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"The "D" Open Pit - Reclamation"

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Abstract

COGEMA Resources Inc. operates the uranium mines and mill at Cluff Lake in Northern Saskatchewan. Several uranium deposits have been mined or are currently being mined by either open pit or underground methods at the Cluff Lake site. One of these deposits, the "D" deposit, was discovered in 1970 and mined as an open pit in 1979 and 1980. The deposit yielded 150 000 tonnes of ore at an average grade of 3.0% uranium.

The company's philosophy is to reclaim and decommission areas on the mining lease as soon as possible after mining work has been completed. With regulatory agency approval, the "D" Open Pit area could be the first to be decommissioned at Cluff Lake.

Since the mining of the "D" pit was completed, the surface facilities have been removed and the area has been recontoured, covered with a layer of local overburden and revegetated. Vegetation was reestablished by hydroseeding the area with a seed mix that was developed on site and which was suited to local soil conditions. The overburden at the "D" site is virtually barren of nutrients when compared to farmlands in the southern part of the province and required the addition of fertilizer at a rate of 850 kg/ha. In addition mulch is also required along with tackifier when seeding on steeper slopes. A thick thatch developed within a few years after completion of the revegetation program. This thatch initially inhibited the invasion of native plants but now shrubs and trees are starting to invade the area.

The water collecting in the former open pit, the groundwater and surface waters have been monitored extensively since 1985 as part of the mine site license requirements. Results to date indicate that the upper 10 metres of water in the pit will meet Saskatchewan Surface Water Quality Objectives (SSWQO). If the water were to overflow the pit area into Boulder Creek it is expected that these objectives would still be met. Also the pit water has had no detectable effect on the surrounding ground water chemistry.

The D pit area is an excellent example of the sustainability of mining in Northern Saskatchewan from initial discovery of a deposit, through mining, finally to decommissioning and returning the area to nature with minimal overall impact.

1. *Introduction*

Cogema Resources Inc., operates the uranium mines and mill at Cluff Lake in Northern Saskatchewan (Figure 1 & 2). Operations began in 1979 with mining of the D deposit located about 1 Km east of the northern end of Cluff Lake in the Boulder Creek valley. Following the mining of D, other deposits including Claude, OP, Dominique Peter and Dominique-Janine were or currently are being mined.

At the completion of the operation at D, the company in consultation with the Atomic Energy Control Board (AECB) and Saskatchewan Environment and Resource Management (SERM) began efforts to reclaim the area affected by mining. These efforts included removal of buildings, settling ponds, other infrastructures and low grade ore stockpiles, recontouring the surface, revegetating the area, and monitoring surface water and groundwater.

The D pit and surrounding area has been extensively monitored and documented over the past twelve years. The results of the monitoring indicate that conditions are stabilizing at levels that meet regulatory limits. This would allow the company to make application to the regulatory bodies to officially decommission the area and therefore demonstrate that land used for mining might be returned to the public domain.

2. *History*

2.1. *General History*

The D ore body was discovered in 1969 by AMOK LTD. (now Cogema Resources Inc.) following an airborne scintillometer survey and geological mapping of mineralized boulder trains (Figure 3). The D ore body was situated in a geologically complex area near the perimeter of the central metamorphic rock core of the Carswell Structure (Amok 1992). The D deposit was located at the overturned contact between the overlying Athabasca Formation and the underlying metamorphosed basement rock (Figure 4 & 5).

The D ore body was located entirely within the Boulder Creek Basin. Groundwater flow within the Boulder Creek basin is gravitational flow infiltrating downwards beneath the upland areas. Groundwater also flows upward and longitudinally beneath the valley of Boulder Creek. It is considered that groundwater discharges upward into the Boulder Creek alluvium and that the entire regional groundwater discharges to Boulder Creek. The surface water from Boulder Creek moves downward into Boulder Creek alluvium west of D ore body to Cluff Lake. During the operation of the D ore body the entire Boulder Creek was intercepted and diverted past the open pit in a semi-circular steel flume. This flume and associated dam upstream of the D orebody were removed in 1993.

In 1979 and 1980, D was mined as an open pit. The pit reached the dimensions of 203m x 90m x 28m deep. The deposit yielded 150 000 tonnes of ore at an average grade of 3.0% uranium.

During the operation of the pit, minewater was collected and treated locally before being released to the environment. After mining was complete in 1981 the water treatment plant operated between April and October. For the rest of the year water was hauled to the mill and used as process make-up water. In July 1981 run-off from a major rainstorm could not be effectively contained and additional berms were constructed.

In April 1983, the pit was flooded by Boulder Creek. The creek returned to its normal channel a few days after the flood occurred. A dyke was constructed between Boulder Creek and the pit in August.

During 1983, all surface facilities were removed and the surface was contoured so that most run-off would flow to the pit. All grades were reduced to 25 degrees or less. The waste rock stockpile was also contoured and 20 centimeters of overburden was placed on top to provide a rooting medium for vegetation.

In 1985, the final earthworks in the immediate area of D, grading the waste rock stockpile, was completed.

In 1993, approval was received to remove the half culvert which lined Boulder Creek and to breach the dam upstream of D. Final contouring of the breach in the dam was completed in 1994 and the area of the breach was hydroseeded.

2.2 Monitoring History

The D-pit area was first monitored by a regional piezometer network, as well as a surface water monitoring program, beginning in 1977-1979. Boulder Creek was sampled at upstream and downstream locations, before, during and after mining. In 1983, after D-pit filled with water, in-pit water quality measurements commenced, and monitoring of selected piezometers continued. This monitoring continues to date.

2.3. *Revegetation History*

In 1981 field studies began on finding the optimum species for the revegetation of the D mining area. Samples of soil and rock from the D area were used in the studies, resulting in the following seed mixture:

	1983		1984
25%	hair grass	26%	slender wheatgrass
15%	red fescue "fortress"	20%	red fescue "fortress"
5%	red fescue "arctared"	7%	red fescue "arctared"
5%	Kentucky bluegrass "sydsport"	14%	fowl bluegrass
5%	Kentucky bluegrass "troy"	7%	Kentucky bluegrass "sydsport"
20%	slender wheatgrass	7%	Kentucky bluegrass "troy"
10%	fowl bluegrass	7%	lax alkali grass
5%	weeping alkali grass	6%	annual bluegrass
5%	annual bluegrass	6%	reed canary grass
5%	reed canary grass		

Additional seed	white spruce	150 g/ha
	Jackpine	150 g/ha

This seed mixture was used in the first major revegetation program conducted in 1983. Reseeding of some areas was done in 1984. Grass cover in the fall of 1984 was dominated (80%) by hairgrass and Kentucky bluegrass that was split evenly at 40%. Red fescue that showed very well in a test was not found. The final seeding of the waste rock stockpile area was completed in 1985. Presently the most dominate of the original species is reed canary grass, which showed poorly in 1984. The vegetation is now well established in the D-pit area, and native species are starting to invade the area (see Section 4.3).

2.4. *Studies*

To date, there have been two specific studies done in the D-pit area. First, from 1986 to 1988, a detailed study of the D-pit area was initiated by Saskatchewan Environment and Cogema Resources Inc. (S.E.R.M., 1993). There were three purposes of this study; "I) determine the physical and chemical changes taking place in the water column; ii) identify the external influences, if any, affecting these changes, and; iii) determine how these changes relate to arsenic concentrations and Saskatchewan Surface Water Quality Objectives" (S.E.R.M., 1993).

This initial study produced several important conclusions, including 1) water quality of D-pit is affected by pit water turn-over and run-off; 2) run-off events, during the spring melt and summer showers, concentrate major ions, metals and radionuclides towards the bottom of the pit; 3) area groundwater has not shown signs of significant contaminant migration.

The second study began in 1992, focusing on the water quality of the D-pit water column, and continues to date. Since 1993, Cogema Resources Inc. assumed full responsibility for this program.

2.4.1. Local Piezometer and Boulder Creek Analyses

Figures 6 to 8 show the raw historical data collected from key monitor wells, located on the south side of D pit and along Boulder Creek.

The raw data for Boulder Creek, upstream and downstream of D-pit is also shown (Figures 9 and 10).

Groundwater quality in the vicinity of D-pit showed limited effects as a result of mining. Immediately south of the pit, (Figure 6) slight increases in sulfate and uranium concentrations occurred after mining, while conductivity and chloride remain at or near pre-mining levels. Groundwater radium concentration has decreased as a result of mining. Nickel concentration is slightly elevated, and arsenic has shown no change.

Downstream of D-pit similar effects were seen in the groundwater quality, with minor elevation of sulfate and uranium concentrations (Figures 7 and 8). Slight increases in sulfate and uranium concentrations occurred, while radium concentrations have decreased substantially after D-pit mining was completed.

Mining in this area appears to have improved local groundwater quality, from pre-mining conditions, with respect to radium concentration.

Water quality results for Boulder Creek upstream of D-pit for arsenic, nickel, Ra-226 and U indicate that this creek was un-affected by mining in this area (Figure 9). During the mining phase, increases in these parameters occurred (Figure 10), specifically between 1980 and 1982.

The last 10 years of monitoring has shown downstream of the pit consistently low concentrations of these parameters, all well within the Saskatchewan Surface Water Quality Objectives (S.S.W.Q.O.). Based on these results, Boulder Creek water is expected to continue to be of excellent quality in the future.

3. Current Monitoring

3.1 What is Monitored Now

Table 1 shows the current status of monitoring in the D-pit. As in previous years, the sample type has remained with the same type of analysis, but the frequency was increased from once per quarter to monthly. This increase in sampling frequency was made to accommodate the second D-pit study, which focused on pit water quality. Additional monthly measurements of temperature, conductivity, and dissolved oxygen were also taken at one metre intervals. To clarify interpretation, field data is examined at five metre intervals in this report.

Weather has been monitored near the Cluff Lake mill since 1981, with an Environment Canada Meteorological Observation station. Data collected (Figure 11) can be indirectly applied to the D-pit area.

3.2. What Trends area Being Observed

3.2.1 Weather

The weather information shown (Figure 11) depicts the normal, average mean values for each month since 1981. The highest average temperature occurs in July, with an average value of 16.8°C. The lowest average temperature occurs in January, with an average value of -19.6°C. Maximum average monthly precipitation is found in July, at 82 mm precipitation, while the lowest value is 17.1 mm in February. The bulk of the spring melt typically occurs in April and May. During the 1986 - 1988 study of D-pit, it was estimated that approximately 7 000 m^3 of spring runoff water enters D-pit, primarily from accumulated snow in the highlands immediately north-east of the D minesite area.

3.2.2 Field Measurements

Table 2 shows the field measurements taken during the current study period, up to August 1995. Figure 12 shows the monthly averages of this data.

Pit water temperature shows seasonal fluctuation at surface and the 5 metre depth. Below 5 metres, the pit shows a definite thermal stratification with an average temperature of 3.6°C, and only the top 5 metres of water being affected by seasonal temperature fluctuation.

Surface conductivity is affected primarily by the spring melt between April and May of each year, giving a 20% decrease in surface water conductivity. At 5 metre and 10 metre depths, conductivity decreases throughout the summer months, with corresponding increases at 15 metres during the summer. At 20 metres, conductivity remains relatively constant throughout the year, at about 1.4 times greater than measurements at 15 metres and above. The lowest point in conductivity at a depth of 20 metres is found in May, in conjunction with the distribution of melt water throughout the pit water. There is thus a definite conductivity stratification in the pit water throughout the year, occurring between 15 metres and 20 metres. This indicates the presence of a stable chemocline at this depth.

Dissolved oxygen results show that recharge occurs between September and November, to a depth of 15 metres. This event is related to the decreased temperature of surface water and at 5 metres during the fall, and to a slight decease in conductivity at the 15 metre depth in September. Dissolved oxygen at the 0 to 5 metre depths consistently meets or exceeds the SSWQO minimum for dissolved oxygen of 6.0 mg/L throughout the year. At a depth of 20 metres, dissolved oxygen concentration is typically very low or absent, and a hydrogen sulfide odour is consistently present.

3.2.3 Analytes

Figures 13 through 17 show the concentrations of arsenic, nickel, Ra-226 and U in D-Pit water, at surface, 5 m, 10 m, 15 m and 20 m, For ease of interpretation, the following summary is based on the individual selected parameters, for the current study period beginning April 1992. Refer to the Figures listed above for each individual element.

Arsenic (Figure 14)
Surface water arsenic concentrations continue to be well below the SSWQO of 50 μg/L. Arsenic levels tend to 'bottom out' in the spring, corresponding to dilution by spring melt, and have not exceeded 20 μg/L since January 1993.

At 5 metres, arsenic concentration declined for the past 3 years, and was consistently lower than 40 μg/L. The arsenic concentrations at surface and 5 m have shown strong similarity since April 1992. A similar trend is seen for arsenic at the 10 metre level. At 15 metres, definite spikes in arsenic concentration are seen, usually between August and October. This was evident in the fall of 1992 and 1993, and was less prominent in 1994. This indicates that, during thermal stratification effect in the fall, some arsenic-bearing sediment mixes with the water at the 15 metre depth, then quickly settles down. There is no indication that this is affecting the water quality from surface to 10 metres.

At 20 metres, arsenic concentrations have increased from an average of about 700 μg/L in April 1992 to an average of about 1100 μg/L, where this concentration has remained for the past 2 years.

Nickel (Figure 15)
In 1994, the average concentration for nickel at surface was 0.019 g/L, with a high of 0.029 mg/L, and a low of 0.007 mg/L. There has been a downward trend in nickel concentration at surface, since April 1992. Similar results are seen at the 5 metre and 10 metre depths. At 15 metres, nickel concentration has fluctuated around the 0.030 mg/L concentration, with a high of 0.042 mg/L and a low of 0.016 mg/L. At 20 metres, nickel has shown a definite downward trend.

Nickel concentration appears to show stratification, with highest concentrations found at the 15 metre depth.

Ra-226 (Figure 16)
Between surface and 10 metres, Ra-226 concentrations have generally been below the SSWQO of 0.11 Bq/L, with the lowest values between June and August, when dilution effects due to rainfall/runoff are greatest. Ra-226 concentrations at 5 metre and 10 metre depths have been less than or equal to 0.05 Bq/L since April 1992.

At the 15 metre depth, the maximum concentration of radium has been 0.16 Bq/L, in September 1994. Peak concentrations at this level tend to occur between April and September. The 20 m depth has shown a general rise in Ra-226 concentration since April 1992, with a plateau of 0.25 Bq/L since August of 1993.

Uranium (Figure 17)
Uranium concentrations from surface to 10 metres have shown very similar downward trends since April 1992. The SSWQO of 200 μg/L U has been met since April 1993. The 15 metre U concentration appears to show stabilization and decreasing concentrations since December 1993, below the 200 μg/L level. From April 1992 to October 1993, uranium concentration rose at the

20 metre depth. The concentration now appears to be stabilized, between 200 μg/L and 225 μg/L.

4. Future Predictions

4.1. Resuspension of Bottom Sediments

Previous studies on D-pit (S.E.R.M., 1993) discussed the possibility of bottom sediments acting as a sink for metals and radionuclides. With the exception of nickel, there tends to be a concentration gradient for contaminants in D-pit, with the lowest levels found near the surface, and the highest levels found at 20 m. The greatest degree of variation in concentrations is found at the 15 metre level (Figure 14), with peak concentrations of arsenic, nickel, radium-226 and uranium occurring in July through September. In contrast, concentrations at the 20 m level remain relatively stable throughout the year. This suggests that, during the late summer or fall, some resuspension of materials from 20 m or deeper does occur, but only up to the 15 metre depth. Resuspended materials then precipitate back to the 20 m depth or below.

Thermal turnover appears to be the primary factor affecting these seasonal changes in chemical concentrations at the 15 metre depth. The chemocline, however, remains intact throughout the year

Resuspension events can also depend on wind/wave action, and presence/absence of ice cover. However, the D-pit is in a small, sheltered basin, so wind effects are thought to be minimal, and at this latitude ice cover is virtually guaranteed.

4.2 When Will The Pit Overflow to Boulder Creek?

D-pit water elevation is shown in Figure 18, for the past 10 years. Yearly averages are shown, along with the high and low values for each year. From 1985 through 1991, pit water elevation rose approximately 12 cm per year, to an average elevation of about 332.25. Higher average water levels from 1992 to July 1995 resulted in a much slower rate of rise, of approximately 1.35 cm per year.

This slower rate of rise is due to two main factors. First, the water elevation has passed the confines of the pit, into a much larger collection area as defined by the south road/berm structure. Second, with the increased water elevation, seepage of pit water into the Boulder Creek alluvium has probably increased.

As the hydraulic head of the pit increases, so will the amount of seepage of pit surface water into the Boulder Creek alluvium. The rate of rise will probably decrease accordingly, and reach a point of equilibrium.

Three possible long-term scenarios are suggested for the D-pit area and are indicated below. In all cases, D-pit surface water quality is expected to meet the S.S.W.Q.O.

Long -Term Scenarios for D-pit Area

<table>
<tr><td colspan="2" rowspan="2">Water Elevation</td><td colspan="2">Boulder Creek</td></tr>
<tr><td>does not overflow into D-Pit</td><td>Overflows into D-Pit (ice jams in Boulder Creek, beaver dams etc.)</td></tr>
<tr><td rowspan="2">D-Pit</td><td>does not overflow (stays below 334.20 m.a.s.l.</td><td>1. Pit water level will determine amount of water seepage into Boulder Creek alluvium</td><td></td></tr>
<tr><td>does overflow (exceeds 334.20 m.a.s.l.)</td><td>2. Sediment build-up in pit seals seepage areas, eventually increasing the pit water elevation over the road.</td><td>3. Amount of water entering the pit exceeds the amount of seepage from the pit.</td></tr>
</table>

This first scenario is that neither the pit nor the Boulder Creek overflow. This is the current status of the D-pit area. If this situation were to continue, water quality data suggests that the SSWQO will continue to be met in the pit, to a depth of at least 10 metres.

The second scenario would occur if Boulder Creek does not overflow, and the level of the pit slowly rises to fill the basin defined by the south road/berm structure. The pit would then overflow into Boulder Creek at the lowest point on the top of the road/berm structure, at 334.2 m.a.s.l.. This could occur as the sediment layers accumulate in the pit, eventually sealing off seepage areas. This scenario should not adversely affect the water quality of the top 10 metres of pit water, since this would occur slowly, over several years or decades. Any water which would be decanted from the pit to Boulder Creek at that time would be expected to meet the S.S.W.Q.O..

The third scenario would occur if Boulder Creek was to overflow into D-pit, causing the pit to fill to the lowest point on the road/berm structure (334.2 m.a.s.l.), and flow back into Boulder Creek. This had occurred in April 1983, prior to the construction of the road/berm structure. The potential exists for an ice jam, beaver dam, or similar restriction in Boulder Creek to cause this to occur again in the future. This mass input of water into the pit would probably cause some stirring of pit water at depth, and temporally elevate the concentrations of some parameters in the pit surface water. It would be expected that, following an event of this nature, the pit water level would reach an equilibrium, and settling would return the pit water quality to its present state within a short period of time, meeting the S.S.W.Q.O.

4.3 Vegetation - Natural Vegetation Encroachment

During the past 12 years, succession has been observed throughout the D-pit minesite. Species observed now include alder, moss, lichen, mixed grasses, jack pine, aspen, cattails and bulrushes.

5. Conclusion

The reclamation of the D-pit area represents the first attempt at officially reclaiming an open pit uranium mine. It is an excellent example of the sustainability of mining in Northern Saskatchewan. Extensive monitoring and documentation over the past twelve years indicates that reclamation activities appear to have been successful, with the S.S.W.Q.O. generally being met to a depth of 10m in the pit. Pit water does not appear to have affected downstream groundwater quality, and natural vegetation is becoming well-established in the area. The results of the monitoring indicate that conditions are stabilizing at levels that are expected to continue to meet regulatory limits. Ultimately, the present state of the D-pit mine will be considered to be the accepted decommissioning condition for this area, and will allow the Company to make application for the release of this property as an officially decommissioned mine site.

6. Lists of Tables and Figures

Tables

Figures

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Table 1 Current Monitoring Status of D-pit Water Quality

1994 Operating License **Sample Location**	**Parameters**	**Frequency**
D-Pit Water	water elevation	Monthly, during ice-free months
	Class C* water analyses at 5m intervals	Monthly

1994 Extended Monitoring Program **Sample Location**	**Parameters**	**Frequency**
D-Pit Water	conductivity, pH, temperature, dissolved oxygen at 1m intervals	Monthly
	Class C* random duplicate analysis	Monthly

* Class C water analysis - Total analysis for - CO3/HCO3**, Ca, Cl, Mg, K, Na, SO4, TSS, Ra-226, U, As, Cu, Fe, Ni, Zn, Pb, pH, conductivity, total hardness, sum of ions, turbidity

** CO3/HCO3 - When pH is greater than 8.3, report CO3 and HCO3. When pH is less than 8.3, report HCO3 only.

D-PIT FIELD MEASUREMENTS
Average By Month - Apr.1992 to Aug. 1995

FIELD DATA FOR "D" PIT SURVEY

Table 2

1992-1995

	Temperature (°C)					Conductivity (mS/cm)					Dissolved Oxygen (mg/L)				
	0 m	5 m	10 m	15 m	20 m	0 m	5 m	10 m	15 m	20 m	0 m	5 m	10 m	15 m	20 m
Apr-92	0	3.2	3.3	3.2	3.4	29	176	180	186	315	10.8	4.7	3.6	1.6	0.1
May-92	6	5.3	4.3	3.2	3.2	161	162	165	188	248	10.5	9.45	7.2	1	0.53
Jun-92	17	5.9	4.1	3.1	3.1	159	161	175	197	267	9	7.5	4.2	0.5	0.7
Jul-92	21.1	6.2	4.2	3.8	3.4	161	162	178	202	268	9.2	7.79	2.6	0.29	0.39
Aug-92	18	7.5	4.2	3.7	3.2	156	159	176	206	255	7.2	5.25	2.2	0.5	0.55
Sep-92	7.5	5.6	5.2	3.6	3.5	161	162	167	215	268	7.72	7.8	6.4	0.75	0.52
Oct-92	1.5	2.5	4.1	4.4	4.7	185	186	188	199	297	7.6	7.1	6.55	5.27	0.25
Nov-92	0.9	3.2	3.3	3.5	3.7	176	171	175	183	271	12.4	9.6	8.7	6.7	0.5
Dec-92	0.1	3.4	3.5	3.5	3.7	181	180	184	193	275					
Jan-93	0.2	3.4	3.5	3.5	3.7	202	272	194	209	299					
Feb-93	0.4	3.3	3.5	3.5	3.7						11.8	6.7	5.1	3.1	0.5
Mar-93	1.5	3	3.1	3.1	3.6	75	175	180	180	265	8.6	5.6	4.2	3.2	1.2
Apr-93	12.8	5	3.2	3	3.2	175	190	195	210	320	11.3	5.6	4.2	2.4	1.7
May-93	16.8	5.8	3.5	3.4	3.5	174	180	195	220	320	11.3	5.6	4.2	2.4	1.7
Jun-93	19.2	8.4	3.8	3.7	3.7	167	178	200	229	330	9.3	6.2	2.7	0.9	0.3
Jul-93	17.9	9.2	3.9	4.1	3.8	164	179	199	226	314					
Aug-93	11.3	10.9	3.9	4.1	3.8	169	169	202	224	327					
Sep-93	5.2	4.8	4.8	4.1	3.8	211	210	209	258	364					
Oct-93	0.3	3.1	3.3	3.4	3.8	205	189	189	194	329					
Nov-93	0.4	3.2	3.3	3.4	3.8	207	190	190	194	331					
Dec-93	0.2	3.3	3.4	3.4	3.8	207	190	190	194	331					
Jan-94	0.2	3.3	3.4	3.4	3.8	194	189	193	198	335					
Feb-94	0.4	3.2	3.4	3.5	3.8	207	211	212	222	371					
Mar-94	0.4	3.2	3.4	3.4	3.8	199	210	214	224	349	6.6	6.3	4.6	4.1	0.6
Apr-94	0.3	3.3	3.4	3.4	3.8	194	211	216	223	368	7.6	6.5	4.8	4	0
May-94	9.1	5.1	4.6	3.8	3.7	177	178	178	190	306	12	9.1	8.3	5.5	0.1
Jun-94	20.9	6.9	4.6	4	3.8	250	208	180	196	340	10.5	8.9	7	3.1	0.2
Jul-94	14.5	7.3	4.6	4	3.8	176	173	182	195	348	9.9	7.3	5.7	1.3	0.1
Aug-94	19.7	8.3	4.5	4	3.8	178	172	182	208	352	9.2	5.7	4.3	0	0
Sep-94	13.4	11.2	4.6	4.1	3.8	175	174	183	214	355	9.4	8.1	3.3	0.1	0.1
Oct-94	8.4	7.5	4.9	4.2	3.8	174	175	181	207	348	10.5	11.6	4.3	1.5	0.1
Nov-94	1.1	3.6	3.7	3.8	3.8	208	207	206	209	389	11.6	10.8	9.8	9	0.6
Dec-94	0.1	3.4	3.7	3.6	3.7	202	205	207	210	389	9.4	8.9	7.9	7.2	0.2
Jan-95	0.1	3.5	3.6	3.6	3.6	204	185	189	191	350	8.4	7.3	6.2	5.8	0.1
Feb-95	0.1	3.4	3.6	3.6	3.6	197	203	208	211	380	8.2	7.7	6.7	6.2	0.2
Mar-95	0.9	3.5	3.6	3.6	3.6	202	202	208	212	385	5.8	7.5	6	5.1	0.1
Apr-95	0.2	3.5	3.6	3.6	3.6						6.7	7	5.8	4.8	0.2
May-95	13.9	3.7	3.5	3.6	3.6	149	189	193	201	358	6.7	3.4	2.6	1.6	0
Jun-95	17	4.2	3.6	3.6	3.6	149	180	187	194	344	8.6	3.4	2.4	1.4	0.2
Jul-95	16.9	5.5	3.6	3.6	3.6	214	205	207	221	393	11.7	4.9	3.8	0.2	0.1
Aug-95	16.1	7.4	3.7	3.6	3.6	210	207	206	219	390	11.4	8.2	6	0.2	0.1

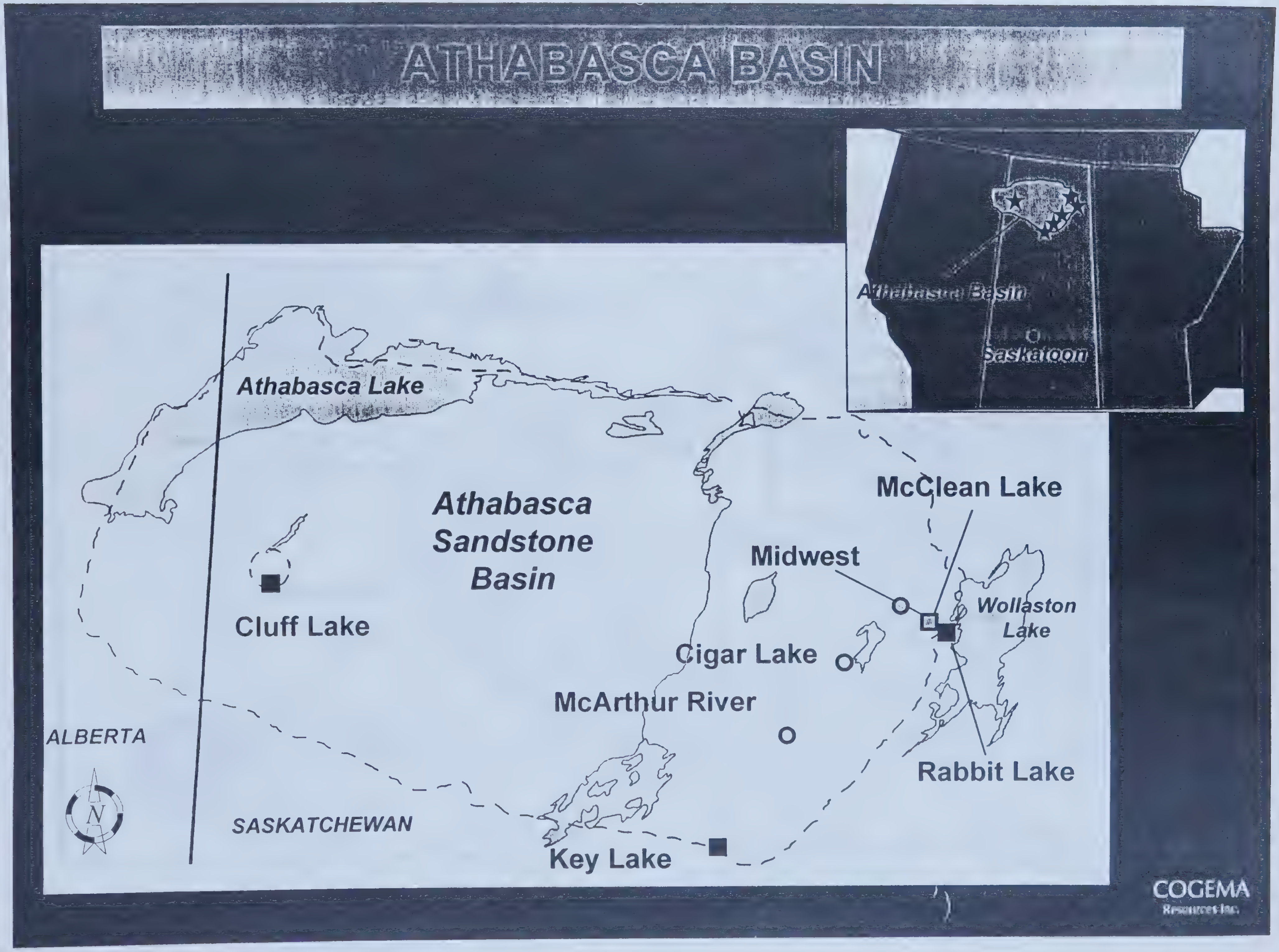

ATHABASCA BASIN
Athabasca Basin
Saskatoon
Athabasca Lake
Athabasca
Sandstone
Basin
Cluff Lake
McClean Lake
Midwest
Wollaston
Lake
Cigar Lake
McArthur River
Rabbit Lake
ALBERTA
SASKATCHEWAN
Key Lake
N
COGEMA
Resources Inc.

Figure 1

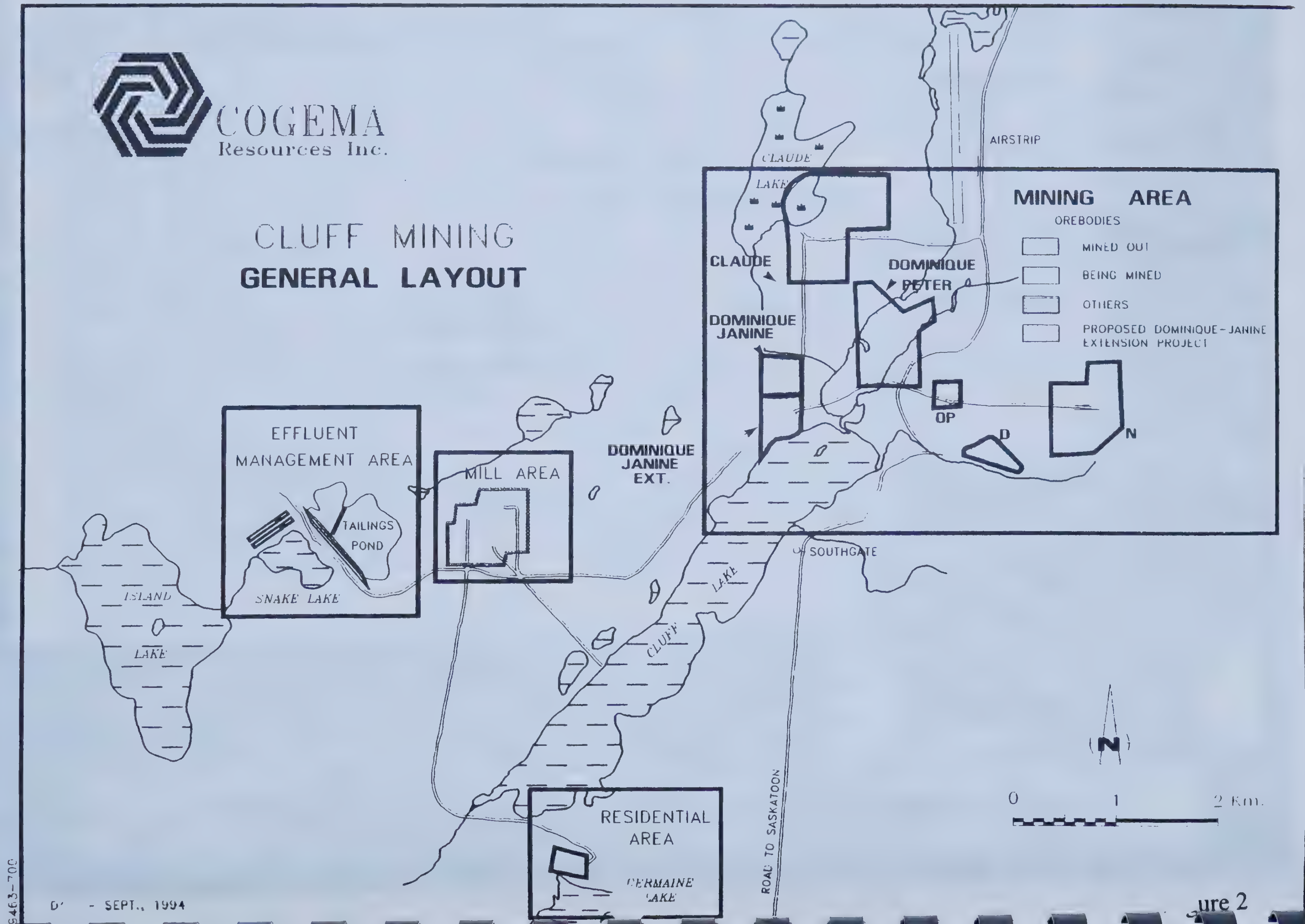
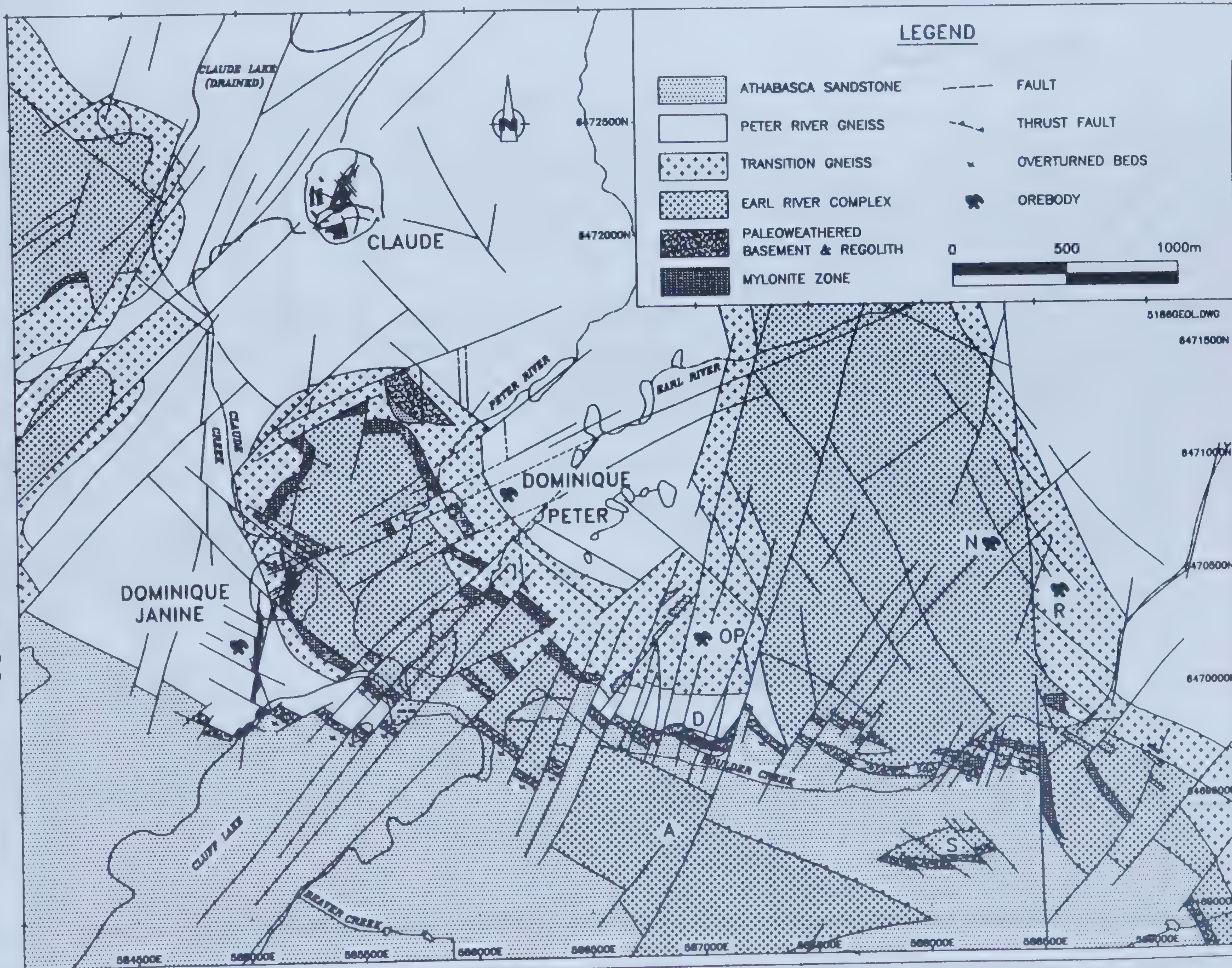
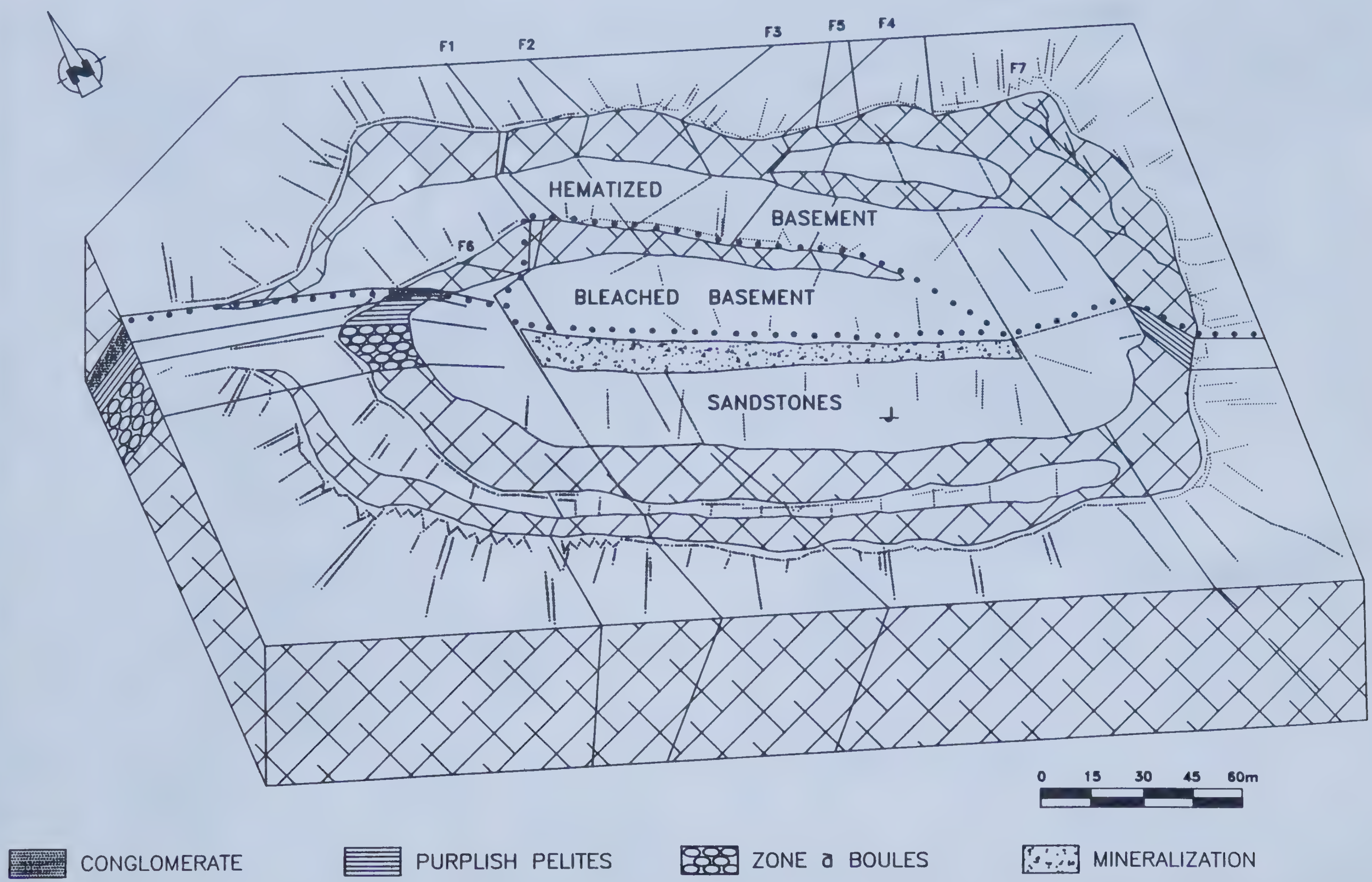

COGEMA
Resources Inc.
CLUFF MINING
GENERAL LAYOUT
MINING AREA
OREBODIES
MINED OUT
BEING MINED
OTHERS
PROPOSED DOMINIQUE-JANINE EXTENSION PROJECT
AIRSTRIP
CLAUDE LAKE
CLAUDE
DOMINIQUE PETER
DOMINIQUE JANINE
OP
D
N
DOMINIQUE JANINE EXT.
EFFLUENT MANAGEMENT AREA
TAILINGS POND
SNAKE LAKE
MILL AREA
ISLAND LAKE
SOUTHGATE
CLUFF LAKE
ROAD TO SASKATOON
RESIDENTIAL AREA
GERMAINE LAKE
N
0
1
2 Km.
- SEPT., 1994
9463-700
ure 2

Figure 3 GEOLOGY OF MINERAL LEASE 5186

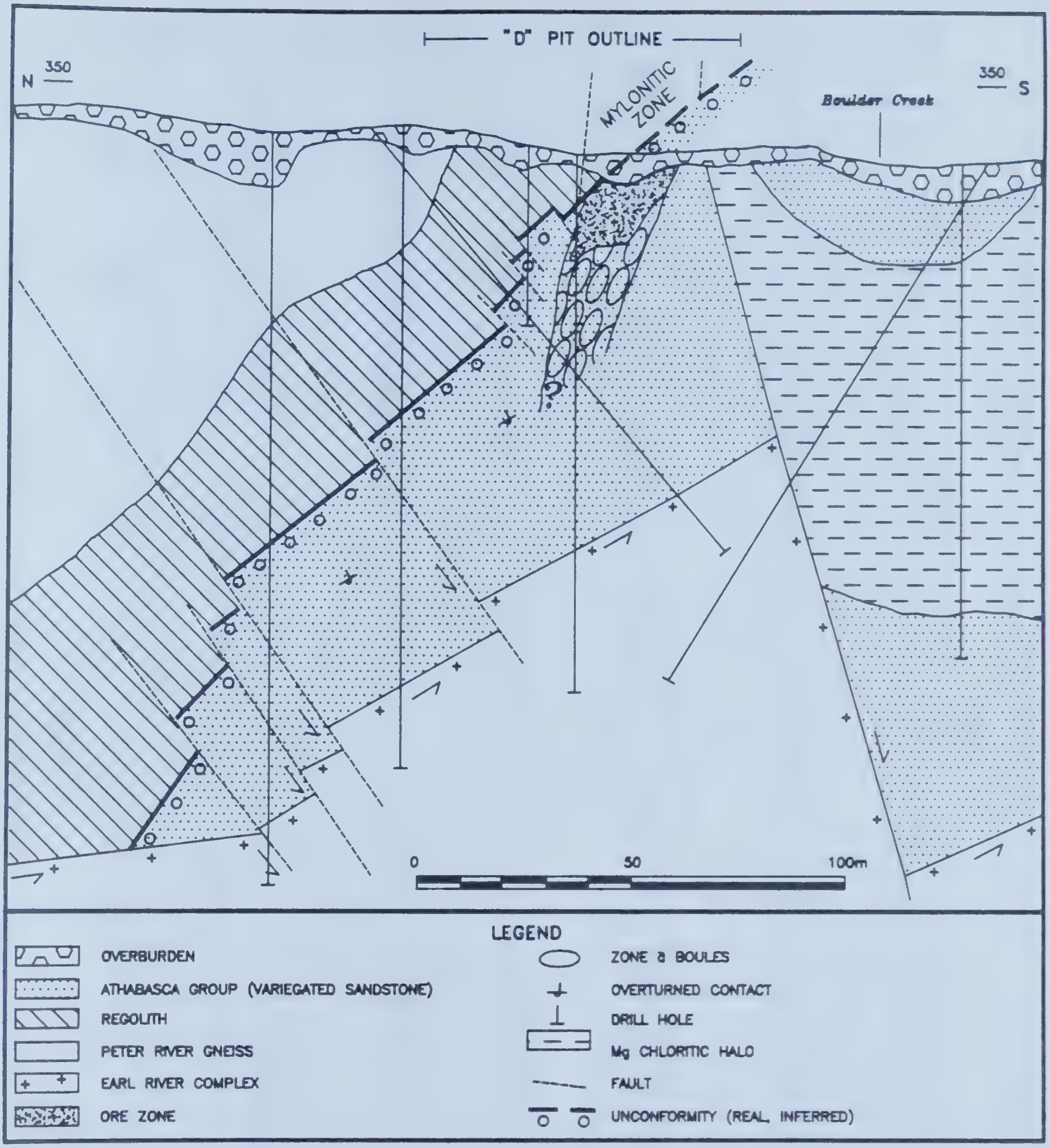




Major lithostructural units in the D open pit at the 323m mining level (walls are hatched, horizontal surfaces are in white).

Figu

C:\I1 \DISPLAY\DPITF1.DW

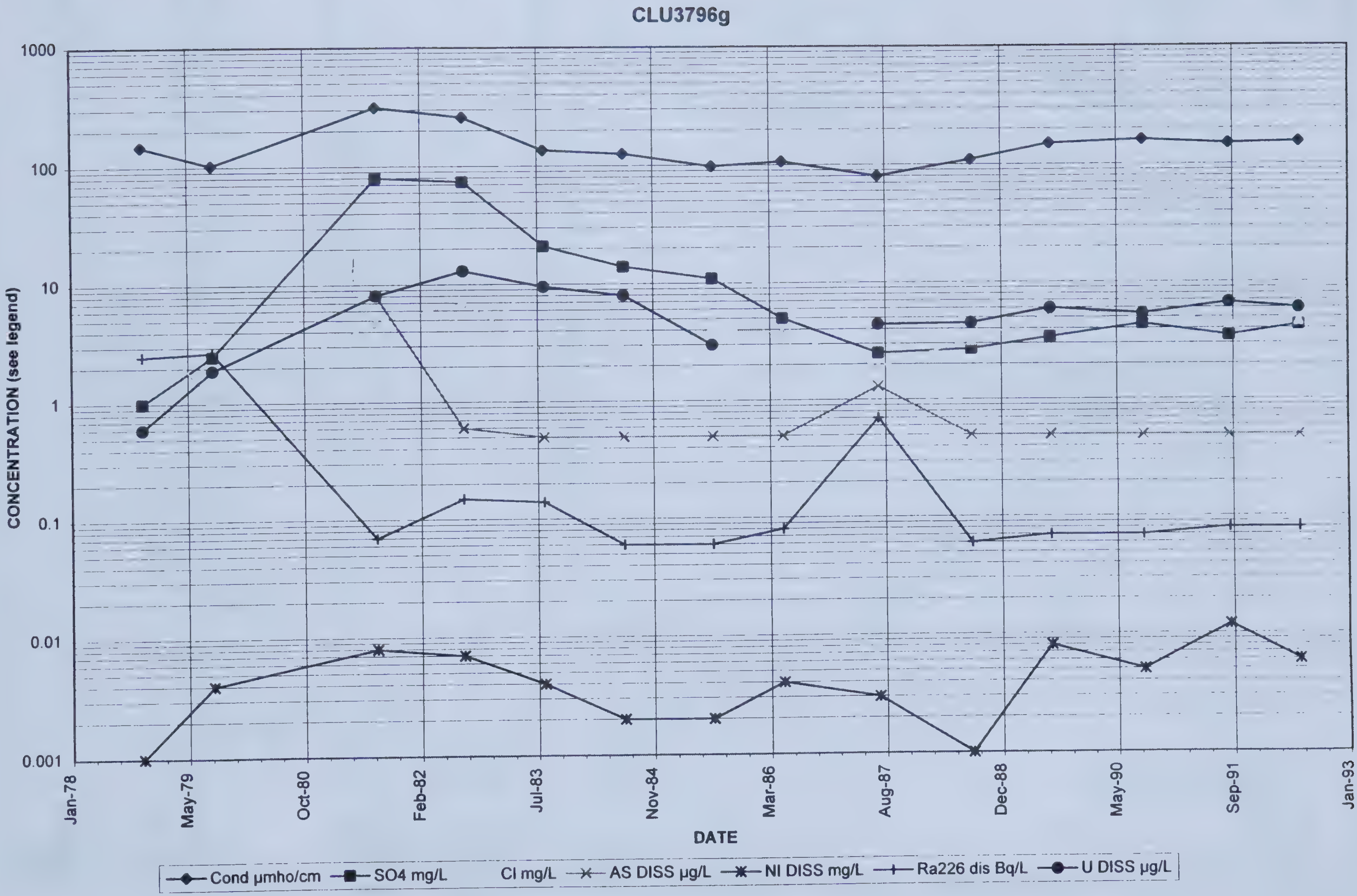


N–S cross section through the D open pit, showing alteration haloes and tectonic features (modified from Ey et al., 1982).

Figure 5

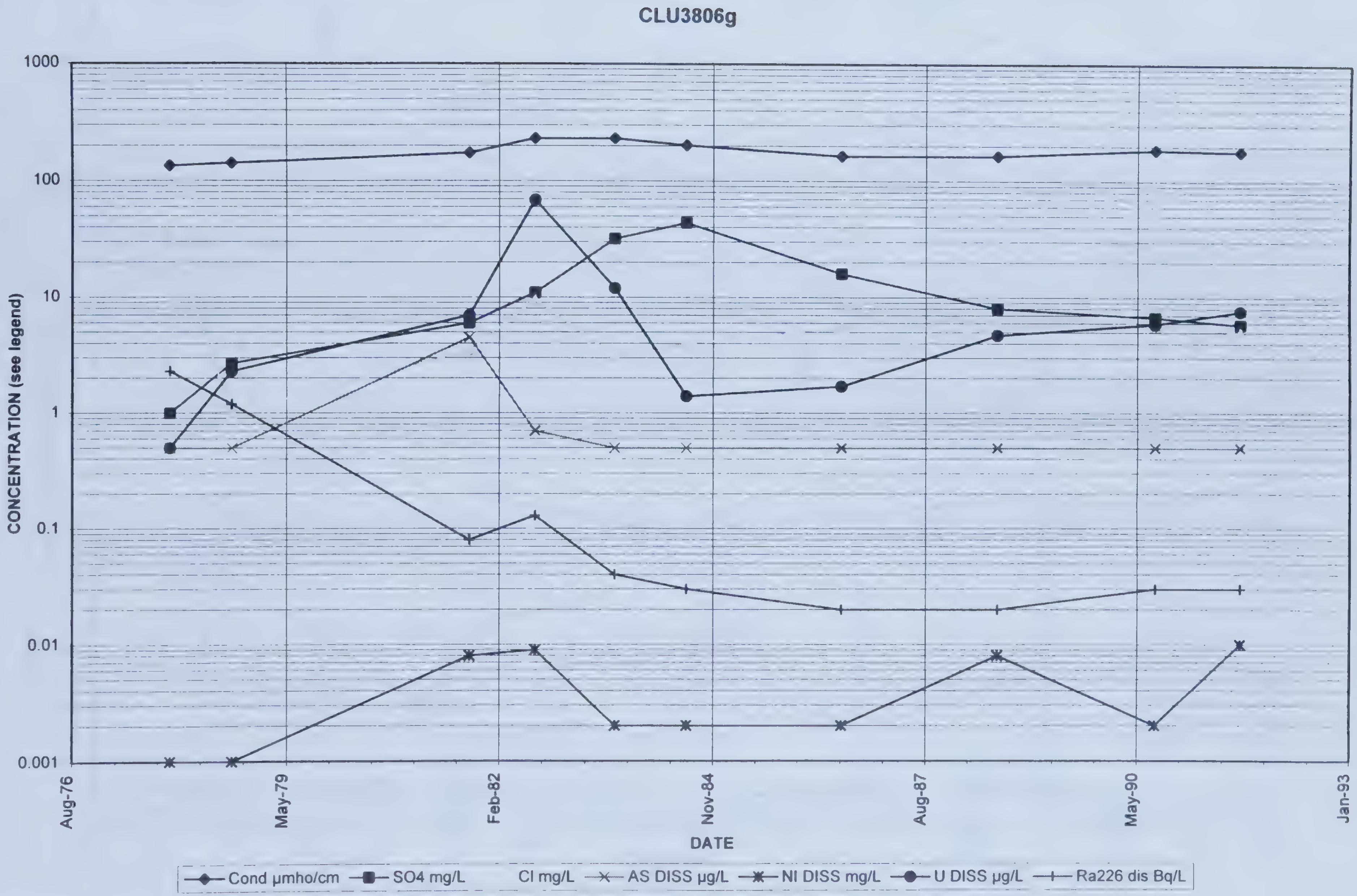
C:\DRAWING\DISPLAY\DPITF11.DWG

Figure 6



CLU3796g
1000
100
10
1
0.1
0.01
0.001
CONCENTRATION (see legend)
Jan-78
May-79
Oct-80
Feb-82
Jul-83
Nov-84
Mar-86
Aug-87
Dec-88
May-90
Sep-91
Jan-93
DATE
Cond µmho/cm
SO4 mg/L
Cl mg/L
AS DISS µg/L
NI DISS mg/L
Ra226 dis Bq/L
U DISS µg/L

Figure 7


CLU3806g
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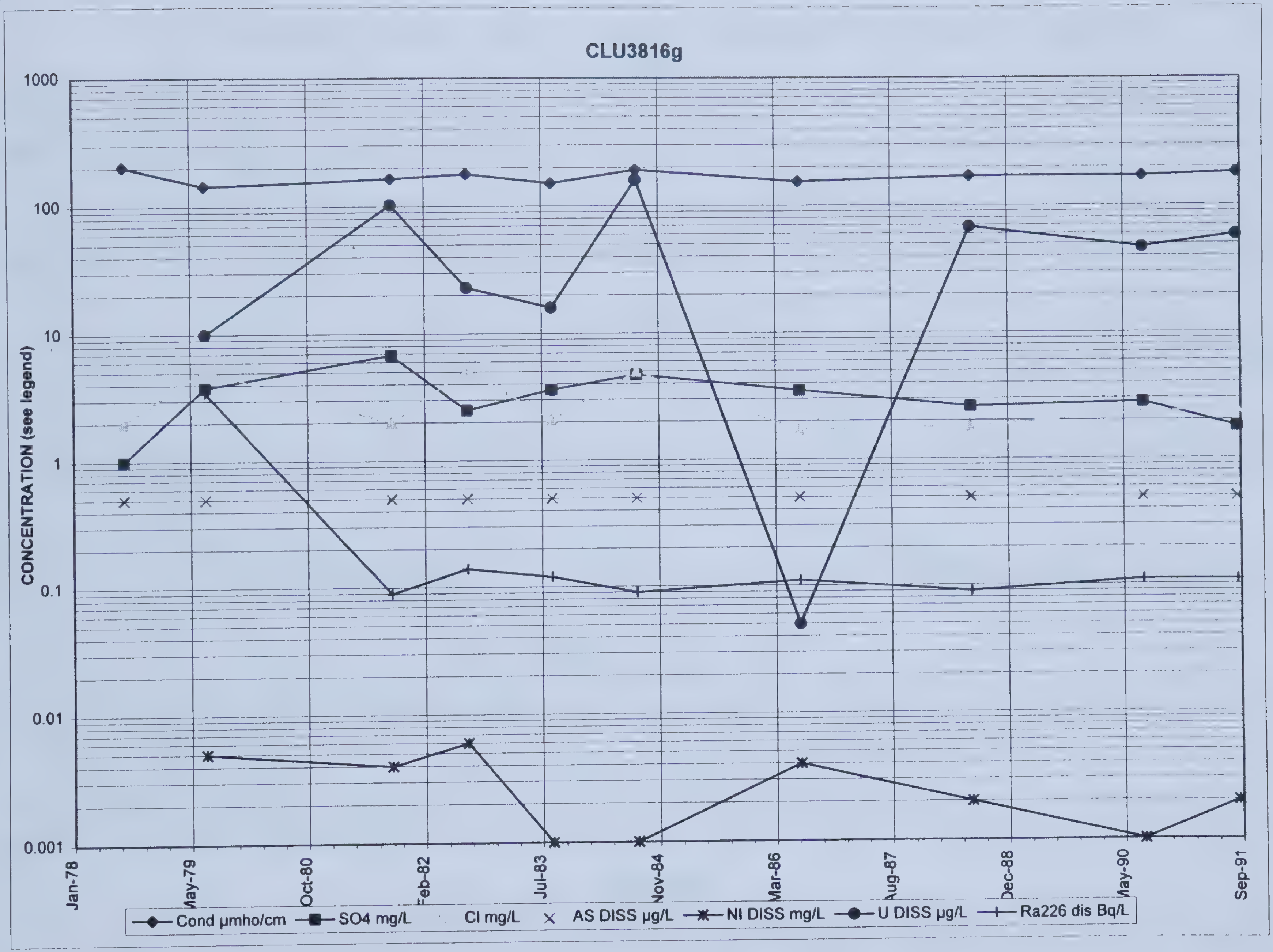
100
10
1
0.1
0.01
0.001
CONCENTRATION (see legend)
Aug-76
May-79
Feb-82
Nov-84
Aug-87
May-90
Jan-93
DATE
Cond µmho/cm
SO4 mg/L
Cl mg/L
AS DISS µg/L
NI DISS mg/L
U DISS µg/L
Ra226 dis Bq/L

Figure 8



CLU3816g
1000
100
10
1
0.1
0.01
0.001
CONCENTRATION (see legend)
Jan-78
May-79
Oct-80
Feb-82
Jul-83
Nov-84
Mar-86
Aug-87
Dec-88
May-90
Sep-91
Cond µmho/cm
SO4 mg/L
Cl mg/L
AS DISS µg/L
NI DISS mg/L
U DISS µg/L
Ra226 dis Bq/L

Figure 9

Boulder Creek Upstream of D-Pit

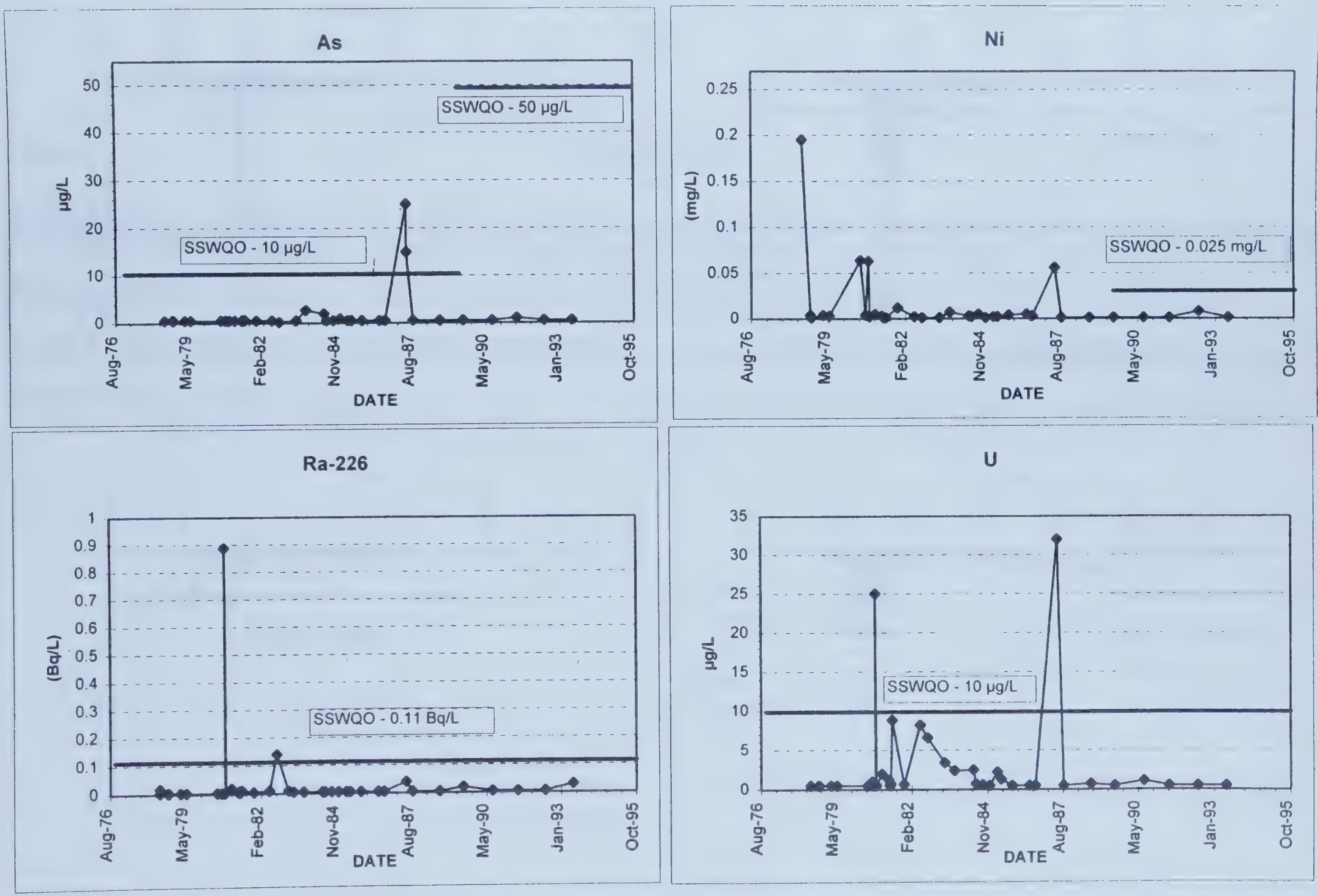


Figure 10

Boulder Creek at Cluff Lake

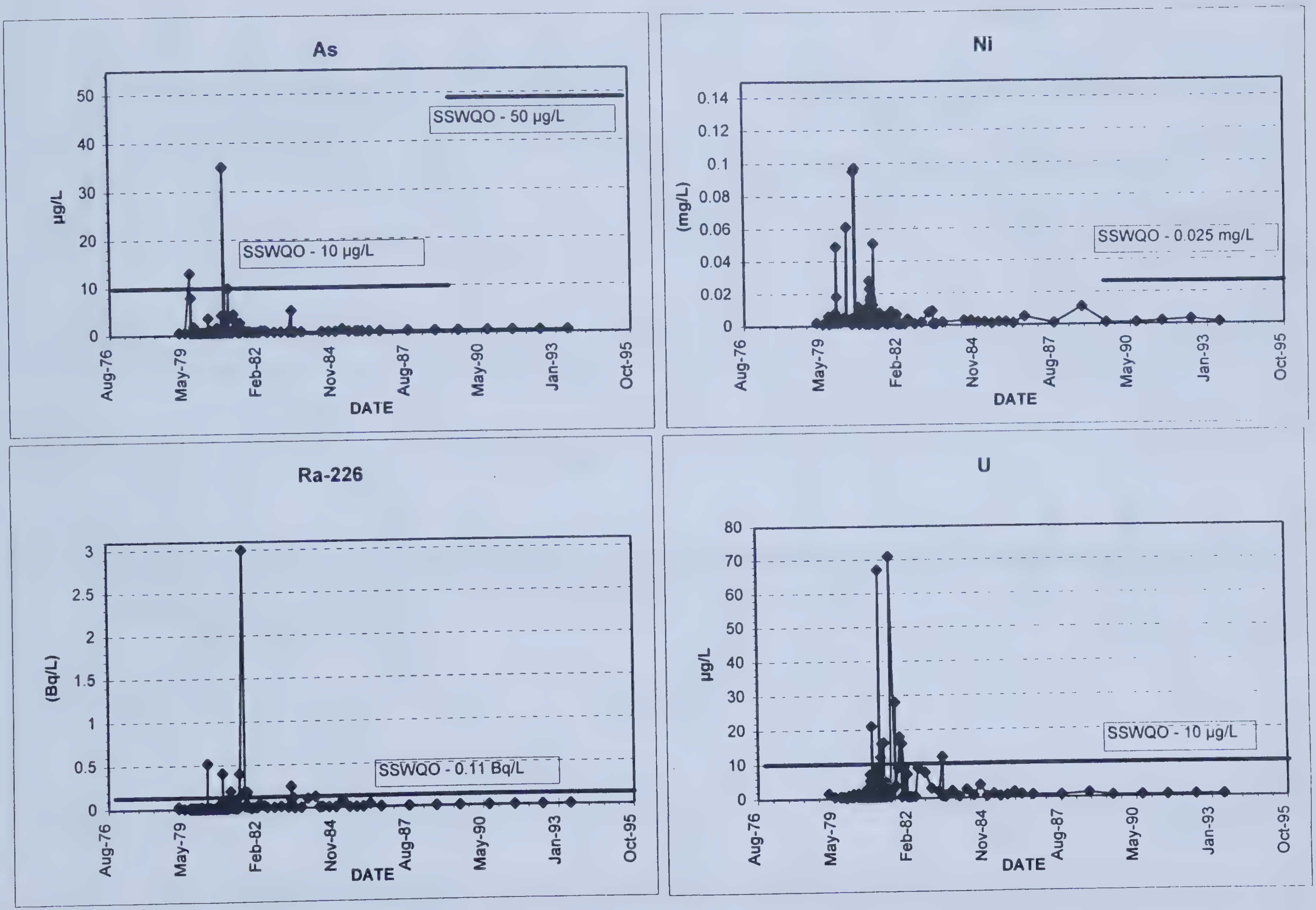


Figure 11

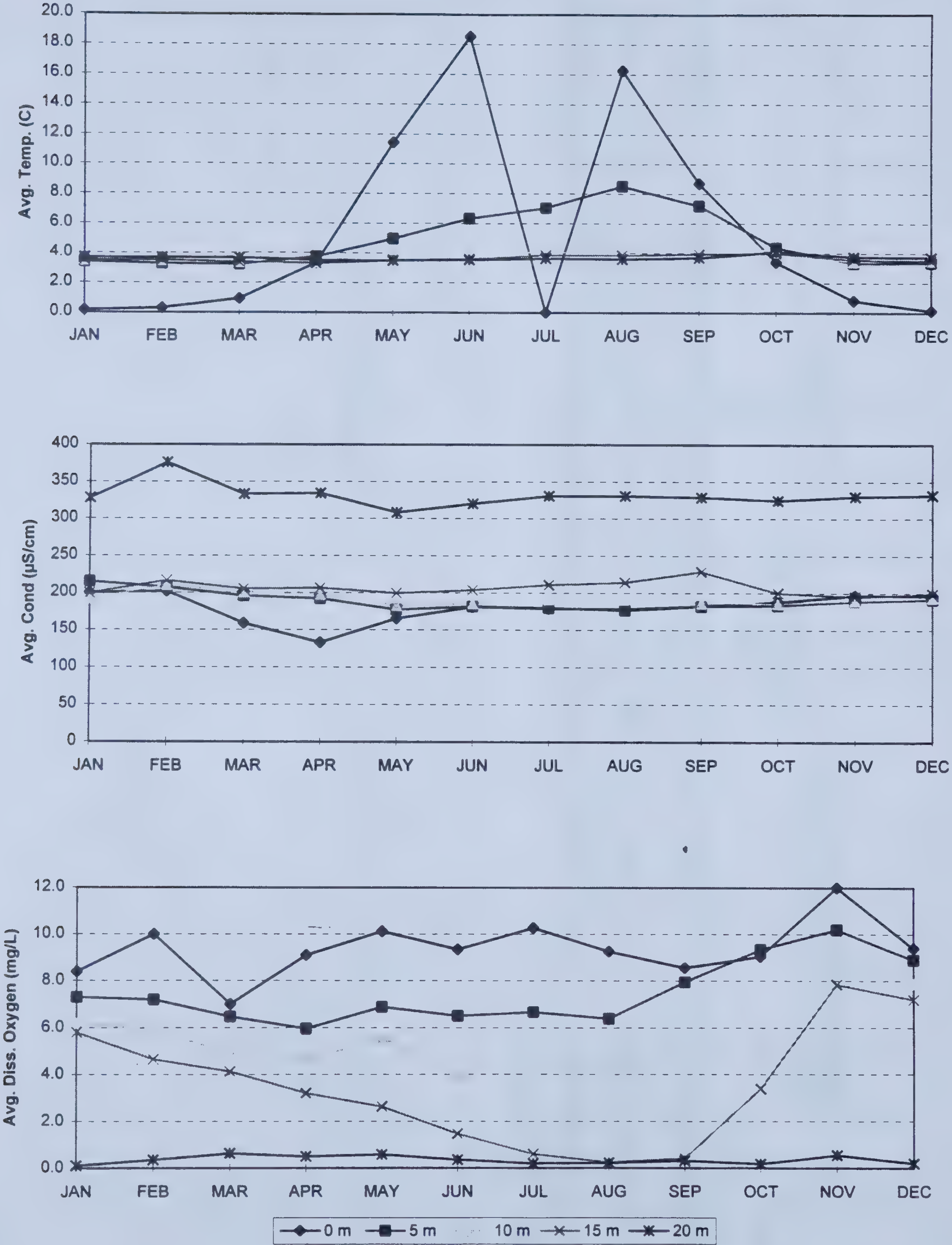
CLUFF MINING
WEATHER DATA
1995

Temperature - Celsius	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Y-T-D
Normal *, Avg Mean Temp	-19.6	-15.9	-8.8	0.6	9.2	14.7	16.8	15.8	8.8	1.1	-11.0	-18.0	-0.5
Normal *, Avg precipitation	18.6	17.1	21.5	17.0	27.4	53.8	82.0	70.5	42.0	36.7	29.2	20.4	427.6

* Normal - average since 1981

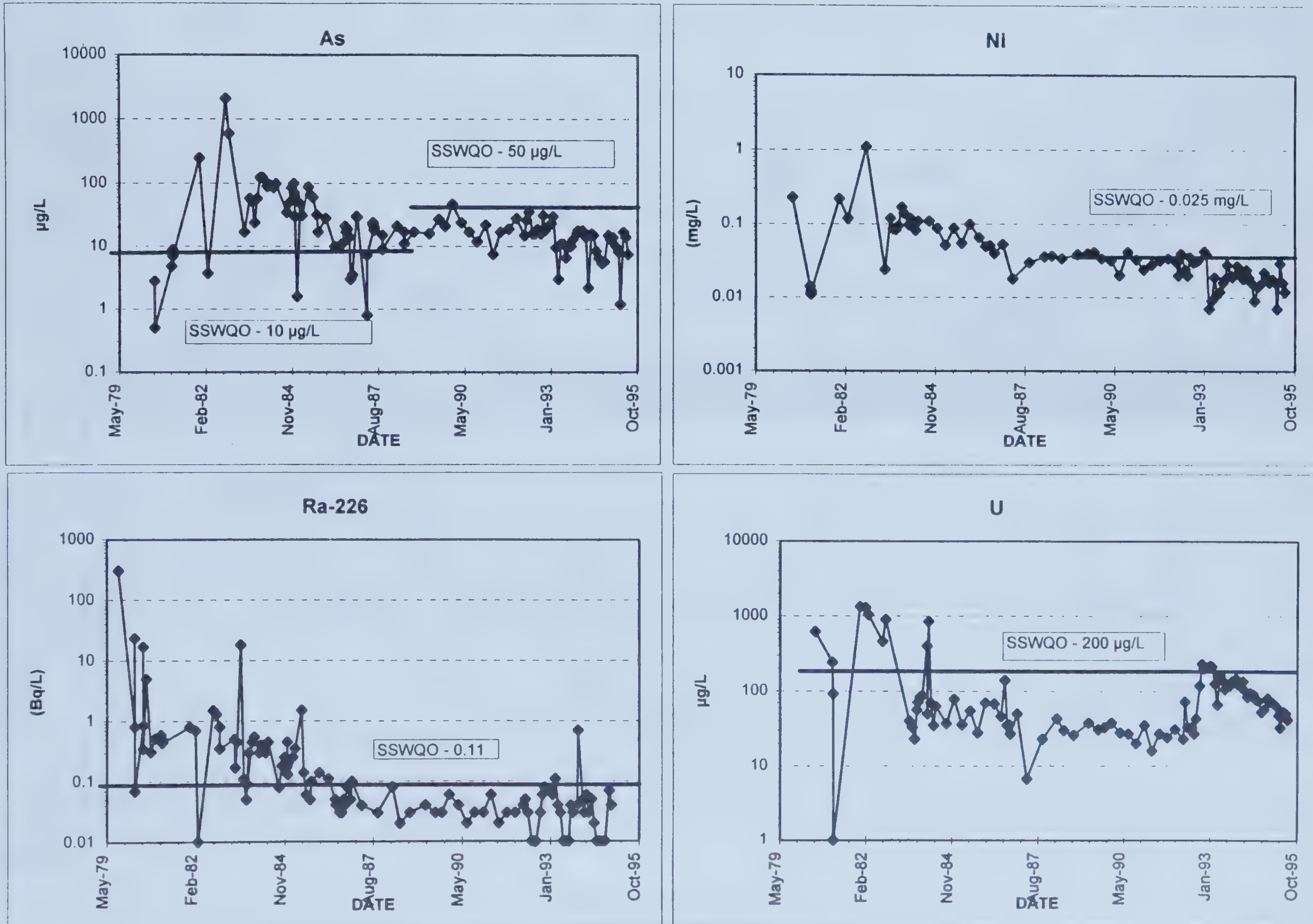
D-PIT FIELD MEASUREMENTS
Average By Month - Apr.1992 to Aug. 1995

Figure 12



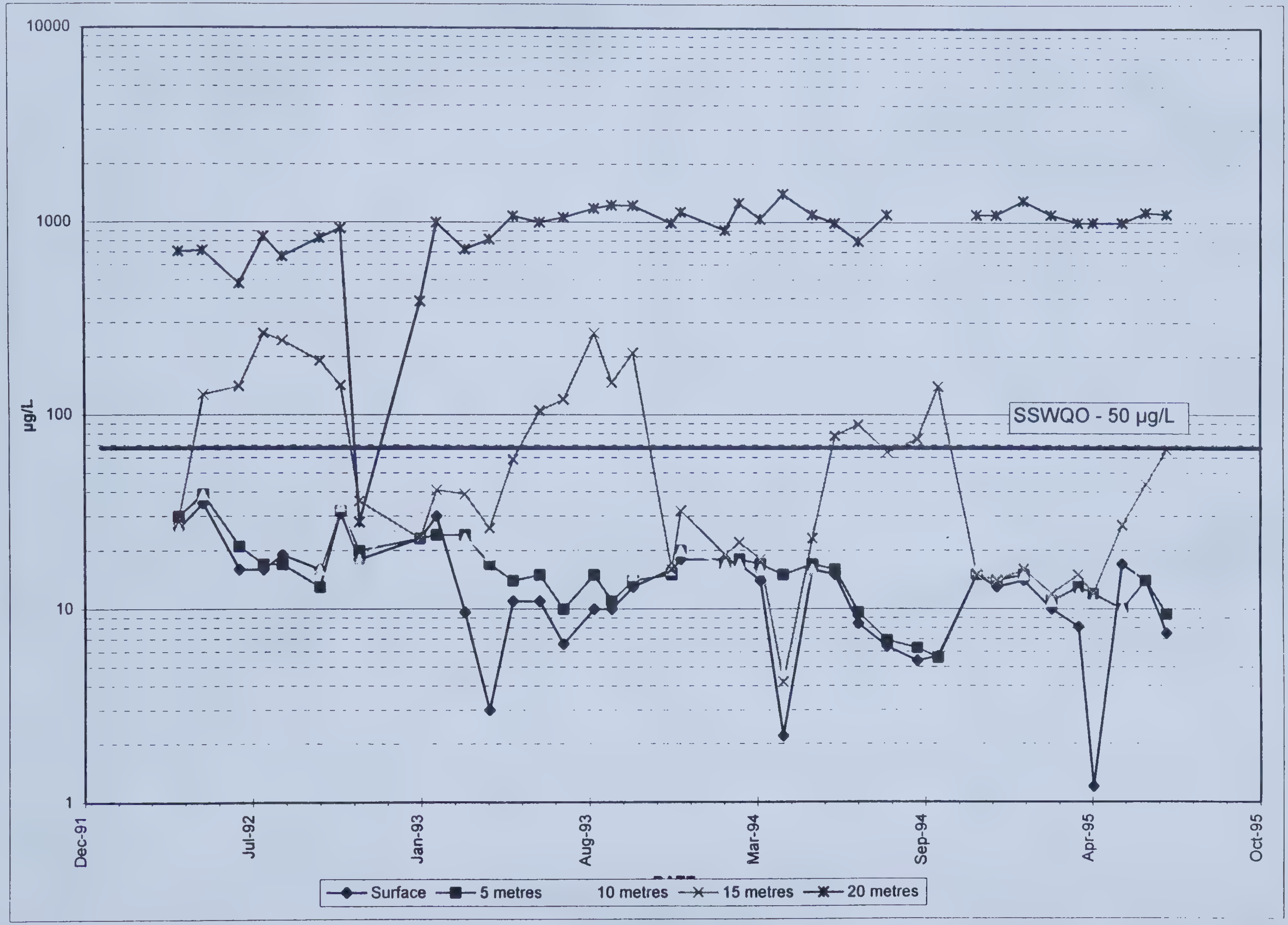
D-Pit Surface Water
Historical Summary - Selected Parameters

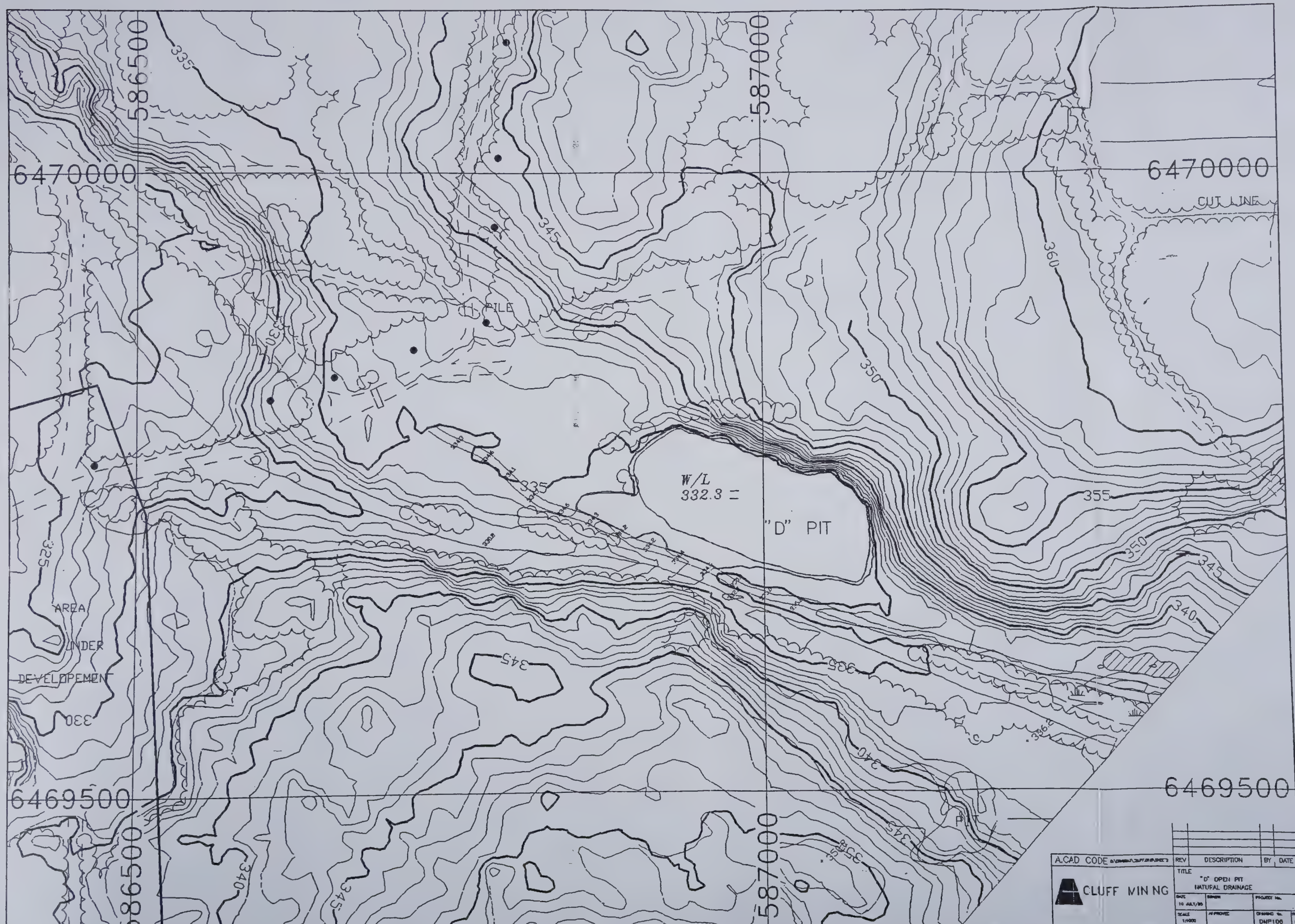
Figure 13



Arsenic Concentration
April 1992 to July 1995

Figure 14





586500
587000
6470000
6469500
CUT LINE
PILE
W/L
332.3
"D" PIT
AREA
UNDER
DEVELOPEMENT
PIT
335
345
360
350
355
340
330
325
A.CAD CODE
REV
DESCRIPTION
BY
DATE
TITLE
"D" OPEN PIT
NATURAL DRAINAGE
CLUFF MINING
SCALE
1:4000
DRAWING No.
DNP106
0

Figure 19

Figure 15

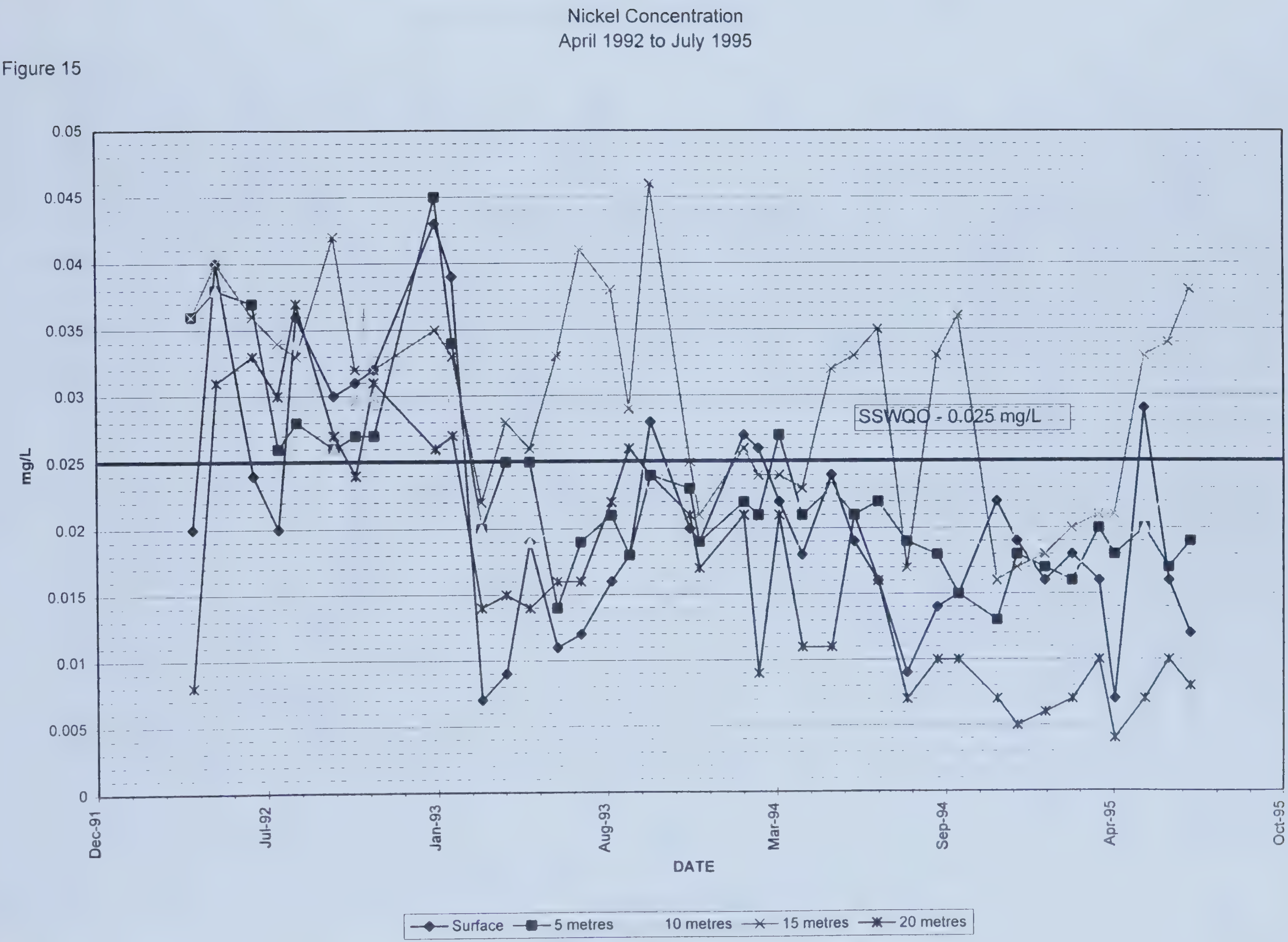
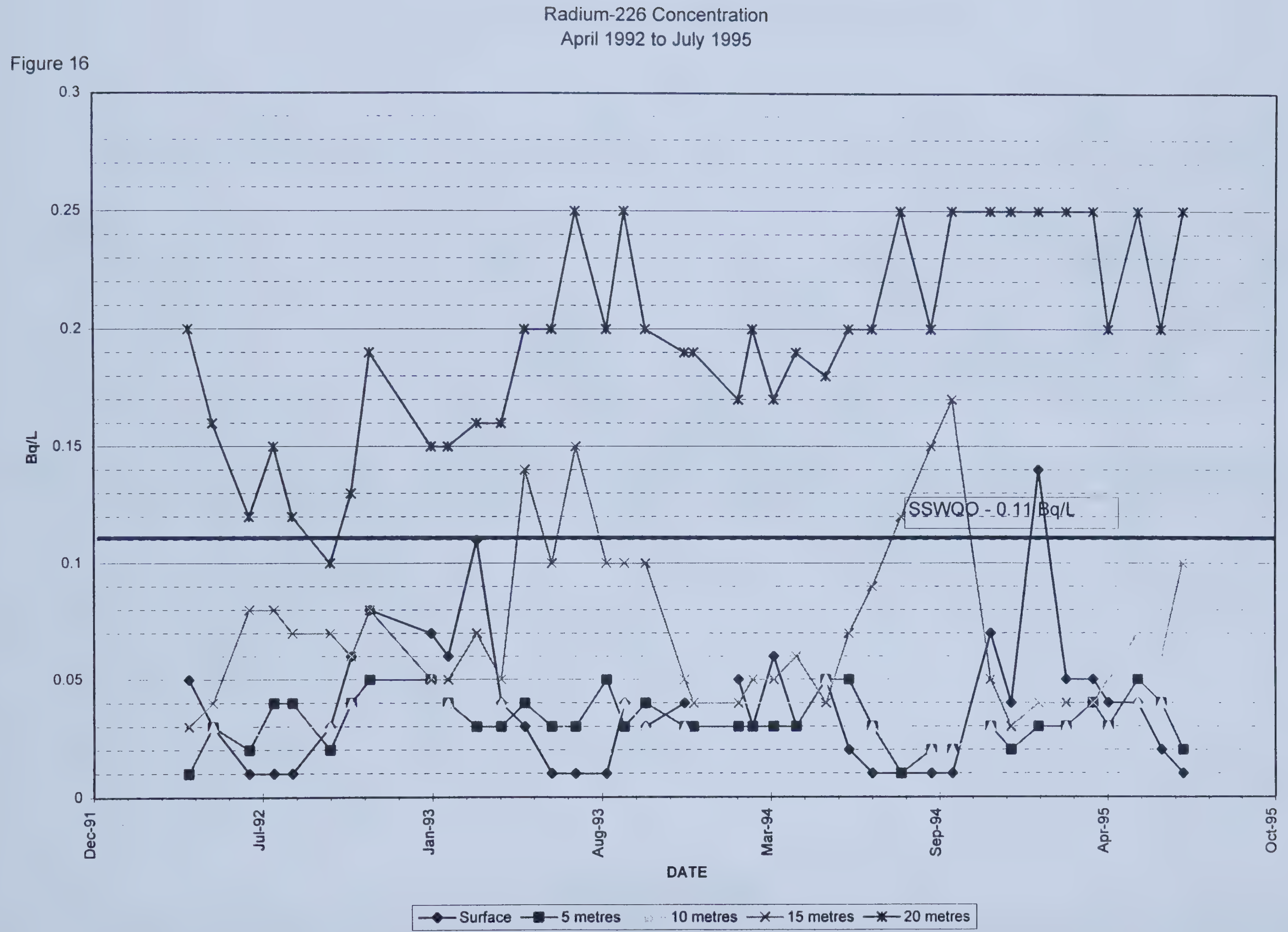

Nickel Concentration
April 1992 to July 1995
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
mg/L
SSWQO - 0.025 mg/L
Dec-91
Jul-92
Jan-93
Aug-93
Mar-94
Sep-94
Apr-95
Oct-95
DATE
Surface
5 metres
10 metres
15 metres
20 metres

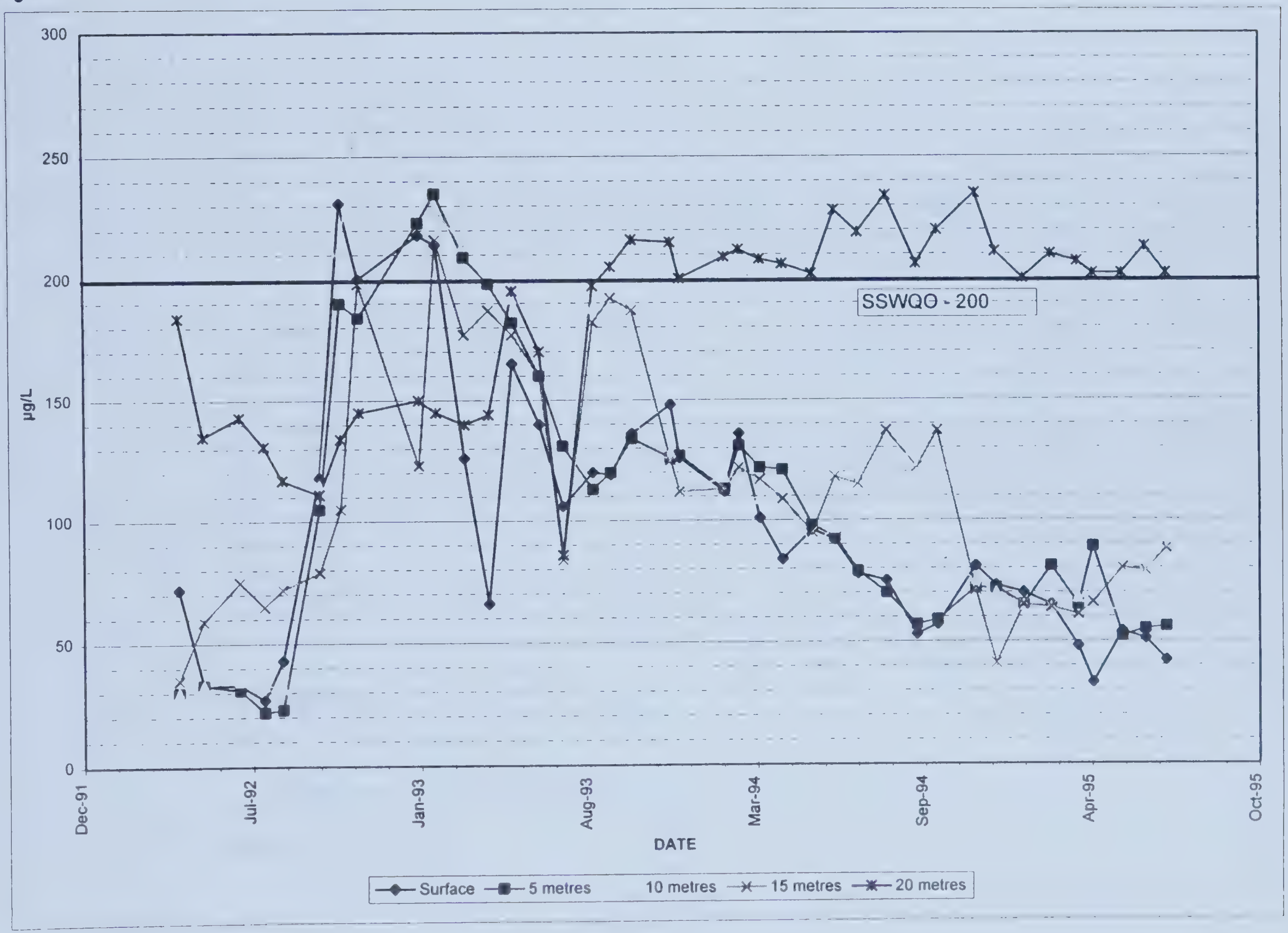
Figure 16



Radium-226 Concentration
April 1992 to July 1995
Bq/L
0.3
0.25
0.2
0.15
0.1
0.05
0
SSWQO - 0.11 Bq/L
Dec-91
Jul-92
Jan-93
Aug-93
Mar-94
Sep-94
Apr-95
Oct-95
DATE
Surface
5 metres
10 metres
15 metres
20 metres

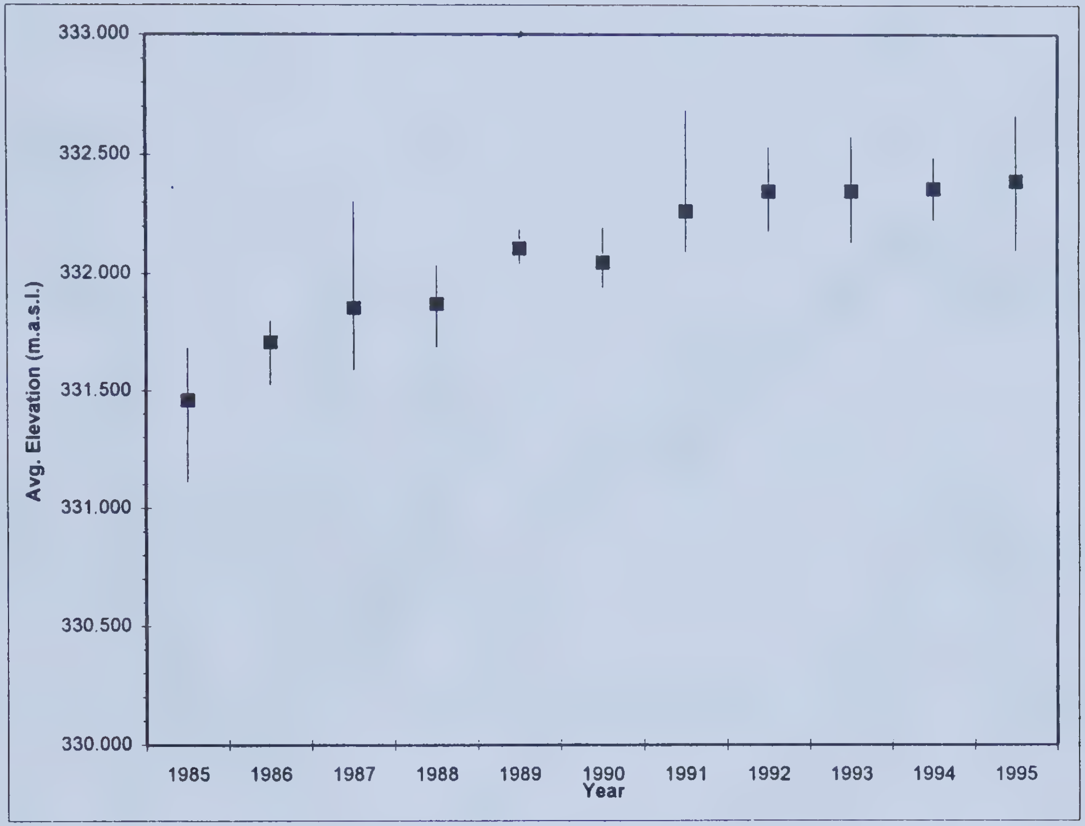
Uranium Concentration
April 1992 to July 1995

Figure 17



D-Pit Water Elevation
1985 to 1995

Figure 18



ENVIRONMENTAL MANAGEMENT FOR MINING

Proceedings of the 19th Annual Meeting of the Canadian Land Reclamation Association/ Association Canadienne de Réhabilitation des Sites Dégradés (CLRA/ACRSD)

October 25-27, 1995
Saskatoon, Saskatchewan