b. Average Annual Sulphate Balance Schematic - Minesite Drainages within the Ladue Creek and Lightning Creek Watersheds

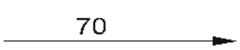
LEGEND

Catchment (bracketed number denotes estimated mean annual sulphate load generated by catchment in tonnes.

A negative value indicates a net sink for zinc in catchment.)

Point source (e.g., discharge from adit or spring.)

Water treatment facility



Flow line (number denotes estimated mean annual sulphate load in tonnes.)

Figure 6-58c. Legend for Sulphate Load Balances

Figure 8-8 shows the zinc loading for the South McQuesten watershed for conditions prior to any exploration or remediation measures, as does Figure 8-9 for the Ladue Creek and Lightening Creek watersheds. In 1993 the plug and water treatment remediation measures were put in place on Galena Hill, and Figure 8-10 shows the calculated zinc loadings in the South McQuesten watershed as a result of these measures. Figure 8-11 is the legend for these figures.

As discussed in Chapter 6, there are apparently sources of metal loading from some of the waste dumps and adit discharge. However, monitoring of the receiving environment to date does not show zinc or sulphate loadings from these sources in the downstream receiving environment. In 1995, shallow groundwater monitoring was installed at the toe of several of these dumps installed to provide additional data regarding the loadings from these dumps.

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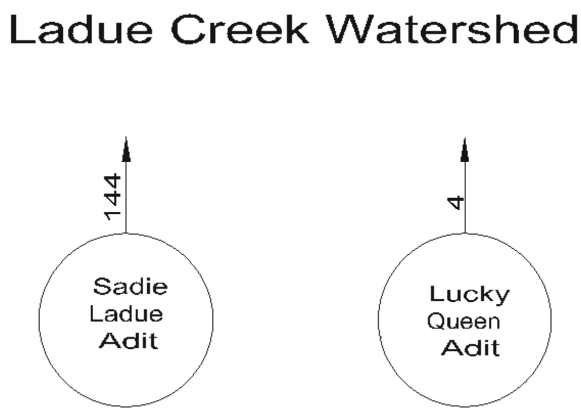


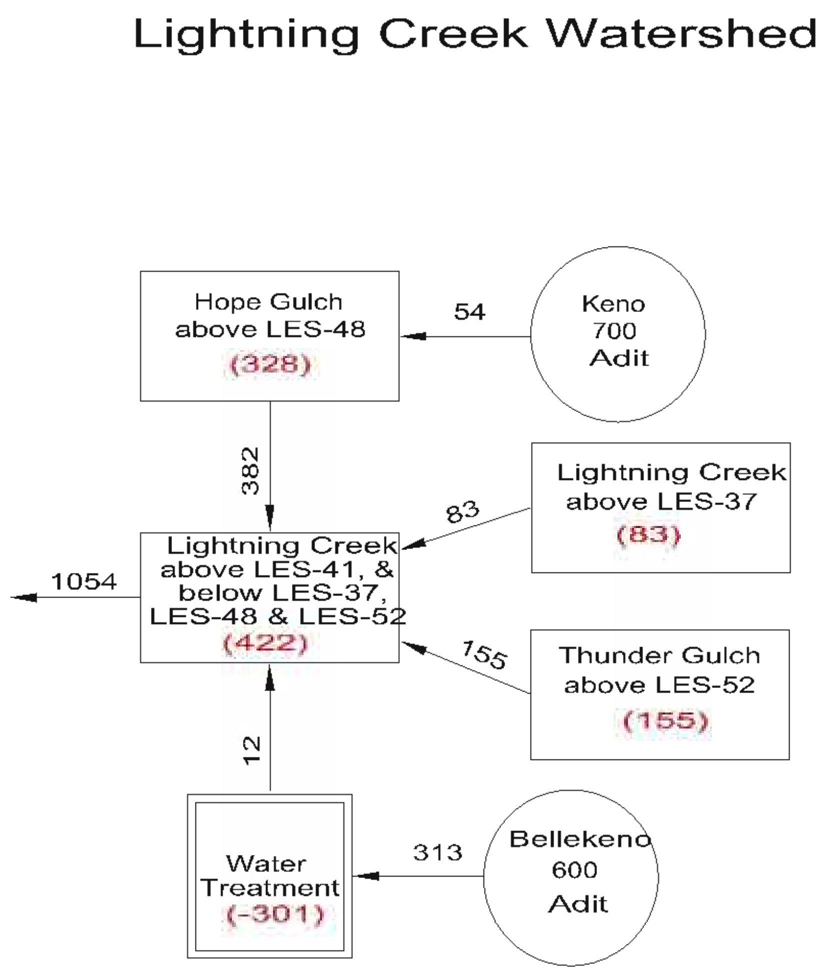


Figure 6-59b. Average Annual Total Zinc Balance Schematic - Minesite Drainages within the Ladue Creek and Lightning Creek Watersheds

DRAFT

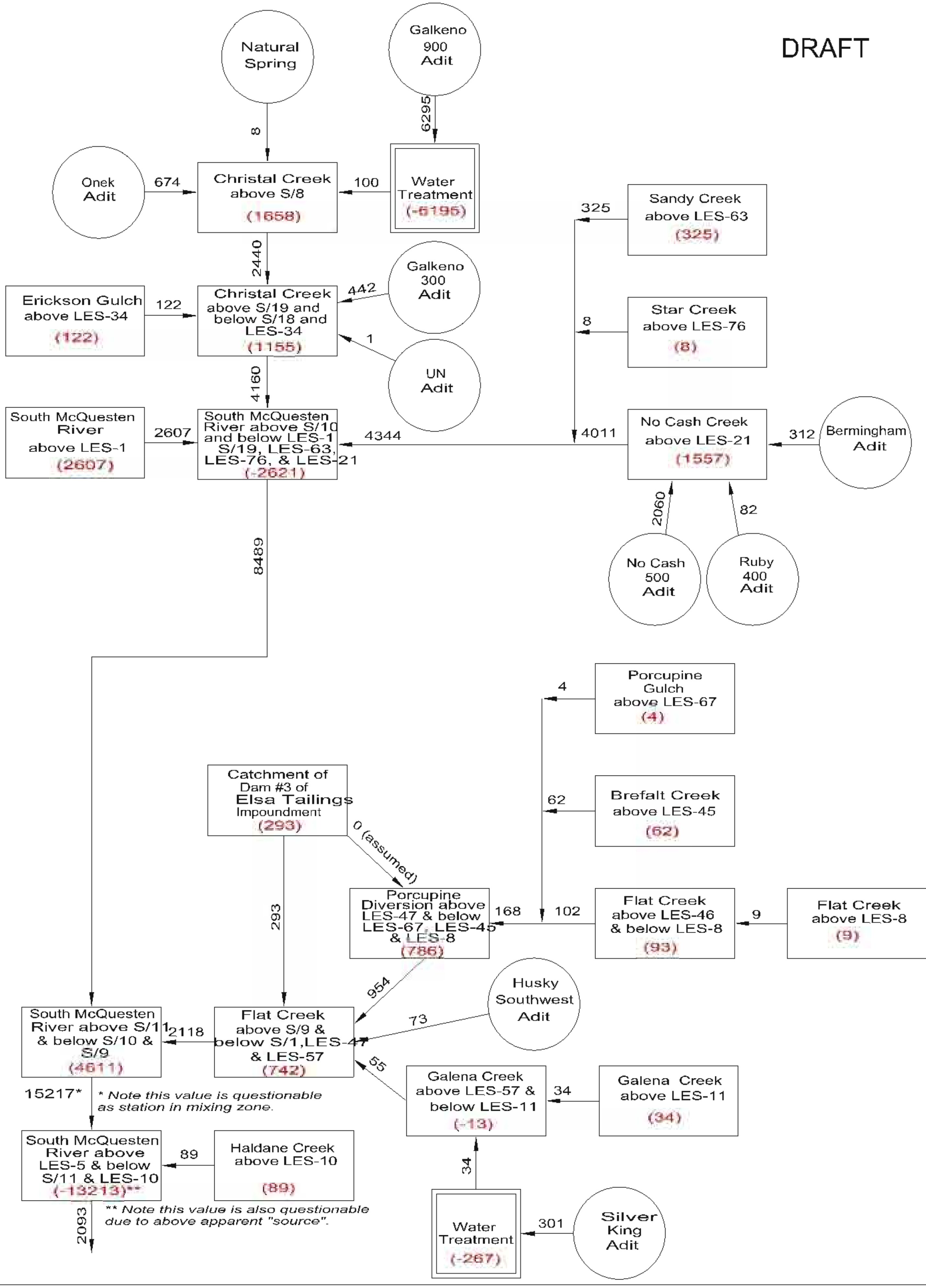


Figure 6-59a. Current Average Annual Total Zinc Balance Schematic Minesite Drainages within the South McQuesten Watershed

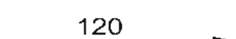
LEGEND

Catchment (bracketed number denotes estimated mean annual zinc load generated by catchment in kg.

A negative value indicates a net sink for zinc in catchment.)

Point source (e.g., discharge from adit or spring.)

Water treatment facility



Flow line (number denotes estimated mean annual zinc load in kg.)

NOTE: The numbers on Figures 6-59a and 6-59b represent total metal content, i.e. dissolved zinc plus particulate zinc.

Figure 6-59c. Legend for Zinc Load Balances

8.2.5 Observations from Loading Balances

8.2.5.1 General

The loading balances are useful to identify key sources and sinks for contaminants. The results presented in Figures 8-1 through 8-11 show:

- the main sources of zinc loadings are the Galkeno 900 adit and the No Cash 500 adit;
- it is interesting note that there appear to be additional sources or sinks within some of the subcatchments for zinc and, to a lesser degree, sulphate;
- while there are significant zinc loads issuing from the Galkeno and No Cash adits, there appears to be considerable capacity for attenuation of zinc in the watersheds. Using the average data, the zinc load contributed from these two adits appears to be removed (possibly by mechanisms discussed in the water chemistry and Galkeno 900 sections) as loadings in the South McQuesten upstream and downstream of the site seem to decrease from the data set;
- the change in sulphate loading the South McQuesten from upstream of the mine to downstream shows that the mine drainage are reaching the South McQuesten River. There is some removal of sulphate locally (Flat Creek) but overall there is an increase in sulphate loading to the river, corresponding to an change in concentration from 30 to 50 mg/L, similar to background values;
- the loadings in both the Ladue Creek and Lightning Creek watersheds are insignificant compared to the sources in the South McQuesten watershed and still correspond to zinc concentrations of about 0.05 mg/L and 40 mg/L sulphate;
- there is a significant load of zinc and sulphate from upstream of the mine (station LES-1) on the South McQuesten River. The source is probably from the Earn Group, as discussed in both the geology and water chemistry sections.

8.2.5.2 Treatment at Galkeno 900

The Galkeno 900 adit was considered to be the single largest source of zinc within the catchment of Christal Creek above station S-18, generating an estimated load of about 6000 kg per year of total zinc. Monitoring of the treatment plant effluent suggests that, on average, the plant removes about 90% of the zinc (based on government and LES data over the monitoring period). Figure 8-8 suggests that there has also been removal of zinc within the catchment - probably by a combination of physical and chemical processes (settling or filtering, sulphate reduction and precipitation).

The data were evaluated to determine the effect of the Galkeno plug and water treatment on the receiving water quality. The concentration in Christal Creek have decreased from peak values of 1 to 3 mg/L in the late 1980's, to generally less than 2 mg/L in 1994 and 1995.

Figure 8-12 shows a plot by month of zinc concentrations in Christal Creek at station S-18, using the government and external data sets, with and without water treatment. This figure shows both seasonal variations in concentration at S-18, and the reduction of zinc loadings to Christal Creek as a result of the plug and treatment system. The seasonal variations are primarily a reflection of the changing flow in the receiving environment, as the discharge from the adit does not show a similar magnitude of seasonal fluctuation.

The graphs show that the zinc concentrations in the receiving environment have been reduced by about half as a result of the treatment system. Given the effectiveness of the lime treatment system in removing a load of 6000 kg per year, a more appreciable change in receiving environment concentrations might have been anticipated. This suggests a number of possible explanations; that prior to the installation of the treatment plant, natural treatment processes were removing zinc from solution along the flowpath prior to station S-18 and/or there is additional seepage of Galkeno adit water from the hillside into the Christal drainage, from seeps remote from the portal area (which have been monitored).

8.2.5.3 Effect on the Receiving Environment of Treatment at Bellekeno 600

Treatment of the Bellekeno adit discharge waters would affect the water chemistry initially at station LES-41 on Lightning Creek. Since the monitoring data are limited for this station, particularly for the period prior to treatment, the evaluation of the effect of treatment on the receiving environment is based on calculation of loadings without treatment.

Figure 8-9 shows that, with treatment of Bellekeno adit discharge, Lightning Creek receives zinc loadings from other upstream "natural" sources resulting in a concentration of about 0.05 mg/L total Zn. With treatment, the Bellekeno adit drainage contributes about 1% of this load of zinc, and about 5% of the total load of sulphate in Lightning Creek. Without water treatment, the contribution of the Bellekeno adit discharge would result in a zinc concentration of about 0.06 mg/L Zn in Lightning Creek.

8.2.5.4 Effect on the Receiving Environment of Treatment at Silver King

The effects of discharge of the adit drainage from Silver King would first be evident in Galena Creek, and then in Flat Creek at Station S-9. Figure 8-13 shows the data at Station S-9, with relatively little change over the period when water treatment was installed. This is perhaps not surprising given that the adit discharge, even at the source, only represents 15% of the total load observed at S-9. It is also anticipated that there would be some removal of metals along the flowpath, decreasing the metal load.

Using a similar analysis to the above for Bellekeno, and with similar cautions about the receiving water database, the effect of water treatment for the Silver King adit discharge of the adit water would result in a significant increase in zinc concentrations in Galena Creek immediately below the discharge (station LES-57), although the predicted concentration is comparatively low at 0.12 mg/L. The change in concentrations at S-9, in Flat Creek, would not be detectable however based on previous data and flow calculations.

Figure 8-12 Christal Creek at S18 - Observed Zinc Concentrations for Periods with and without Treatment of Galkeno 900 Discharge

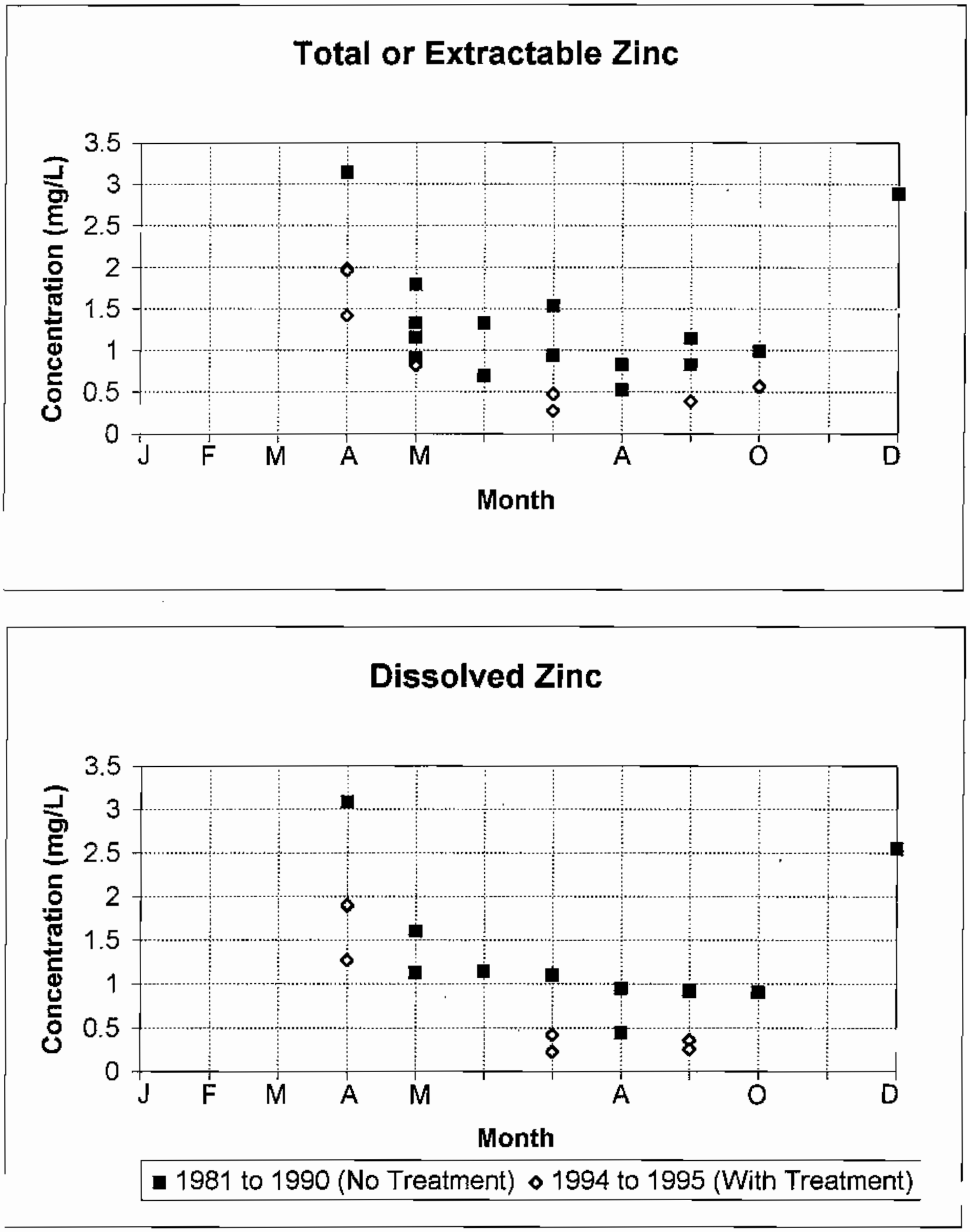
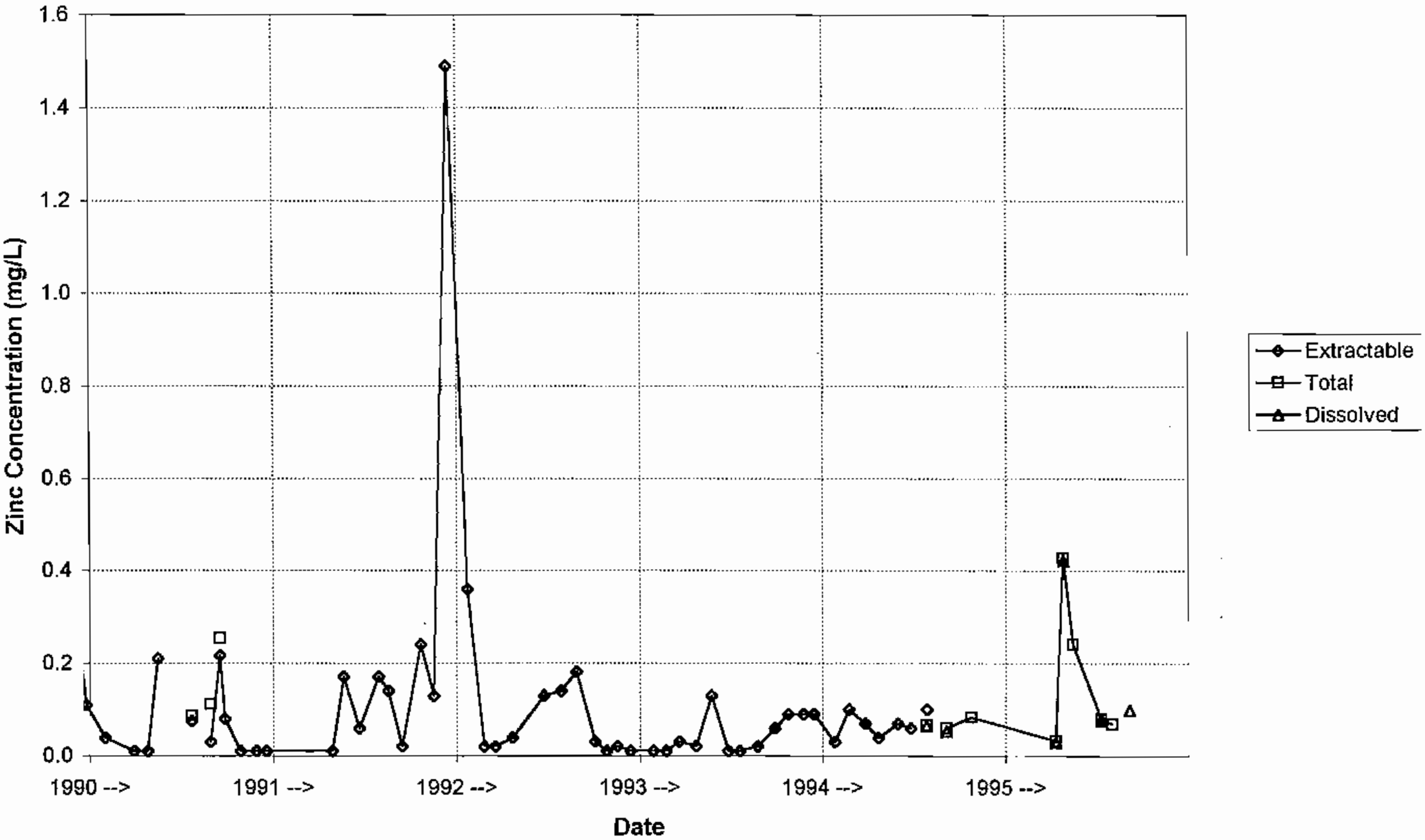


Figure 8-13 Flat Creek at mouth (S9)



8.3 Impact Assessment

8.3.1 Introduction

The impact assessment for the UKHM' property considers three broad ecosystem components. These components are discussed as separate sections and include aquatic resources, and terrestrial resources. Other resource users are discussed in Chapter 4.

The aquatic resources section discusses the basis for the assessment and then each catchment area is discussed separately. A brief catchment description is provided along with the presentation of impact assessment data. A historical impact assessment is then presented for each drainage.

For the impact assessment for terrestrial resources and for other resource users, both the potential causes and the historical impacts on wildlife, habitat and other resource users are presented.

8.3.2 Aquatic Resources

8.3.2.1 Basis for Assessment

The site chemical loading balance and water quality data discussed in Section 8.2 were used to assess potential impacts of mining activities on the local aquatic resources. The approach taken was to compare the water quality data with the CCREM freshwater aquatic life guidelines and regulated effluent standard limits set in UKHM's present Type B water use licence. Where possible natural background receiving waters quality were compared as well.

The CCREM freshwater aquatic life guidelines are comprehensive national guidelines developed with the objective of protecting the most sensitive life stages of sensitive freshwater species during all periods. These guidelines are used to evaluate receiving water quality and provide an indication of potential impacts on sensitive species. When using the guidelines, the actual impacts of exceeding a CCREM guideline are dependent upon the receiving waters most sensitive species present. Within the immediate drainage areas affected by mining, the most sensitive fish species present were arctic grayling.

For this assessment, the key parameter of interest is total zinc concentrations. Although other parameters are of concern, i.e. cadmium and lead, the site chemistry and contaminate loading is dominated by zinc. Zinc does provide a good indication of these other parameters. The CCREM freshwater aquatic life guideline for zinc is 0.03 mg/L.

The following sites were selected for discussion of the impact assessment:

- for the Flat Creek catchment, station S-9 (LES 9) Flat Creek upstream South McQuesten River;
- for the Christal Creek catchment, stations S-18 (LES 6) Christal Creek at Keno Highway and station S-19 (LES 7) Christal Creek at Hanson road;
- for the South McQuesten River catchment, stations LES 1, South McQuesten River upstream Christal Creek, station S-10 (LES 2) South McQuesten river at pumphouse, station S-11 (LES 4) South McQuesten River downstream Flat Creek, and station LES 5 South McQuesten River 9 km downstream of Flat Creek; and,
- for the Lightning Creek catchment, stations LES 37, Lightning Creek upstream Hope Gulch, and station LES 41, Lightning Creek at Keno City.

Two periods of actual record were used in the impact assessment. The data set for the years 1990 to 1993 was considered as one case - mean annual before treatment, and the data set between 1994 to 1995 considered as the other - mean annual with treatment. A figure illustrating zinc contaminant loads and concentrations for these two cases are presented in Figure 8-14. This figure appears at the end of this section as it is referred to throughout this discussion. Technical Appendix X provides tables with contaminant loading model runs and are presented in quarterly and yearly averages. Figure 8-14 uses annual average concentrations to illustrate the distribution of zinc in the receiving environment. These are calculated on the basis of seasonal values which are presented in Technical Appendix X.

In evaluating the impacts of the current site conditions on the environment, it is instructive to consider historic activities that have occurred in the area and the response of the environment to these activities. Where possible actual documented information has been used to assist with the impact assessment analysis. To provide a understanding of the consequences that these activities have had on the local environment and the resultant impacts, a general discussion is provided for each catchment area which describes the more significant activities or events that have occurred.

8.3.2.2 Flat Creek Catchment

A summary of observations and conclusions from the field studies and the existing data on this catchment follows:

- the Flat Creek valley is located downstream of the tailings dams in a low lying valley dominated by wetlands and mature forest;
- fisheries utilization is restricted to the lower reaches, mainly near the confluence with the South McQuesten River;
- the benthic community has a low abundance and diversity reflecting an impacted drainage, but has recovered in more recent years;
- mean annual total zinc concentrations in Flat Creek for 1994 and 1995 using LES data was 0.133 mg/L;
- historic data indicates a peak in total zinc concentrations in the creek in June 1973 (8.6 mg/L) and a trend of decreasing concentrations to the current level of 0.18 mg/L (February 1996 YTWB Monthly Water Report) ; and,
- the aquatic resources and stream chemistry in the creek has been influenced by tailings deposition and tailing supernatant and adit discharge.

Figure 8-14 and Technical Appendix X-1 show that before treatment the mean annual zinc concentrations in the creek were 0.18 mg/L. This level is above the CCREM guideline for protection of aquatic life. It is interesting to note however that there is little change in the Flat Creek water chemistry, even with treatment. The mean annual zinc concentrations continue to exceed the CCREM guidelines at 0.18 mg/L (Figure 8-14 and Technical Appendix X-2). Despite the effectiveness of the treatment of the Silver King waters, these data indicate that metal concentrations have not appreciably decreased since treatment at Silver King adit.

This observation corresponds to the water chemistry analyses in Chapter 6, and the water treatment discussion in Chapter 8.2 wherein it is observed that the water chemistry in Flat Creek is not appreciably affected by discharge from the Silver King area. The data do suggest that the seepage from the tailings, particularly seepage from the older tailings which bypasses the No. 3 tailings dam, is the primary source of zinc to the Creek (see Figure 8-4).

It should be noted when comparing these values with the background Flat Creek station upstream of the Porcupine Diversion, that zinc concentrations upstream also exceeded the CCREM guideline. This may reflect the natural background stream chemistry or indicate that Flat Creek may have been influenced by other anthropogenic sources.

Fisheries studies conducted in 1994 and 1995 confirm the absence of fish habitat and fish species throughout the majority of Flat Creek, with only the lower most reach at the confluence of the South McQuesten River providing suitable habitat for fish species. Fish sampled from this reach had tissues analyzed for metal content (sculpin and one arctic grayling) as shown in Chapter 3, Table 3-7. Although the tissue metals data for other lakes (Table 3-8) do not report arctic grayling tissue data, the Flat Creek fish tissue metal results were comparable with fish species and tissue data collected in Mayo and Wareham Lakes.

Historically, the Flat Creek drainage has been affected by deposition and migration of tailings. There is documented evidence that tailings solids were released to Flat Creek drainage as a result of the No. 1 and No. 2 dam failure in the early 1970's. It is expected that the aquatic habitat and resources in Flat Creek deteriorated as a result of tailings loss since tailings solids altered the natural stream bed composition and metals concentrations exhibited acute and or chronic toxic effects on local fish populations. There were reported fish kills in this drainage as a result of tailings loss. The tailings are now impounded behind engineered structures and their performance regularly monitored.

In addition, effluent from the valley tailings is discharged to Flat Creek. Occasionally this discharge has exceeded regulated concentrations for pH, metals, suspended solids, and cyanide with a resultant impact on the water quality and aquatic habitat and resources in Flat Creek. Water quality data collected from lower Flat Creek has historically exceeded CCREM guidelines for freshwater aquatic life for certain metals (cadmium, lead, zinc), although in recent years water quality has improved in Flat Creek. This is improvement in water quality, and potential for recovery of the receiving environment is due in large part to improved management of the tailings solids and discharge water chemistry.

8.3.2.3 Christal Creek Catchment

A summary of conclusions from field studies and existing data on this catchment is as follows:

- the Christal Creek valley is located downstream of Christal Lake which receives drainage from Galkeno 900 adit and the old MacKeno tailings. This valley is dominated by a variety of habitats including wetlands and mature forest;
- fisheries utilization is restricted to the mid to lower reaches and mainly near the confluence with the South McQuesten River. No overwintering arctic grayling were encountered;
- the benthic community has moderate abundance and diversity, but does reflect an impacted drainage. Data indicates a trend towards recovery in more recent years;
- mean annual total zinc concentrations in Christal Creek for LES data collected in 1994 and 1995 at the Keno highway were 0.94 mg/L, and 0.25 mg/L in Christal Creek at the Hansen Road;
- historic data indicates a peak in total zinc concentrations in Christal Creek at the Keno Highway in April 1988 (3.14 mg/L) and 1.47 mg/L zinc in Christal Creek at Hansen road in April 1987;
- there is a decreasing trend in zinc concentrations at both of these stations to current levels of 0.022 mg/L at Keno highway and 0.70 mg/L at the Hansen Road (UKHM YTWB Monthly Water Reports) ; and,

- the aquatic resources and water chemistry in the creek has been influenced by tailings deposition and adit discharge.

Figure 8-14 and in Technical Appendix X-1 show that mean annual zinc concentrations before treatment were 1.6 mg/L and 0.7 mg/L in Christal Creek at the Keno Highway and at Hansen Road, respectively. This level is above the CCREM guideline for protection of aquatic life.

The mean annual zinc concentrations at both Christal Creek stations (Figure 8-14 and Technical Appendix X-2) are lower, at 1.0 mg/L and 0.4 mg/L, respectively, however continue to exceed the CCREM guidelines. It is noteworthy that after treatment of the Galkeno 900 adit discharge, water quality in Christal Creek has improved. It is expected that continued treatment will further improve water quality although it appears that there are additional sources of loading from the hillside, as discussed earlier.

Fisheries surveys conducted in 1994 and 1995 indicate that Christal Creek is utilized by arctic grayling up to the mid stream reaches where an obstruction prevents further upstream migration. These fish are not avoiding this drainage even with zinc concentrations exceeding the CCREM guidelines.

Fish tissues were analyzed for metal content in Christal Creek and Christal Lake (sculpin and arctic grayling) (Table 3-7). Fish tissue metals data for other local lakes are presented in Table 3-8, however arctic grayling tissue samples were not collected. The fish tissue metals results were comparable and in some instances lower than fish species and tissue data collected from Mayo or Wareham Lakes.

From a historical perspective, the Christal Creek drainage has also been impacted from previous mine and milling operations. Tailings from the MacKeno mill were deposited on land near Christal Lake during the 1950's. These tailings have been partially inundated and there is evidence of tailings migration into Christal Creek. In addition, the Galkeno 900 adit which contains high concentrations of metals, particularly cadmium, lead and zinc has discharged into Christal Lake since the early 1960's.

Water quality data collected from Christal Creek has historically exceeded CCREM guidelines for certain metals (cadmium, lead, zinc). Fisheries studies recently conducted confirm the presence of arctic grayling up to the mid stream reaches of Christal Creek and have documented habitat alternations resulting from tailings solids release and impaired water quality.

Galkeno 900 adit drainage is now treated to meet regulated effluent limits and it is expected that aquatic resources will continue to improve as mitigation measures (effluent treatment, passive wetlands) are implemented.

8.3.2.4 South McQuesten River Catchment

The South McQuesten River is the final receiving waters for both the Flat Creek and Christal Creek catchments. A summary of conclusions from field studies and existing data on this drainage is as follows:

- the South McQuesten River valley is located both upstream and downstream of mining activities. Flat Creek and Christal Creek report to the river. This valley provides a variety of habitats including wetlands and mature forest and a variety of flow regimes and fish habitats;
- a wide variety of fish species utilize the river throughout all life stages. Adult and juvenile Chinook salmon are found in the river, upstream to the confluence of Haggart Creek;
- the benthic community is both abundant and diverse. There is a general trend towards reduced benthic productivity from the influences of Christal and Flat Creek drainages, however abundance and diversity increase downstream of the Flat Creek drainage;
- mean total zinc concentrations in the South McQuesten River (LES 1994 and 1995 data) at stations upstream of Christal Creek, at the pumphouse, downstream of the confluence of Flat Creek, and 9 km downstream of Flat Creek were 0.016 mg/L, 0.023 mg/L, 0.062 mg/L, and 0.014 mg/L; and,
- the river has reported background concentrations of total zinc that range from near detection limits to slightly exceeding the CCREM freshwater aquatic life guidelines.

Figure 8-14 and Technical Appendix X-1 show that mean annual zinc concentrations in the early 1990's (before water treatment) in the South McQuesten River were 0.02 mg/L upstream of Christal Creek, 0.07 mg/L at the pumphouse, 0.11 mg/L downstream of Flat Creek and 0.01mg/L 9 km downstream of Flat Creek. These zinc levels indicate that the South McQuesten River located upstream of Christal Creek and 9 km downstream of Flat Creek are within the CCREM guideline for protection of aquatic life. The CCREM guideline is slightly exceeded in the South McQuesten river at the pumphouse.

The results reported for the South McQuesten river downstream of Flat Creek should be viewed with some caution. The station is located within the immediate mixing zone of Flat Creek which is a source of zinc loadings. A transect survey was completed at various locations on the South McQuesten River downstream of Flat Creek and it was determined that this station should be relocated further downstream to ensure that a representative downstream receiving water sample is collected from the South McQuesten River. This recommendation was supported by Environment Canada in a letter dated June 27, 1995 to the company.

Zinc concentrations for the period with treatment are the same as mean annual zinc concentrations before treatment for all stations (Figure 8-14 and Technical Appendix X). Zinc loadings have been reduced in waters draining Christal Creek, however, these levels are not significant enough to appreciably change the concentrations in the South McQuesten River.

Fisheries surveys conducted in 1994 and 1995 indicate that the South McQuesten River is utilized by a wide variety of fish species during all life stages. While benthic surveys have indicated reduced species abundance and diversity in the South McQuesten River between Christal and Flat Creek, there is no evidence habitat of fisheries population loss. Recent monitoring has indicated an improvement in the South McQuesten River benthic community between this stream reach.

Arctic grayling fish tissues were collected and analyzed for metal content in the South McQuesten River (Table 3-7). Although the tissue metals data for other lakes (Table

3-8) do not report arctic grayling tissue samples, the results were comparable and in some instances lower than fish species and tissue data collected from Mayo or Wareham Lakes.

From a historical perspective, the South McQuesten River has been influenced by activities in both the Christal and Flat Creek drainages. Each of these is has been impacted over the past 100 years by development and mining activity, in terms of water quality and aquatic resources. Metal loadings from these drainages have on occasional impacted the water quality in the South McQuesten River.

This watershed has also been logged and a number of log jams exist on the river. A log jam located on the river upstream of the confluence with Haggart Creek acts as a fish barrier for migration of Chinook salmon.

The South McQuesten River is considered an important local drainage. Based on a review of historical data and recent studies, this system does not appear to be irreversibly affected by local development as water quality and benthic data indicate an improvement in the ecosystem quality.

8.3.2.5 Lightning Creek Catchment

Lightning Creek is a separate drainage that is influenced by mining activities. This creek reports to the Mayo River. A summary of conclusions from field studies and existing data on this drainage is as follows:

- Lightning Creek is located both upstream and downstream of mining activities. Hope Gulch and Thunder Gulch flow into this creek. This valley is narrow with a steep gradient. The drainage has been impacted by other anthropogenic activities;
- arctic grayling utilize the creek with adult fish seeking clear upstream waters and juveniles located in more turbid waters downstream;
- mean annual total zinc concentrations in Lightning Creek stations upstream of Hope Gulch and downstream of the confluence of Thunder Gulch in 1994 and 1995 were 0.008 mg/L and 0.05 mg/L.

Figure 8-14 and Technical Appendix X show that mean annual (with treatment) zinc concentrations in Lightning Creek are 0.008 mg/L upstream of Hope Gulch and 0.05 mg/L at Keno City. These levels indicate that the upstream station is below the CCREM guideline while the downstream station zinc concentrations are slightly above the CCREM guidelines. Water quality data before treatment are not available.

It should be noted that Thunder Gulch contributes a significant metal loading to Lightning Creek as a result of upstream placer mining activity. For example, during the September 08, 1994 sampling event, zinc concentrations in Thunder Gulch upstream of the Bellekeno adit was 6.71 mg/L.

Fisheries surveys conducted in 1994 and 1995 indicate that arctic grayling utilize the drainage with adult grayling preferential to clearer waters located upstream of Thunder Gulch. No benthic surveys were conducted in this drainage as natural and anthropogenic disturbances have in the past repeatedly changed the natural stream conditions, lessening the usefulness of a survey in terms of meaningful long term data.

The Lightning Creek drainage has been historically impacted from localized placer mining and quartz mining activities. Mine adit drainages from Bellekeno and Keno 700 eventually report to the Lightning Creek drainage. The loadings from these sources is considered marginal compared with sediment and metals loadings from other anthropogenic activities.

8.3.3 Terrestrial Resources

The approach taken to addressing impacts on terrestrial resources was to understand potential causes of impacts and then consider these impacts within the context of historical and present regional activities. A summary of the key terrestrial resources within the regional area is provided:

- the area is characterized by widespread discontinuous permafrost with a variety of habitat types including low wetland areas to scree dominated mountainous areas
- a wide variety of wildlife is supported including ungulates, fur bearers, small mammals, upland game birds and waterfowl
- there are no known rare or endangered plant or wildlife species present in the area

The Elsa Keno Hill area has a long history of occupation and development. The area has been used for centuries by the local first nations for their traditional life style. Terrestrial resources were subjected to utilization and harvesting pressures as a result of increasing occupation in the area. With the development of the Wernecke, Keno City and Elsa camps came increased access to the local area. Increased access provided a corresponding increase on the local terrestrial resources.

There has been some wildlife population loss as a result of increased access and hunting. Traditional knowledge has indicated that a local thin horn sheep population on Keno Hill has been lost, due to overhunting pressure. It is not known whether this species could be successfully re-introduced to the area.

Although there were local reports of wildlife shortages, generally there were no significant concerns raised by wildlife managers or the local community. No unique studies were initiated, outside of regional moose surveys, to address concerns with reduced wildlife or waterfowl populations. In addition, there has not been significant changes in the local wildlife or waterfowl populations to warrant changes to wildlife management practices in the area.

Limited collection and analyses of local vegetation and wildlife tissues indicates that metal update in plants and accumulation in animals in not of concern, however the database for this assessment is quite limited. Government programs and studies are attempting to address the issue of country food health.

Mining activity in the region covers a large area, however development has been quite localized and a relatively small number of hectares have been disturbed in relation to the mine claim block. Areas that were once used for past mining activities has successfully revegetated. The new and older tailings areas also show evidence of revegetation. Waterfowl and small mammals are routinely seen in the valley tailings area and their is no evidence of wildlife fatalities in any of the open pits.

There is no question that past anthropogenic activities have altered the local landscape and affected local wildlife populations. However, observations of these impacts over time have indicated the environment's natural capacity to regenerate habitat and sustain wildlife and waterfowl populations in the face of past development and occupation pressures.

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