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The COAL AUTHORITY

Durham

Options for the Control of Mine Water East of the River Wear

for

The Coal Authority

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REFERENCES

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3. Report on Mine Water Recovery in North East England. IMC Report to The Coal Authority, May 1999.

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1.0 INTRODUCTION

IMC Consulting Engineers Limited were requested by the Coal Authority to report on the options for the control of mine water in the area of abandoned mines in County Durham to the east of the River Wear.

The area of the study extends inland from the coastal pits of Ryhope, Vane Tempest, Dawdon, Easington, Horden and Blackhall to the River Wear (see Figure 1). Prior to the cessation of mining, water had been controlled by pumping from the active coastal pits and three inland pumping stations, Lumley 6th, Nicholsons and Sherburn Hill, which prevented mine water flowing to the coast from the older shallow coal workings inland. These three pumping stations remained in operation following the cessation of mining in the area and became the responsibility of the Coal Authority in 1994. To establish the interconnections between the various collieries and pumping stations in the area east of the River Wear, pumping at the remaining three inland sites was gradually reduced following agreement with the Environment Agency.

This report uses the mine water recovery obtained from the various Coal Authority and Environment Agency monitoring sites to interpret the inter-colliery connections and predict the timing and sites of potential mine water discharges, both at surface and into aquifers. Data from British Coal and Coal Authority records of volumes and quantities pumped from mines in the area together with recent chemical analysis of the open shaft water columns are used to assess the likely volumes of mine water that would be discharged or pumped and the quality of that water. The alternative methods and sites available for the control and/or treatment of mine water discharges are then assessed.

2.0 BACKGROUND INFORMATION

2.1 Sources of Data

The mine water problems associated with the abandonment of all mine workings in Durham and Northumberland were first addressed by British Coal in June 1981 in an internal report. This report extended the National Coal Board Working Party Report on mine water problems in the north east to include the mine water position when all mining had ceased. The report was updated in August 1984 and September 1992 when the scope of the report was further extended to include the views of the National Rivers Authority (NRA). The British Coal report on Mine Water Pumping and Water Problems in the Northumberland and Durham Coalfield Area (British Coal, September 1992) has been used to provide the background information in this report together with the reports that have been commissioned by the Coal Authority since the closure of all deep mines in the Durham Coalfield (see References).

The other principal sources of data are the Environment Agency and Coal Authority mine water monitoring sites and the Coal Authority Mining Records Office (MRO) and Mining Reports.

2.2 Mining Area

The area requiring mine water control extends inland from the coast to the River Wear and is restricted to the north and south by areas of coal workings unconnected by mining. To the north is the Wearmouth/Westoe/Boldon block (see Figure 1) where mine water levels are monitored and known to be currently at a level of between 182 and 331 m BOD. This area is expected to take a number of years to recover. Adjacent to Wearmouth is the Silksworth block, the workings in this area are also believed to be isolated from the surrounding mines but there are no monitoring sites to confirm this.

To the south the boundary of the study area is separated from other mining blocks by the Butterknowle Fault and pillars of un-worked coal in the case of the Trimdon/Wingate Grange area.

To the west of the study area mining connections are known to exist under the River Wear to the north of Durham in the vicinity of Chatershaugh while to the south of Durham old shallow mine workings may also allow flow of mine water. A scheme to control the mine water west of the Wear by means of a gravity discharge into the River Wear at Page Bank (South Brancepeth) is currently under consideration and the subject of a separate report (Proposed Page Bank Gravity Discharge, IMC, March 2001).

The mining history of the area is largely governed by the geology of the area. The general north-west to south-east dip of the Coal Measures and the presence to the south and east of water bearing Permian strata above the Coal Measures resulted in the oldest workings being to the west and the last pits being sunk through the water bearing Magnesian Limestone in the east. The Magnesian Limestone is a major supply of potable water in the area with several pumping stations operated by Northumbrian Water.

Contamination of the Permian strata via mine entries or mining induced or natural fractures is one of the major risks to be addressed.

The geology of the area also generally controls the topography of the area. The Magnesian Limestone outcrop forms the highest ground and dips down to the coast whilst the lowest levels, apart from the coast, are in the Wear Valley.

It is these two areas, the coast and the Wear Valley, where surface discharges would occur if mine waters were allowed to fully recover in the mine workings to the east of the River Wear.

2.3 Mine Water Recovery

The pumping of mine water by British Coal was designed to de-water operational mines and prevent inrushes of mine water into the operational mines from abandoned mines. The pumping from abandoned mines always assumed open connections between mines even where dams had been constructed in the roadways to prevent water movement. This resulted in the general assumption that all the mine workings were interconnected and the conclusions reached by British Coal (Reference 1) that the water in the Durham Coalfield "would rise to the natural water table level subject to issues to surface from mine outlets .... these issues will be from low level shafts in the Haugh lands along the banks of the Rivers Tyne and Derwent and the beach tunnels from the shafts of the South Durham coastal collieries". The assumed interconnection of the major mining blocks is generally correct but monitoring of mine water recovery has shown that some areas apparently connected can have very poor hydraulic conductivity through the mine workings. Conversely other areas not directly connected by mining can be hydraulically connected via natural or mining induced permeability in the Coal Measures. The degree of hydraulic conductivity will govern the hydraulic gradient and the flow in both the mine workings and the Coal Measures. It cannot be assumed therefore, that mine water levels will be controlled by a few outflows from the lowest mine entries in a coalfield or an area of workings such as the east of the Wear block. Similarly the volume of water and the quality of the water will be dependent on the recharge, the hydraulic conductivity of the flow path, the head of water and the path(s) the water takes, again both in the mining and the naturally permeable horizons.

The monitoring of mine water recovery at various sites within the different mining blocks is therefore the only way to accurately assess the degree of interconnection of mine workings and the hydraulic gradients that develop as mine water levels recover. To enable these assessments to be carried out mine water levels are monitored at all the available open shafts by the Coal Authority and at specifically sited boreholes by the Environment Agency or the Coal Authority. The monitoring sites in the area east of the River Wear and adjoining blocks are shown in Figure 1 and listed in Table 1.

Table 1 – List of East of Wear Sites

SITE NAME	Water Level		Datum	Remarks
	mBGL	mAOD	mAOD	
Boldon (S17)	360.20	-330.90	29.30	
Chaterhaugh (S19)	61.50	-53.88	7.62	
Dawdon (S24)	105.60	-69.78	35.82	
Horden (S40)	117.00	-53.69	63.31	
Kibblesworth (S43)	101.50	-27.49	74.01	
Lumley 6th (S49)	97.50	-47.51	49.99	
Nicholsons (S56)	105.00	-46.12	58.88	
Sherburn Hill (S70)	130.00	-11.38	118.62	
Easington (S85)	122.00	-60.72	61.28	
Hawthorn (S86)	203.95	-83.80	120.15	
Westoe Crown Shaft (S95)	201.70	-182.46	19.24	
Thrislington (S202)	44.50	83.20	127.70	Apr-01
Mainsforth (S203)	8.60	79.64	88.24	Apr-01
Houghall (24-5-150)	3.17	34.86	38.03	Feb-01
Warden Law (24-5-156)	195.45	-59.24	136.21	Feb-01
Robin House (24-5-158)	97.24	1.52	98.76	Feb-01

Water Levels for June 2001 unless otherwise stated

2.4 Mine Water Pumping

Mine water pumping data is available from 1980 for the operational mines east of the River Wear and the inland pumping stations used to protect the deep mines from the old shallow workings water. This data in conjunction with the mining connections and the likely head of water that could develop in the workings can be used to estimate the potential volume of mine water that would discharge or need to be pumped to control the mine water east of the River Wear. Table 2 lists the pumping stations and volumes pumped prior to abandonment of mining in 1992 and the quantities pumped at Lumley 6th, Nicholsons and Sherburn prior to the temporary cessation at these site to allow mine waters to recover to test the connections.

The volumes of water pumped from the area east of the River Wear remained consistent during the period from 1980 to 1992 even though some pumping stations (Chatershaugh and

Blackhall) and some collieries (Horden, Blackhall, Herrington, Eppleton, South and East Helton) ceased pumping. The closure and cessation of pumping at East Hetton Colliery may be linked to the increased pumping at Horden but the closure of Blackhall is the more likely cause. Assuming that Chatershaugh, Lumley 6th and East Hetton are part of the east of Wear block then the volume of water pumped varied from 10,330 gpm (783 l/sec) to 13,557 gpm (1,027 l/sec) with a mean of 12,535 gpm (950 l/sec).

No detailed information has been found for the periods 1992/1993 and 1993/1994 and since then the only pumping was at Lumley 6th, Nicholsons and Sherburn Hill. Pumping was gradually reduced after 1998 to the current situation where there is no pumping but all three stations remain operational so that pumping can be recommenced if and when required.

The volume of mine water that would outflow from the east of Wear block or that would be needed to be pumped to prevent surface discharges or contamination of aquifers is not known. The volume of water will be dependent on the recharge which will come directly from rainfall entering shallow workings and permeable Coal Measure strata and indirectly from higher saturated strata, ie the Magnesian Limestone, superficial deposits, undersea strata. Some flows into the mine workings will remain relatively constant while mine water levels recover. Examples of these would be flows from the Magnesian Limestone, superficial deposits and shallow workings. Other flows which enter the mines at depth will gradually reduce as the strata re-saturates and the difference in head between the aquifer and the water level in the mine workings decreases. The flow from the other sources will also reduce during the later stages of recovery, eg. any Magnesian Limestone flows once the water level in the mine workings begins to rise above the base of the Permian. No detailed assessment has been made of all the individual flows entering the mines in the study area but comparisons can be made with other mining areas where mine waters have recovered to outflow, are pumped to prevent outflow, or have been monitored and the inflow assessed based on void space and recovery rate. In these examples the flows near surface are in the range of 10% to 20% of the original pumped volumes. Using a similar range for the east of Wear block and an original inflow of 12,535 gpm (950 l/sec) the outflow would be in the range of 1,253 gpm to 2,506 gpm (95 l/sec to 190 l/sec).

2.5 Mine Water Quality

Mine water quality data has been obtained from British Coal records for the majority of the pumping stations and the operational mines in Durham east of the River Wear prior to closure. Water quality data has been taken for Sherburn Hill, Nicholsons and Lumley 6th pumping stations since coming under the control of the Coal Authority and both sets of data are listed in Table 3.

The mine waters pumped from the Durham Coalfield on a whole have been the subject of several academic studies, in particular the work by Dr P L Younger at Newcastle University on the geochemical processes and hydrochemical products (Younger 1998).

As part of his research Dr Younger has identified the sources of the contaminants within the pumped mine waters and divided the waters into groups dependent on the chemistry. Research into the likely chemical composition of mine waters in Durham, including the east of Wear block is continuing at Newcastle University with the support of the Coal Authority.

In addition to the sampling of previously pumped mine water in the east of Wear block discrete sampling of the shaft water columns was carried out in January 2001 at Sherburn Hill, Dawdon (Theresa Shaft), Hawthorn, Horden South Shaft and Easington South Shaft. Fluid conductivity, temperature and flow logging was also carried out to determine at what level and over what interval water quality was changing and to observe any flows up or down shafts between insets.

Crossplots of sulphate and chloride for all the samples available for Lumley 6th, Nicholsons, Sherburn Hill and Chatershaugh continue to show that the waters at Chatershaugh and Lumley 6th are different from the waters at Sherburn Hill and Nicholsons (see Figure 2). Analysis of the data for each site does not show any trends which could suggest a partial mixing of these waters. (See Figure 3, 4 and 5).

The results of all the water analyses are listed in Table 3 and the results of the fluid conductivity temperature and flow logging is in Appendix A.

Table 2

Mine Water Pumping Data 1980 to Present

Year	Chatershaugh	Lumley 6th	Nicholsons	Sherburn Hill	Blackwell	Horden	Dawdon	Easington	Murton	Herrington	Eppleton*	Seaham*	South Hetton*	East Hetton		Totals: Not included East Hetton	Totals: Included East Hetton
1980	490	575	589	1270	3059	2218	99	711	484	125	360	599	585	1293		11,164	12,457
1981	408	487	575	1161	2602	2113	105	1079	543	145	363	609	411	1320		11,601	12,421
1982	400	501	579	1080	3459	2414	93	1285	463	141	343	604	262	1345	Closure	11,629	12,974
1983	270	540	600	1072	3778	2853	222	1450	440	151	360	609	277	-	of mine	12,722	
84/85	323	484	585	1131	4042	3579	242	1365	442	184	343	608	209	-		13,557	
85/86	351	538	586	1140	3719	3543	280	1538	409	-	343	608	283	-		13,348	
86/87	400	505	340	1103	-	4533	180	1956	381	-	-	609	73	-		10,330	
87/88	-	448	627	1010	-	5104	603	2243	750	-	-	575	-	-		11,410	
88/89	-	464	543	1209	-	5404	641	2079	925	-	-	573	-	-		12,438	
89/90	-	401	286	1097	-	5112	708	3622	489	-	-	562	-	-		12,277	
90/91	-	315	405	1109	-	5410	138	4400	661	-	-	466	-	-		12,904	
91/92	-	369	491	1296	-	4935	4	4523	1135	-	-	326	-	-		13,079	
92/93									No data available 1992/1993								
93/94									No data available 1993/1994								
94/95		305	422	1014												1741	
95/96		343	373	1096												1812	
96/97		412	455	1215												2082	
97/98		416	349	974												1739	
98/99		788	95	735												1618	
99/00		381	3	-												384	
00/01		-	-	-												-	

- Includes water from Magnesian Limestone

All figures in gallons/minute

Table 3

Mine Water Quality Data from the East of Wear Area

Date	pH	Calcium	Magnesium	Total Hardness	Sodium	Potassium	Ammoniacal Nitrogen	Total Iron	Total Alkalinity	Sulphate	Chloride	Ionic Balance %	Total Dissolved Salts Calc	Total Dissolved Salts Determined	Ca Bicarb	Ca Sulph	Mag Bicarb	Mag Sulph	Sod Bicarb	Sod Sulph	Sod Cl	Pot Cl
															Percentage of total in meq/l							
1 Durham Coast																						
Dawdon																						
09.02.83	7.1			2500				18		150	7300			12200								
Easington																						
11.03.93	6.5	2130	1410	11191	50180	4470	6.8	7.6	140	5020	84500	0.63	147890			4			5*		86	5
07.10.83	6.6			13200				48.5		3470	84500			142830								
Eppleton																						
23.02.84	7.5			700				0.2		70	410			930								
Hawthorn																						
03.06.87	7	210	126	1049	865			2.3	876	1620	256	-0.01	4146		18		12	6		52	12	
Murton																						
11.03.93	7.7	330	120	1324	1470	558	3.9	1.4	560	330	2120	-0.81	6996		11	5		9		20	41	14
24.11.83	7.3			410				16		1180	520			3040								
Seaham																						
04.11.82	6.9			1160				10.8		1300	2930			7020								
10.06.81	8			408				0.2		77	160			590								
Vane Tempest																						
27.08.82	2.2			1500				352		14910	33000			41900								
2 Nicholson's, Sherburn Hill																						
Nicholson's																						
24.03.00	7.1	150	69	662	590	35		18	830	800	130	3.64	2787	2200	20		16		9	45	8	2
1995	7	173	71	728	530	26		6	735	1052	112	-1.97	2861		23		15		1	53	6	2
16.03.93	6.9	90	50	433	549	23	0.8	7.1	750	490	150	5.90	2268									
07.01.87	7.1			680				7		1170	140			2650								
Sherburn hill																						
24.01.99	6.7	199	107	943	189	20.6	0.8	3.3	462	802	81	-1.22	1963		34	3		31		24	6	2
22.07.98	7.2	232	107	1025	230	25		2	568	721	128	1.72	2136	1860	38	1		29		20	10	2
16.04.98	7	200	92	883	260	23		13.8	392	710	106	7.03	1870	1840								2
1995	6.7	221	107	998	238	23		7.7	550	967	93	-4.62	2320		36			28		27	7	2
16.03.93	6.8	130	80	658	240	20	0.5	6.3	550	480	110	-0.08	1732		27		19	8		33	11	2
07.01.87	7.1			870				12.6		870	150			2000								
3 Chatershaugh, Lumley Sixth																						
Chatershaugh																						
23.01.86	7.7			370				1.2		590	750			3190								
Lumley																						
10.07.00	7.2	170	71	720	300	29		14	840	550	510	-20.50	2655	2500								
12.05.00	7.3	170	71	720	970	30		7.3	910	650	620	7.58	3621	2900								
04.04.00	7	180	73	754	880	39		7.4	910	630	650	4.45	3562	2900	18		12		6	27	35	2
21.01.00	7.2	180	72	750	890	41		6.9	790	300	740	12.06	3187	3000								
1995	6.9	149	61	626	577	27		4.2	895	420	462	-1.84	2788		20		13		14	19	32	2
15.03.93	6.8	80	40	366	590	23	0.4	3.7	850	170	560	-3.95	2501		12		10		29	10	37	2
07.01.87	7.6			600				2		370	640			2390								

* Magnesium chloride not sodium bicarbonate.

The results of the fluid conductivity and water analysis of the discrete samples show as expected a layering of the mine waters in the shafts and qualities which in most cases vary greatly from the quality of water pumped when the mines or pumping stations were operational. A comparison of the waters pumped when operational and the shaft waters samples in 2000 has been carried out for the potential pumping sites.

2.5.1 Hawthorn Mine Water - Probable Chemical Quality

Results of analysis are available for both water pumped when the colliery was working (1987) and for water standing in the shaft at different depths in 2000. The results given in table 4 show three different types of water. The pumped water had a high total concentration of dissolved salts (TDS value), with over 50% of the salts being sodium sulphate. The shaft water nearest the surface had a low - moderate TDS value with 75% of the salts being bicarbonates. The deeper waters, from below the Main Coal goaf, were highly saline, with TDS values in excess of 50,000 mg/l and over 80% of the salts were sodium chloride.

It is suggested that the water found on top of the column of water in the shaft was groundwater from nearer the surface, which had run into the shaft.

The pumped water had a higher alkalinity than found in the sample from –255m. This suggests that it was not "local" water but originated from further inland, passing through old workings to reach Hawthorn. It appears to have been near-surface groundwater from "inland" which had had long contact with pyrites. The 1987 sample may have contained a mixture of waters from different horizons, but there is no indication of the presence of any significant proportion of deep-zone water in it. Due to its high bicarbonate content, the iron content was low.

It is thought unlikely that water pumped to the surface at Hawthorn would be exactly similar to any of the three types listed.

Water pumped from near the water level is thought likely to be mainly near-surface groundwater which has been in contact with old workings. The chemical composition would vary dependent on the proportion of "local" to "inland" water, and the degree of contact with old workings. The worst case would be "local" water with a low alkalinity in contact with previously dry old workings. This could be slightly acidic with an iron content around 100 mg/l.

The most likely situation would be a mixture of waters, which suggests that the pumped water will have a lower concentration of both alkalinity and sulphate than in 1987. This water should still contain sufficient bicarbonate alkalinity to deposit iron prior to reaching the surface, so it should be possible to remove any residual iron by simple aeration and settlement.

The pumped water had a Ryznar Index of 5.9, which indicates that it would be scale forming. The sample from – 255 m had a Ryznar Index of 6.7, which is near neutral. Reaction of this water with pyrites would produce a corrosive water. If a final mixture had an alkalinity of 200 mg/l and a sulphate of 1000 mg/l, this would have a Ryznar Index of c.8, which is aggressive. The sulphate concentration would put it in Class 2 with regard to its effect on concrete.

However, it is possible that some of the saline water from greater depth would also be drawn into the pump. This water had a sulphate concentration greater than 3000 mg/l and only a trace percentage of bicarbonates. A high proportion of saline water could, as at Frances Colliery in East Fife, give a water that was resistant to treatment by aeration. However, the "old workings" contribution in Durham is not expected to be as acidic or highly sulphated as at Frances, so the problem should not be so acute.

It would be prudent to allow for the possibility that chemical treatment of pumped mine water will be required, although it is thought unlikely to be necessary.

The deep–zone waters would be corrosive due to their high salinity, which is likely to over-ride any calcium/carbonate reactions at a chloride concentration above 2 - 5,000 mg/l. The effect on the final mixture would be dependent on the proportion of deep-zone water in it. The sulphate concentration would be likely to increase sufficiently to put the water in Class 3 with regard to its effect on concrete.

Table 4

Analysis Results – Hawthorn Mine water

Sampling Point	As Pumped	@ -255 m	@ -290 m	@ -350 m	@ -390 m
Sampling Date	03.06.87	27.01.00	27.01.00	27.01.00	27.01.00
pH	7.0	7.9	6.1	6.0	6.1
Calcium as Ca	210	56	1130	1680	1820
Magnesium as Mg	126	22	1050	1280	1330
Sodium as Na	865*	119	17900	26100	32100
Potassium as K	N.D	28	917	1760	2220
Ferrous Iron as Fe	N.D	N.D	190	178	5.5
Total Iron as Fe	2.3	1.0	192	191	44.9
Total Aluminium as Al	N.D	< 0.01	0.3	0.4	.4
Total Alkalinity as $CaCO_3$	876	402	105	135	31
Total Acidity as $CaCO_3$	N.D	0	0	0	33
Sulphate as SO_4	1620	84	3370	4370	3920
Chloride as Cl	256	54	31600	46900	57800
Total Dissolved Solids (TDS) (calc)	4150	850	56000	81000	97000

All results except pH expressed as mg/l.

* Calculated value

2.5.2 Dawdon Mine Water - Probable Chemical Quality

Results of analysis are available for both water pumped when the colliery was working (1983) and for water standing in the shaft at different depths in 2000. The results are given in table 5.

The limited analysis available for the pumped water show it had a high total concentration of dissolved salts (TDS value), with c.75% of the salts being sodium chloride. The sulphate concentration, as reported, was very low, equal to only 1% of total salts. The shaft water nearest the surface (at –165 m) had a moderate TDS value (4900 mg/l), with again 75% of the salts being sodium chloride. The sulphate concentration was again low, although not to the same extent, equal to c.4% of total salts. The deeper waters were highly saline, with TDS values in excess of 70,000 mg/l and over 80% of the salts were sodium chloride.

When the shaft samples were taken, there were no obvious shallow feeders to the shaft and conductivity increased gradually with depth. It is suggested that the samples with lower TDS values contained a mixture of saline "deep-zone" waters with groundwater from nearer the surface. The low sulphate concentrations suggest that this groundwater had had little contact with old workings.

The chemical composition of any mine water pumped in the future would vary dependent on the proportion of near-surface groundwater, and whether this had been in contact with old workings. The waters pumped from Eppleton and Seaham (staple pit) can be taken as examples of near–surface groundwater. They had an alkalinity around 200 mg/l. This water in contact with previously dry old workings would produce an acidic water with an iron content around 100 mg/l.

While the worst case for acidity and iron content would be a high proportion of this acid water, the previous results suggest that there is not a high probability of groundwater passing through previously dry old workings.

Water pumped from near the water level could be similar to that found at –165m, with a slightly higher concentration of sulphates but this is thought to be unlikely. The alkalinity should be sufficient to precipitate any iron, and the pH value should stay neutral or slightly acidic. A similar chloride concentration (c 2500 mg/l) would probably mean a discharge to inland waters would not be possible.

It is possible that the proportion of saline water from greater depth in the pumped water would be higher. This water had a sulphate concentration around 3000 mg/l and only a trace percentage of bicarbonates. A high proportion of saline water could give a water that was resistant to treatment by aeration. However, a high proportion of deep-zone water would mean a low proportion of "old workings" water and therefore a lower iron content.

It would be wise to allow for the possibility that chemical treatment of pumped mine water will be required, although it is thought unlikely to be necessary.

The water from –165m had a Ryznar Index of 6.2, which indicates that it would be scale forming. A small proportion of "old workings" water would increase the index value to a neutral position. The deep-zone waters would be corrosive due to their high salinity, which is likely to over-ride any calcium/carbonate reactions at a chloride concentration above 2 – 5,000 mg/l. An increase in the proportion of deep-zone water in the pumped water would increase salinity and make the latter corrosive.

The low sulphate concentration of the water from –165m would put it in Class 1 with regard to its effect on concrete, while the high concentrations of the deep-zone waters would make them Class 3 or 4. The sulphate concentration of a pumped mine water would depend on the proportions of "clean" groundwater, "old workings" water and deep-zone water, but would probably average to Class 2.

Table 5

Analysis Results – Dawdon Mine Water

Sampling Point	As Pumped	@ -165 m	@ -310 m	@ -383 m	@ -470 m
Sampling Date	09.02.83	27.01.00	27.01.00	27.01.00	27.01.00
pH	7.10	7.5	6.0	5.7	5.8
Total Hardness as $CaCO_3$	2500	610*	9920*	10200*	13800*
Calcium as Ca	N.D	103	2080	1970	2980
Magnesium as Mg	N.D	86	1150	1290	1550
Sodium as Na	N.D	1400	23900	30400	39300
Potassium as K	N.D	37	1170	2350	2480
Ferrous Iron as Fe	N.D	0.7	108	67	144
Total Iron as Fe	18	1.9	114	79	142
Total Aluminium as Al	N.D	0.07	0.3	0.3	.0.4
Total Alkalinity as $CaCO_3$	N.D	654	82	68	80
Total Acidity as $CaCO_3$	N.D	0	0	0	0
Sulphate as SO_4	150	128	2610	4430	3940
Chloride as Cl	7300	2350	43600	55600	69800
Total Dissolved Solids (TDS)	12200	4900*	74700*	96000*	120000*

All results except pH expressed as mg/l.

* Calculated value

N.D Not Determined

2.5.3 Horden Mine Water - Probable Chemical Quality

Results of analysis are available for water standing in the shaft at different depths in 2000 but not for water pumped when the colliery was working. The results are given in table 6.

The water nearest the surface (at –180 m) had a high total concentration of dissolved salts (TDS value), with c.70% of the salts being sodium chloride. The sulphate concentration was low, c.10% of total salts. The deeper waters were highly saline, with TDS values in excess of 40,000 mg/l, and around 80% of the salts were sodium chloride.

When the shaft samples were taken, there was a large inflow at -180m, -330m (Low Main) and -365m (Hutton). Whilst the sample from the greatest depth (-380m) appears to have been deep-zone strata water, the others were more of a mixture.

Water test pumped at Frances in East Fife was thought to be a mixture of saline "deep-zone" waters with groundwater from nearer the surface which had been in contact with old workings. This may be the case here. The chloride concentration of the sample from -350m was 44% of that from -380m, but the sulphate concentration at -350m was 78% of that from -380m.

The waters pumped from Eppleton and Seaham (staple pit) can be taken as examples of near-surface groundwater. They had an alkalinity around 200 mg/l. This water in contact with previously dry old workings would produce an acidic water with an iron content around 100 mg/l. A mixture of 56% acidic water with 44% deep-zone water does produce ionic concentrations similar to those found at -350m, although the calcium and magnesium values are low. This suggests that the mixing process had taken place, but also some buffering of the water with calcium and magnesium salts.

The water at -180m had a relatively high alkalinity and is thought to be a mixture of saline "deep-zone" waters with natural near-surface groundwater which had had little or no contact with old workings.

The chemical composition of any mine water pumped in the future would vary dependent on the proportion of near-surface groundwater, and whether this water had been in contact with previously dry old workings.

The water found at -180m had a low concentration of easily-settleable iron, a sulphate concentration in Class 2 with regard to its effect on concrete and a Ryznar Index of 6.6, which indicates that it would be scale forming. However, the high salinity (chloride 3820 mg/l) would be likely to over-ride any calcium/carbonate reactions and cause the water to be corrosive.

Addition of one part of acid water to three parts of this water would, in theory, retain a trace of alkalinity and so precipitate out all the metals. The sulphate concentration would remain in Class 2 but the Ryznar Index would increase to c.10, which is strongly aggressive.

Alternatively, the proportion of saline water from greater depth could be higher. Addition of one part of the mixed water from -350m to three parts of the water from –180m would, in theory, produce a net-acidic water with an iron content of around 50 mg/l. The sulphate concentration would increase to Class 3 and at a chloride of 9000 mg/l, the water would be corrosive.

In summary, a pumped water may contain a low concentration of iron which could be removed by aeration, but it is more likely that chemical treatment would be required. The chloride concentration would probably make the water corrosive and make a discharge direct to sea essential.

Table 6

Analysis Results – Horden Mine water

Sampling Point		@ -180 m	@ -350 m	@ -380 m
Sampling Date		27.01.00	27.01.00	27.01.00
pH		7.3	6.0	6.2
Total Hardness	as $CaCO_3$	1300*	6640*	9500*
Calcium	as Ca	199	1200	1830
Magnesian	as Mg	194	886	1200
Sodium	as Na	1790	12700	30000
Potassium	as K	150	666	2510
Ferrous Iron	as Fe	N.D	213	3.1
Total Iron	as Fe	1.0	234	17
Total Aluminium	as Al	0.05	0.3	0.3
Total Alkalinity	as $CaCO_3$	270	91	35
Total Acidity	as $CaCO_3$	0	173	0
Sulphate	as SO_4	480	3520	4480
Chloride	as Cl	3820	24000	54200
Total Dissolved Solids (TDS)		7000*	43300*	94000*

All results except pH expressed as mg/l.

* Calculated value

N.D Not Determined

2.5.4 Easington Mine Water - Probable Chemical Quality

Results of analysis are available for water pumped when the colliery was working (1983 and 1993) but not since. No discrete water sampling was undertaken at this shaft. The results are given in table 7.

The two sets of analysis are very similar. They both indicate a deep-zone, highly saline, water with a TDS value in excess of 100,000 mg/l. Over 80% of the salts were sodium chloride.

It is likely that the chemical composition of any mine water pumped in the future would be different, due to the presence of groundwater from nearer the surface. The actual composition would depend on the proportion of near-surface groundwater, and whether this had been in contact with old workings.

The waters pumped from Eppleton and Seaham (staple pit) can be taken as examples of near-surface groundwater. They had an alkalinity around 200 mg/l. This water in contact with previously dry old workings would produce an acidic water with an iron content around 100 mg/l.

While the worst case for acidity and iron content would be a high proportion of this acid water, the previous results suggest that this is unlikely.

Water pumped from Easington is thought likely to be a modified version of that previously pumped, i.e. remaining highly saline. The addition of 20% of acid water would only reduce the chloride content to 68000 mg/l, but could remove all the remaining alkalinity, leaving a small concentration of iron in solution, probably less than 20 mg/l.

A water of this type would only be suitable for discharge to the sea. If it were necessary to remove iron, chemical treatment would probably be necessary.

The waters would be corrosive due to the very high salinity and the high sulphate concentration of the deep-zone water would make it Class 3 or 4 with regard to its effect on concrete.

Table 7

Analysis Results – Easington Mine Water

Sampling Point		As Pumped	As Pumped
Sampling Date		07.10.83	11.03.93
pH		6.6	6.5
Total Hardness	as $CaCO_3$	13200	11200*
Calcium	as Ca	N.D	2130
Magnesium	as Mg	N.D	1410
Sodium	as Na	N.D	50200
Potassium	as K	N.D	4470
Ferrous Iron	as Fe	N.D	N.D
Total Iron	as Fe	48.5	7.6
Total Aluminium	as Al	N.D	N.D
Total Alkalinity	as $CaCO_3$	N.D	140
Total Acidity	as $CaCO_3$	N.D	N.D
Sulphate	as SO_4	3470	5020
Chloride	as Cl	84500	84500
Total Dissolved Solids (TDS)		143000	148000*

All results except pH expressed as mg/l.

* Calculated value

N.D Not determined

3.0 CURRENT SITUATION

3.1 Mine Water Recovery Situation and Mining Connections

The mine water recovery in the east of Wear block since 1994 is shown in Figure 6 and the recovery for the last year in Figure 7. As can be seen from graphs of mine water levels since 1994 the coastal collieries of Dawdon, Easington, Horden and Hawthorne have recovered along a typical exponential recovery curve with clear flow to the lowest point at Hawthorn shaft. The direction of flow and the hydraulic gradients based on the current water levels are shown in Figure 8. A connecting roadway between Easington and Horden had been dammed in the 1980's to prevent mine waters from the area south of the Ludworth Whin Dyke flowing north. However it is clear from the water level data that this dam has failed and Easington and Horden are hydraulically connected. The extent of mining connections in the area between the Ludworth Whin Dyke and the Butterknowle fault is to some extent conjecture due to the absence of monitoring points in some mining blocks.

The water levels in the coastal collieries have still to reach the levels of the inland pumping stations at Sherburn Hill, Nicholsons and Lumley 6th and therefore it is not possible yet to say how well interconnected the older shallow workings are with the coastal pits. The water quality from Sherburn Hill Nicholsons and Lumley 6th taken prior to the temporary cessation of pumping at these sites showed no significant change in the water quality suggesting there was no mixing of the waters between Lumley 6th waters and the Sherburn Hill/Nicholsons type.

The failure of a barrier that was causing the Sherburn Hill waters to recover higher than expected is clear from the rapid drop in water level at the site in June 2000. (See Figure 7). The most likely site of the failure was a dam in the roadways at the Low Main horizon (25.9 m BOD) through the Ludworth Whin Dyke which connected Sherburn Hill with Thornley Colliery. Thornley Colliery was connected via Shotton Colliery to Horden therefore is likely that the mine waters from Sherburn Hill are flowing to the coast and mixing with the mine waters from the coastal collieries.

The position at Lumley 6th and Chatershaugh is also as yet unclear. The two sites are interconnected by mining and the flow is from Lumley 6th to Chatershaugh. From Chatershaugh the water may be flowing towards Kibblesworth via the Ravensworth Ann connection at 64 m BOD. or alternatively the mine waters may be flowing through Herrington and Houghton Colliery and on to the coast via the connections to Eppleton. The connection via Ravensworth Ann at 64 m BOD had until recently been above the water levels both in the Kibblesworth and Unsworth/Washington blocks, the latter being directly connected to Chatershaugh. It is possible therefore that some of the recovery seen at Kibblesworth (Figure 9) is the result of an increased flow to the area from the Washington/Unsworth area.

Nicholsons water level has followed the predicted recovery in that it initially rose slightly to overflow to Houghton colliery and then remained level for a period (Figure 6). Warden Law which is a drilled borehole into the Houghton workings, began to rise at approximately the time that the Nicholsons overflow occurred but the rise at Warden Law could also have been caused by the general recovery in the coastal collieries (Figure 6). However, Warden Law, Lumley 6th, Chatershaugh and Nicholsons are now recovering roughly in parallel which strongly suggests a direct hydraulic connection (see Figure 10). The degree of connection between Houghton and Eppleton should become clear in the near future because the rate of recovery at the coastal pits of Dawdon, Easington, Horden and Hawthorn is greater than at Nicholsons, Lumley 6th, Chatershaugh and Warden Law, which if it continues, would result in an apparent reversal of the hydraulic gradient if the blocks are not connected.

3.1.2 Projected Recovery Times to Surface

3.1.2.1 The Coast

Based on the current rates of recovery at the coastal collieries of Easington, Dawdon, Horden plus Hawthorn the mine water will reach sea level first at Horden (S40) sometime between June 2004 and July 2006. The times vary dependent on the method of projection used. The earlier projection dates are probably the most accurate and should be used for the planning of any pumping and/or treatment works proposed. Figures 11 to 14 show the individual projected recovery curves for Horden, Dawdon, Easington and Hawthorn which give the shortest recovery period. Figure 15 shows the longer term projected recovery.

The data for all the monitoring sites using the two methods of projection of mine water recovery to sea level are listed below.

Site	Earliest Recovery Date	Later Recovery Date
Horden	June 2004	July 2006
Easington	Sept 2004	Dec 2006
Dawdon	April 2006	Dec 2007
Hawthorn	April 2005	April 2009

It should be noted that the earliest recovery to sea level based on the current hydraulic gradient in the mineworkings at the coast is likely to be at Blackhall Colliery which also had a beach adit. The earliest recovery date to sea level at Blackhall is likely to be two to three months before Horden. All the above assumes that the current direction of flow and hydraulic gradient is maintained. The beach adits from the coastal shafts are several metres above sea level and therefore there would be a delay of several months before water overflowed from a beach adit. The recovery time to sea level should still be used for planning purposes because of the increased risk of contamination of the Magnesian Limestone aquifer as the mine water level recovers above sea level.

Table 8

Licenced Water Abstractions from the Magnesian Limestone

Site	Licence No	Aquifer	RWL (m AOD)	Initial Test Pump Water Level (m AOD)	Average Water Level During Pumping (m AOD)
Cleadon (D)	23/5/1	ML	2.6		
Stoneygate	24/5/1	ML, PS, CM	-	-	-
Fulwell	24/5/35	ML	7.3	-9.22	
Seaton	25/5/1	ML	22.6	-2.2	
North Dalton	25/5/2	ML, PS	10.91	-	-15
Thorpe	25/5/3	ML, PS	-12.44	-32.44	-25
Dalton	25/5/4	ML, PS	~2.0	-19	-15
Ryhope (D)	25/5/5	ML, PS	-1.51	-3.05	-2
Peterlee	25/5/6	ML	5.96	-36.88	-36
Hawthorn	25/5/7	ML, CM	20.48	-29.84	-25
New Winning	25/5/8	ML		3.05	
Mill Hill	25/5/32	ML, PS, CM	19.51	0.0	
Burdon	25/5/34	ML	36.7	24.21	

3.1.2.2 The Wear Valley

The potential area at risk from surface outflow inland is the low lying land adjacent to the River Wear. Estimation of recovery times in these areas is more difficult as most of the inland monitoring sites are not yet recovering as rapidly as the well interconnected coastal collieries and Hawthorn. However assuming that a similar recovery rate will develop as at the coastal pits and projecting this to the surface a minimum recovery period could be calculated. Assuming a surface level of between 5 m and 30 m AOD for the lowest possible discharge site and projecting the recovery from the current water level (July 2001) at the same rate as Dawdon, then the water levels would reached 5 m and 30 m AOD as detailed below and in Figure 16.

Site	Earliest Recovery Date 5 m AOD	Later Recovery Date 30 m AOD
Sherburn Hill	March 2002	Sept 2003
Nicholsons	June 2004	April 2007
Lumley 6th	Sept 2004	Aug 2007

These recovery times are not considered to be realistic but do highlight the fact that if and when the area east of the Wear does recover in unison then recovery to levels where surface discharges may occur may only be a matter of a few months unless pumping is controlling the recovery rate. There is minimal risk of an uncontrolled surface discharge as the pumping stations at Sherburn, Nicholsons and Lumley 6th will be retained for control of mine water levels should monitoring indicate a risk of surface discharge.

3.2 Potential Areas of Mine Water Contamination

There are two areas of potential contamination by mine water, the contamination of aquifers and the surface discharge of mine water into rivers or the sea.

3.2.1 Aquifers

The principal aquifer at risk from contamination from mine water is the Permian Magnesian Limestone and Basal Sands. Other minor aquifers are found in the Coal Measures sequence and locally developed sands and gravels in the superficial deposits will also be at risk.

Northumbrian Water currently has 13 licensed water abstraction sites (see Table 8) with water currently being abstracted at eight of these sites. The position of the sites are shown in Figures 1 and 8. The water from these wells is used untreated, therefore the sites are very vulnerable to any aquifer contamination. The eight pumping stations abstract on average eight million gallons per day with a licence for up to 12 million gallons per day.

The Magnesian Limestone is primarily at risk where mine entries pass through the aquifer. Contamination of the aquifer by mine water migration through Coal Measure strata above mine workings is not considered a significant risk because of the constraints placed on mining below an aquifer. The thickness of Coal Measure strata left (60 m) and the strains allowed on the base of the aquifer or sea (10 mm/metre) are specifically designed to prevent water flow from the aquifer into the mine workings. If connections have been made historically the area of mine workings would have rapidly flooded and been isolated from the general body of the mine workings that are currently recovering.

The mine entries that pass through the Magnesian Limestone date from 1821 with the sinking of Hetton Colliery. The positions of the shafts that pass through the Permian are known and in most cases the details of the linings are known and where abandoned details of the fill material and shaft capping are recorded. The current open shafts are at Dawdon, Horden, Easington and Hawthorn but potential contamination of the Permian aquifer could occur at both filled and open shafts.

In addition to the pathway provided by the mine entries the other key factors controlling any potential contamination of the Permian aquifer are the relative heads of the water in the Permian and in the mine workings. This will control the direction of water flow between the Permian and the mine entries and will influence the quality of the water in the mine entry.

The piezometric surface in the Magnesian Limestone prior to pumping at the water abstraction wells varies from 20 m to 30 m AOD inland to within a few metres of sea level at the coast (see Table 8). However, the water levels during pump are depressed by several metres, the lowest levels being at Thorpe (25 m BOD), Peterlee (36 m BOD) and Hawthorn (25 m BOD). The extent of the cone of depression from these sites is not known but given the high permeability of the Magnesian Limestone it is likely that the gradients are low and therefore the cone of the depression large with extensive areas around the abstraction wells where water levels are below sea level.

The head of water that will develop in the mine workings is not known but is expected to be related to the level of workings in the area between the River Wear and the Permian outcrop. The surface level in this area is generally between 50 m to 100 m AOD and the water level in the workings will probably recover to somewhere in this range, dependent on the permeability and the hydraulic gradient that develops.

The hydraulic gradients that have been recorded in the Coal Measures are usually in the range of 1 in 500 (.002) to 1 in 1,000 (.001). However, steeper gradients do develop over short areas of older mine workings and for the purpose of assessing the risk of surface outflow or aquifer contamination a gradient of 1 in 250 (.004) has been used as a probable worst case. Assuming an outflow of mine water at 5 m AOD at the coast and a hydraulic gradient of 1 in 250 (.004) the water level in the mine working 10 kms from the coast, ie at approximately the outcrop of the base of Permian, would be about 45 m AOD.

This level is well below the level of the base of the Permian. Therefore any water flow in mine entries away from the coast would be from the Permian into the mine workings. However, at the coast the water levels in the Permian and the piezometric head in the mine workings will be very similar, ie at or just above sea level and where water levels in the Magnesian Limestone are depressed by pumping, ie Thorpe, the flow could be from the mine entries into the Magnesian Limestone if water levels in the mine workings are allowed to fully recover and outflow. The water abstraction sites considered to be at risk are those at Thorpe, Peterlee and Hawthorn. Thorpe pumping station would be at the highest risk due to the presence of roadways, used by British Coal for a water supply which was driven inland in the Magnesian Limestone from Easington Shafts to within 320 m of the north adit at Thorpe. Plans of the roadways are in Appendix B. The roadway in the Magnesian Limestone is connected via the shafts to the beach adit which has an outflow level of 4.09 m at the beach. However, water would have to recover to 8.5 m at Easington Shaft before it would overflow into the beach adit whereas for water to overflow into the roadways driven inland the water level in the shafts only has to rise to 2.5 m AOD.

Beach tunnels also exist at Horden, Dawdon and at Blackhall Collieries. At Horden the shaft overflow level is 8.7 m AOD and the beach adit discharge level 5.2 m. The level of the overflow at Blackhall is 7.6 m AOD and the beach adit level is 6.6 m AOD. The position of the beach adit at Dawdon is known but no information was available regarding the level at the shaft or the beach.

The quality of the mine water that is likely to outflow at the coastal collieries cannot be accurately predicted. Discrete sampling of the shaft columns has shown that during recovery the mine waters have layered and that the water at the top of the shafts is generally good quality (see Section 2.5). However, while the water quality from a gravity discharge is expected to be better than water pumped from the shaft, there is no guarantee that the quality will not deteriorate with time as the flow paths are established.

The risk of contamination of the Magnesian Limestone aquifer is considered to be significant enough that the recovery of mine water to surface for gravity discharge at the coast should not be attempted until the water levels are controlled by pumping and more detailed information is available regarding the quality of the potential discharge.

3.2.2 Contamination from Surface Discharge

The two areas at risk of contamination from surface discharge are the coast where mine water would discharge from the beach adits linked to the shafts of the coastal pits and the low lying areas of land associated with the Wear Valley where there are numerous shafts and water drainage adits.

3.2.2.1 The Coast

The points at risk from surface outflow of mine water at the coast are the beach adits driven in the Magnesian Limestone associated with Easington, Horden, Dawdon and Blackhall Collieries (details in Appendix B). These tunnels were used for the discharge of mine water when the mines were operational but by pumping water up to the overflow level in the shaft and then using gravity to discharge the water via pipes in the beach tunnels. The pipe work is now either missing or will be highly corroded and therefore any flow of water from the shafts would be into the beach adits themselves. While the majority of the water may flow in the adit there is likely to be some flow into the Magnesian Limestone from the shaft depending on the condition of the shaft, the level of shaft insets and the rest water level in the Magnesian Limestone. Assuming the water rises to a level in the shafts where it can overflow into the beach adits the lack of pipework will probably result in some losses into the Magnesian Limestone from the beach tunnels themselves and possible large losses into open fractures near the mouths of the tunnels. These flows will probably still outflow onto the beach but in an uncontrolled manner from Magnesian Limestone fissures.

The key issue regarding a gravity from a beach adit would be the water quality, which will only be accurately known as and when a discharge occurred. Therefore before any gravity discharge of water is considered the mine water recovery should be controlled by pumping and engineering works carried out in the shaft(s) and in the beach adit(s) to ensure the overflow and discharge onto the beach or into sea is contained. The design of the gravity outflow would also be dependent on the quality of water to be discharged and the consent requirements.

Any water discharge at the coast would have to meet the consent set by the Environment Agency under the Water Resources ACT (1991) and Surface Waters Regulations 1989. Risk assessments would also be required regarding the ecological effects on the beach and/or sea and the concentration of metals on the beach.

3.2.2.2 The Wear Valley

The low lying land in the Wear Valley varies from about 5 metres AOD near Offerton Haugh where the River Wear flows over the barriers separating the Wearmouth/Westoe pond for the east of Wear block to about 37 metres AOD near the southern boundary of the area to the south east of Durham. Within this area mine entries will form the principal pathway for potential surface mine water discharge. Other potential pathways would be via shallow workings surface outcrops of Coal Measure sandstones or via permeable superficial deposits. The presence of Boulder Clay associated with the buried valley of the River Wear greatly limits the area where potential water discharges from natural permeable strata and shallow mine workings could occur. Where the Coal Measures are at or near surface in the Wear

Valley or its tributaries there are generally numerous mine entries which would usually provide an easier flow path.

The type of mine entries where mine water would be most likely to outflow to surface are the old drainage soughs which were specifically designed to capture and drain water from mine workings, initially solely by gravity and later using some form of mechanical lift to raise water from lower levels. The drainage soughs or adits will be at the lowest level possible to drain water into the Wear and while the mouths of the adits may have collapsed or become blocked this will not prevent the outflow of water once the workings become resaturated. Shafts will also provide pathways for mine water whether filled or open and discharges of mine water would occur if the flow of water from the soughs was restricted.

As discussed in section 3.1 the general interconnection of the shallow old workings previously controlled by pumping at Sherburn Hill, Nicholsons and Lumley 6th shafts is still to be proved. Therefore it cannot be assumed that mine water will outflow from the lowest mine entries in the Wear Valley. If there are isolated blocks of mine workings in areas with restricted connection then the hydraulic gradients that develop in parts of the mine workings may be steeper than in the generally well connected areas resulting in potential surface discharges in the higher parts of the Wear Valley.

There are over 50 adits and over 100 shafts recorded in the low lying areas associated with the River Wear and its tributaries. There will also be a significant number of unrecorded shafts and adits mainly due to the age and type of mine workings.

The positions of the known shafts and adits in the vicinity of the River Wear and its tributaries are shown in Figures 17 and 18. This information is supplied from the Coal Authority Mining Records database.

The impact of a mine water discharge into the River Wear would be dependent on the quality, size and site of any discharge. Northumbrian Water abstract and treat water from the River Wear at Great Lumley (see Figure 19). The current licence is for the abstraction of 45 million litres per day (mld) and the volumes abstracted are typically 22 to 25 mld in winter and 35 to 40 mld in summer. This works and the associated river water quality monitoring station is already affected by the upstream mine water discharge of mine water from Vinovium which causes variations in the total dissolved solids (TDS) in the river as a result of the night time pumping. Mine water discharge(s) could occur upstream and/or downstream of the Northumbrian Water abstraction point and with the current information it is not possible to predict either the size or quality of the potential outflow. There would also be potential visual and environmental problems associated with an outflow of mine water, again dependent on the size quality and site of the discharge(s).

It is considered that there is a significant risk of a surface discharge of a quantity and quality that would impact on the River Wear and the Northumbrian Water abstraction if mine waters are allowed to recover uncontrolled and discharge to surface.

4.0 OPTIONS FOR THE CONTROL AND TREATMENT OF MINE WATER

The principal options for the control for mine water in the area of Durham east of the River Wear are:-

- To recover and treat any mine water discharges as and when they occur.
- To pump water from the mines to prevent recovery to surface
- To pump water while gradually allowing water levels to recover to surface.

4.1 Recovery and Surface Discharge

Historically the method of dealing with mine water has been to allow the mine workings to flood and wait for any mine water discharges to occur. Many of these historic discharges that are highly contaminated are now to be treated but there are often difficulties in capturing the water and also in treatment due to the site of the discharge and the lack of suitable land for a treatment system.

Allowing mine waters to recover and then treating the discharges as and when they occur is not considered a viable option for the east of Wear mine water recovery for the following reasons.

1. There is a significant risk of contamination of the Magnesian Limestone aquifer by mine water from the shafts of the coastal collieries prior to surface discharge to the beach.

2. In addition to potential discharges at the coast there is a significant risk of surface outflows of contaminated mine water in the Wear Valley or one of its tributaries, the site or sites of which cannot be reliably predicted.

3. The building of mine water treatment systems for potential outflows in the Wear Valley without the exact knowledge of the discharge site(s) and the quality and quantity of water is not considered possible.

4. Any significant discharge of contaminated mine water into the River Wear systems upstream from the Northumberland Water abstraction point at Great Lumley could affect the viability of the treatment works as well as causing a general pollution problem.

4.2 Mine Water Pumping

The pumping of mine water from the remaining open shafts is considered to be the best short term option for control of mine water east of the River Wear as it will prevent or greatly reduce both the risk of surface outflows and contamination of Magnesian Limestone aquifer. However the number of pumping sites is limited as is the availability of land for a mine water treatment system. The use of a single pumping station to control mine water recovery over the whole of the east of Wear area will ultimately depend on the degree of interconnection of the mine workings which has yet to be proved. The open shafts available for pumping are at Sherburn Hill, Nicholsons, Lumley 6th, Chatershaugh, Hawthorn, Dawdon, Easington and Horden. The alternative, if no open shafts were suitable for pumping would be a new large diameter pumping borehole sited to provide suitable access to the mine workings and with land available for treatment if this could be found.

The main problem with the drilling of a new pump borehole is finding a suitable site. In general the best sites are found in shaft pillars where major underground roadways can be intercepted. Therefore many of the principal sites will be adjacent to the open shafts already under consideration. Alternative pumping sites along the major underground roadways as shown in Figure 1 could be investigated if no suitable land can be obtained for treatment at the open shafts.

4.2.1 Sherburn Hill

Sherburn Hill pumping station is not considered suitable for controlling mine water levels over the whole of the east of Wear area because of its poor connection with the general body of mine workings and its general position in the south west corner of the block. However the site should be retained as a potential pumping site to control mine water to prevent outflows to the River Wear from old workings to the east and south east of Durham.

4.2.2 Nicholsons

Nicholsons pumping station is a relatively shallow shaft (149 metre depth) with limited connections to adjacent collieries and is therefore not suitable to pumping mine water to control the east of Wear area. It is likely that this station will only be required in the long term if monitoring shows the mining connections to be different from the current understanding or blockages of connections occur.

4.2.3. Lumley 6th

The lack of proven connection and the geographic position of Lumley 6th pumping station at the north west corner of the east of Wear block makes Lumley 6th pumping station unsuitable for control of mine water over the whole of the area. However, as with Sherburn Hill, the station may well be required in the long term to prevent surface discharges from old workings in the Wear Valley downstream of Great Lumley.

4.2.4. Chatershaugh

This shaft is right on the boundary of the east of Wear block and could be considered as part of the Washington/Unsworth block to the north. It would not be feasible to control mine water levels in the east of Wear block by pumping from Chatershaugh. However, because of its low elevation (7 metres AOD) and position adjacent to the Wear, it could be used as a pumping station to prevent surface discharges from the numerous mine entries in this area (Figure 18) or potentially as a controlled surface discharge.

4.2.5. Dawdon Shaft

Dawdon shaft is interconnected with the general body of mine workings in the east of Wear area via Murton Colliery and with Easington Colliery via two roadways, one in the Low Main Seam (J) and one in the Main Seam (F). The Low Main was reportedly dammed. Dawdon was considered by British Coal as a pumping station to prevent water flow to Easington. This scheme however involved no flow through the mining connections whereas pumping from Dawdon to control mine water levels over the whole of the east of Wear would be reliant on there currently being sufficient flow and no blockages in the future. There are therefore significant risks associated with this strategy. The other major problem with Dawdon shaft is a lack of a suitable mine water treatment area (20,000 m^2) adjacent to the shafts.

Dawdon beach adit does have a borehole and brick lined beach adit for mine water disposal but it is unlikely that these would still be useable. (See Appendix B).

4.2.6 Horden

Horden Colliery is generally interconnected with Blackhall but had only single roadway connections with Easington and Shotton, both of which were reportedly dammed. Monitoring of the water levels at Easington and Horden has confirmed the failure of the dam between these collieries and it is likely that Horden and Shotton are hydraulically connected. The problem with pumping at Horden is similar to pumping at Dawdon. There is a risk that the degree of connectivity would not allow sufficient flow for control of mine water over the whole block.

Horden is also similar to Dawdon in that there is only limited areas of land available for the construction of a suitable passive treatment area.

4.2.7 Easington

Easington Colliery is situated between Dawdon and Horden Collieries with limited connections to these collieries as described above. While all three collieries are hydraulically connected there are significant risks that pumping from Easington would not control mine water recovery inland because of restrictions in flow through these connections.

Easington also has restricted areas of land for the construction of a mine water treatment system in the vicinity of the open shafts.

4.2.8 Hawthorn Shaft

Hawthorn Shaft is a modern concrete lined structure sunk in the 1950's as part of a major restructuring of the mines in the area. It is linked by major roadways to Elemore, Eppleton, South Hetton and Murton (see Figure 1) and currently has the lowest water level of any of the monitoring sites.

Hawthorn Shaft has by far the best general connections with the east of Wear block and is therefore considered to be the lowest risk option for a pumping shaft to control mine water recovery in the east of Wear area. The main drawbacks of using Hawthorn are that there are only two shaft insets and these are both towards the base of the shaft (see Appendix C) and that the mine water pumped is likely to contain levels of chloride (5000mg/l) that would not be consented for discharge into a surface water course, therefore a discharge pipe to the coast would be required.

There is land available for a suitably sized treatment system at the Hawthorn site, but this is currently being restored by English Partnerships. The construction of a pipe line to the coast allows alternative sites for treatment to be considered along this route.

4.3 Pumping and Controlled Surface Discharge

The pumping of mine water to prevent mine waters from contaminating either the Magnesian Limestone aquifer or surface waters will initially have to be very conservative regarding both the volume of water pumped and the level at which the water is pumped. The use of the natural hydraulic gradient in the mine workings and having a centrally situated well connected pumping station as Hawthorn will be an advantage when pumping commences.

In the longer term the aim should be to allow mine waters to recover to as high a level as possible without risk of contamination of the Magnesian Limestone or surface discharge thereby reducing both pumping costs and the volume of water to be treated. The possibility of controlled surface discharges either at the coast or in the Wear Valley of relatively uncontaminated mine waters could then be investigated. Having a centrally placed pumping station at Hawthorn would be ideal in this situation in that it could be used to allow a very gradual recovery around the edges of the mining area, i.e. in the Wear Valley and at the coast, so that potential surface discharges or small scale pumping of relatively unpolluted mine waters could be investigated with minimum risk.

4.4 Mine Water Treatment

Mine water treatment will almost certainly be required for any pumped mine water discharge. Controlled gravity discharges may be possible without treatment but these can only be established following a period of controlled recovery and monitoring.

The type of treatment, the area of land required and the quality of the discharge will be dependent on the quality and volume of mine water to be pumped and the site of the pumping station(s) and treatment system. However, as a general guide based on the water qualities in section 2.5 and an estimated pumped volume of 190 l/sec (2,500 gpm) the area of land required will be in the order of 2 hectares (20,000 m^2) for a passive treatment system. The potentially high levels of chloride in the mine waters pumped from the coastal collieries including Hawthorn will require a discharge directly to the sea. The availability of land of the required size adjacent to the open shafts is limited. Undeveloped areas of land do exist at both Easington and Horden within short distance of the shafts which could be used for mine water treatment if the land could be acquired. The problems with both these sites is the degree of connectivity to the rest of the mining area. Dawdon has only limited areas of land available adjacent to the shafts. Any treatment scheme linked to Dawdon would require the water to be pumped to the treatment site via a pipe.

There is sufficient land potentially available adjacent to Hawthorn shaft for a mine water treatment site but a new pipe to the coast will be required for the discharge.

All the potential mine water treatment sites are at or near reclaimed former collieries and as such there is likely to be opposition to returning the site to what will be perceived as a mining use.

5.0 CONCLUSIONS

- Mine water recovery in the area of the Durham coalfield east of the River Wear will potentially result in surface discharges and contamination of the Magnesian Limestone aquifer.

- The site(s) of the surface discharges and the quality and quantity of the water cannot be accurately predicted at this stage.

- Contamination of the Magnesian Limestone will only occur from mine entries associated with the coastal collieries but is likely to occur before any surface discharge at the coast.

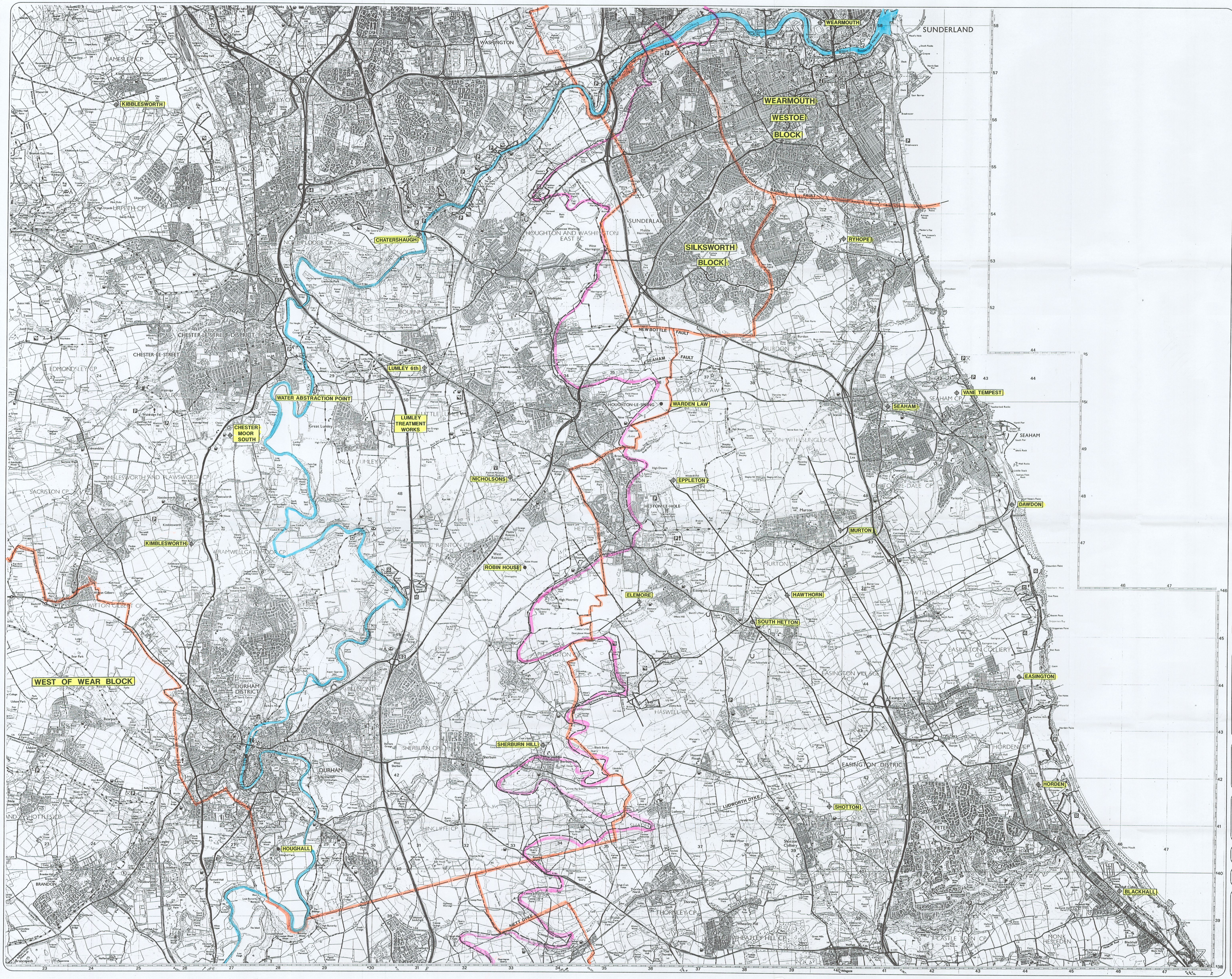
- The pumping of mine water is considered to be the only option available to control mine water recovery and prevent contamination of the Magnesian Limestone and/or surface water.

- The use of a central large pumping station to control mine water with potential smaller pumping stations or gravity discharges around the periphery of the area is considered to be the best option for the long term recovery of mine water east of the River Wear.

- Any pumped mine water will require treatment prior to discharge into the sea or a surface water course.

FIGURE 1

THE WEST OF WEAR AREA SHOWING MONITORING SITES AND MINING AREAS



NOTES

REV	DATE	BY	CKD	APD	MODIFICATIONS

SAVED LOCATION PATH
SAVED

DO NOT SCALE - IF IN DOUBT ASK

CLIENT

THE COAL AUTHORITY

PROJECT TITLE

Options for the Control of Minewater East of the River Wear

DRAWING TITLE

Figure 1

The East of Wear Area showing monitoring sites and mining areas

DRAWN / DATE	CHECKED / DATE	APPROVED / DATE	SCALE
JG/AUG 2001	KRW/AUG 2001		1:25,000

STATUS	PROJECT	NUMBER	REV
	/	/	

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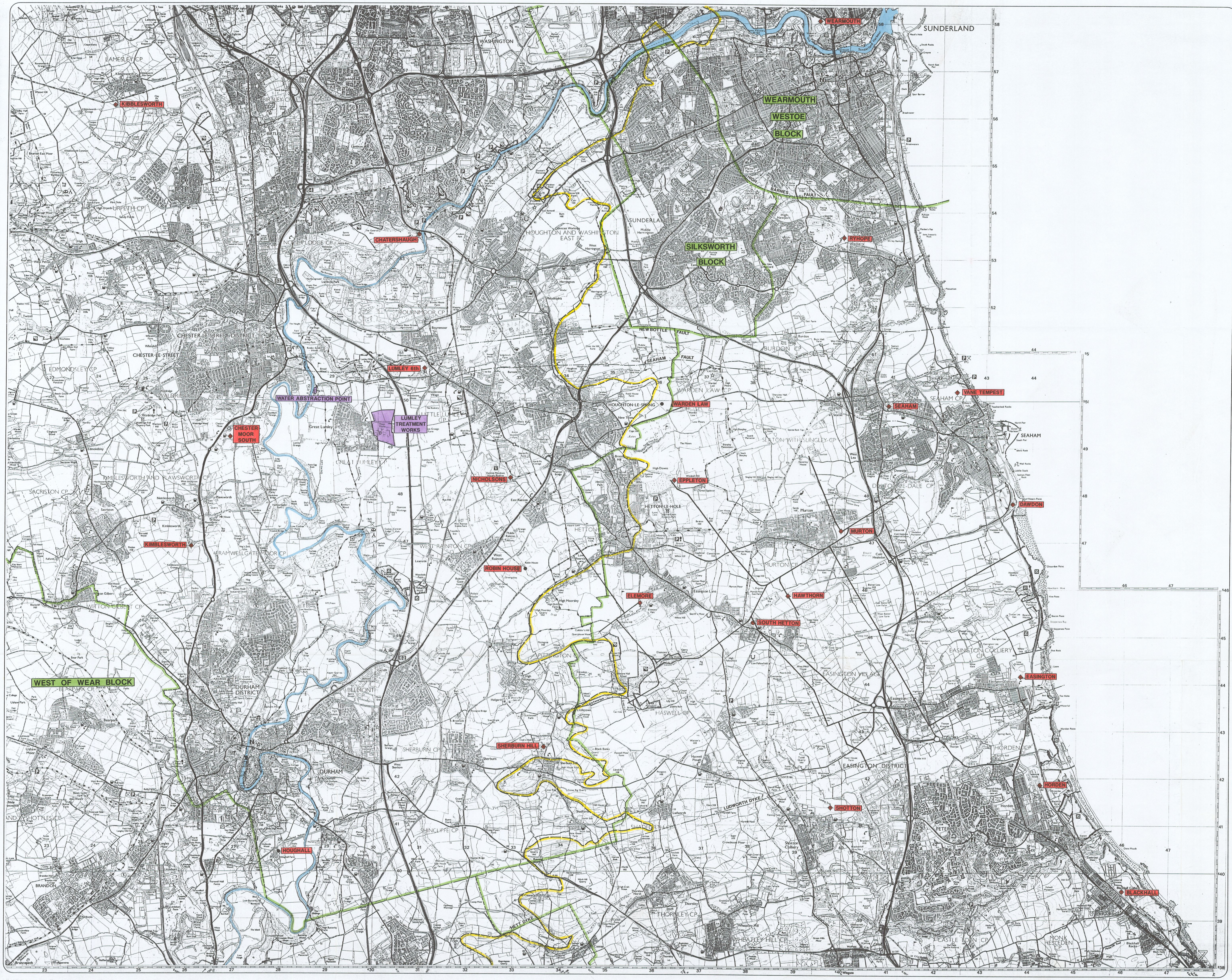
INSTITUTE OF ENVIRONMENTAL MANAGEMENT & ASSESSMENT iema
Associate Environmental Impact Assessor Member
IMC Consulting Engineers are a corporate member of the IEMA

constructionline
U.K. REGISTER OF QUALIFIED CONSTRUCTION SERVICES
REGISTRATION NO. 20411

Cert. No. FS 36943



NOTES

KEY

- Major faulting
- Boundaries of mining blocks
- Base of Permian outcrop
- Environment Agency Boreholes
- Major Colliery Sites
- Major underground roadways

REV	DATE	BY	CKD	APD	MODIFICATIONS

SAVED LOCATION PATH
SAVED

DO NOT SCALE - IF IN DOUBT ASK

CLIENT

THE COAL AUTHORITY

PROJECT TITLE

Options for the Control of Minewater
East of the River Wear

DRAWING TITLE

Figure 1

The East of Wear Area showing
monitoring sites and mining areas

DRAWN / DATE	CHECKED / DATE	APPROVED / DATE	SCALE
JG/AUG 2001	KRW/AUG 2001		1:25,000

STATUS	PROJECT	NUMBER	REV
	/	/	

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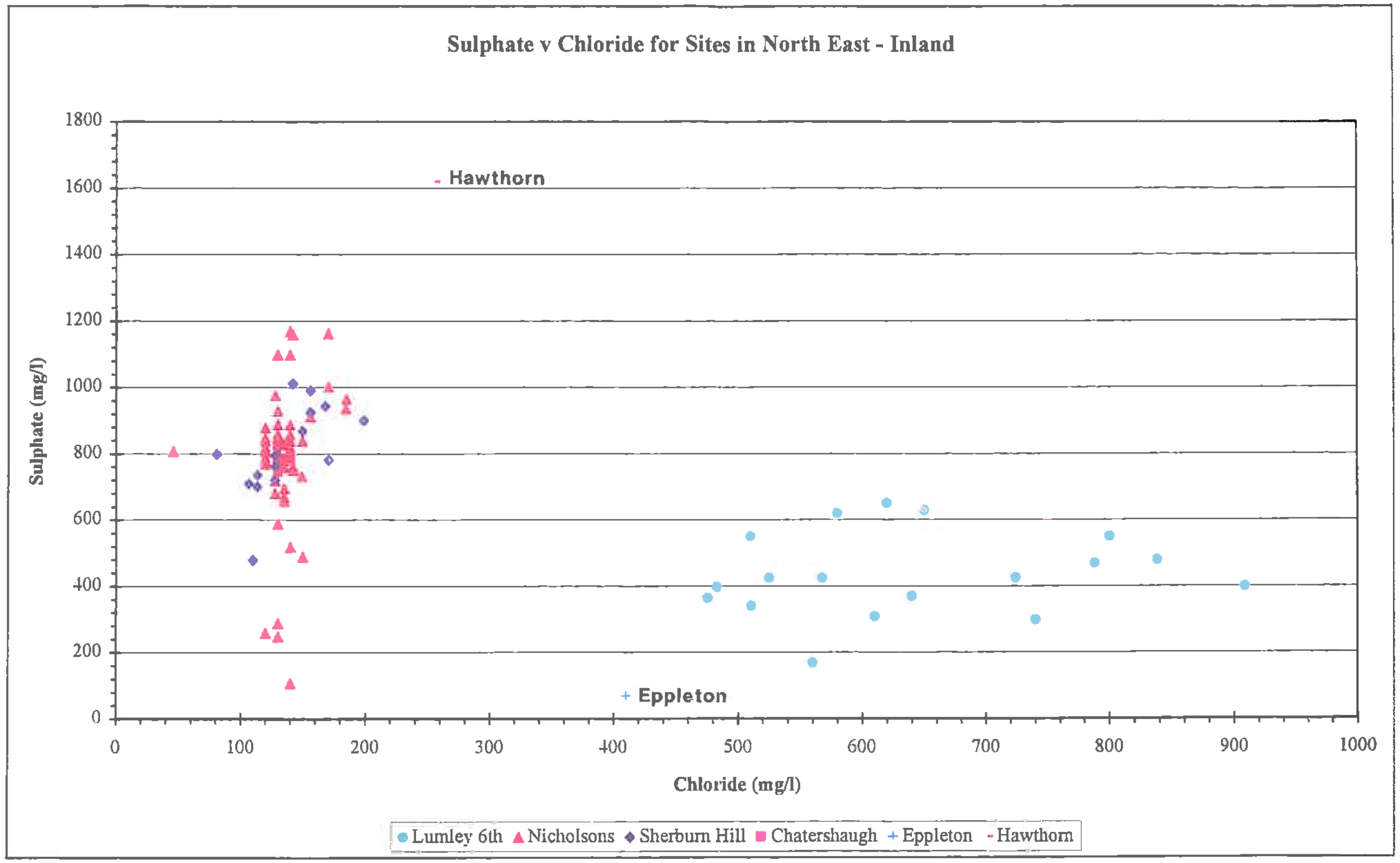
FIGURE 2

CROSSPLOT OF SULPHATE AND CHLORIDE CONCENTRATIONS FOR MINE WATER PUMPED EAST OF WEAR



PROJECT	Options for the Control of Minewater East of the River Wear - The Coal Authority 7208
TITLE	Crossplot of Sulphate and Chloride concentrations for minewater pumped East of Wear

ENGINEER	KRW
TRACED BY	JG
CHECKED BY	
APPROVED BY	
DATE	AUGUST 2001
DRG. No.	Figure 2

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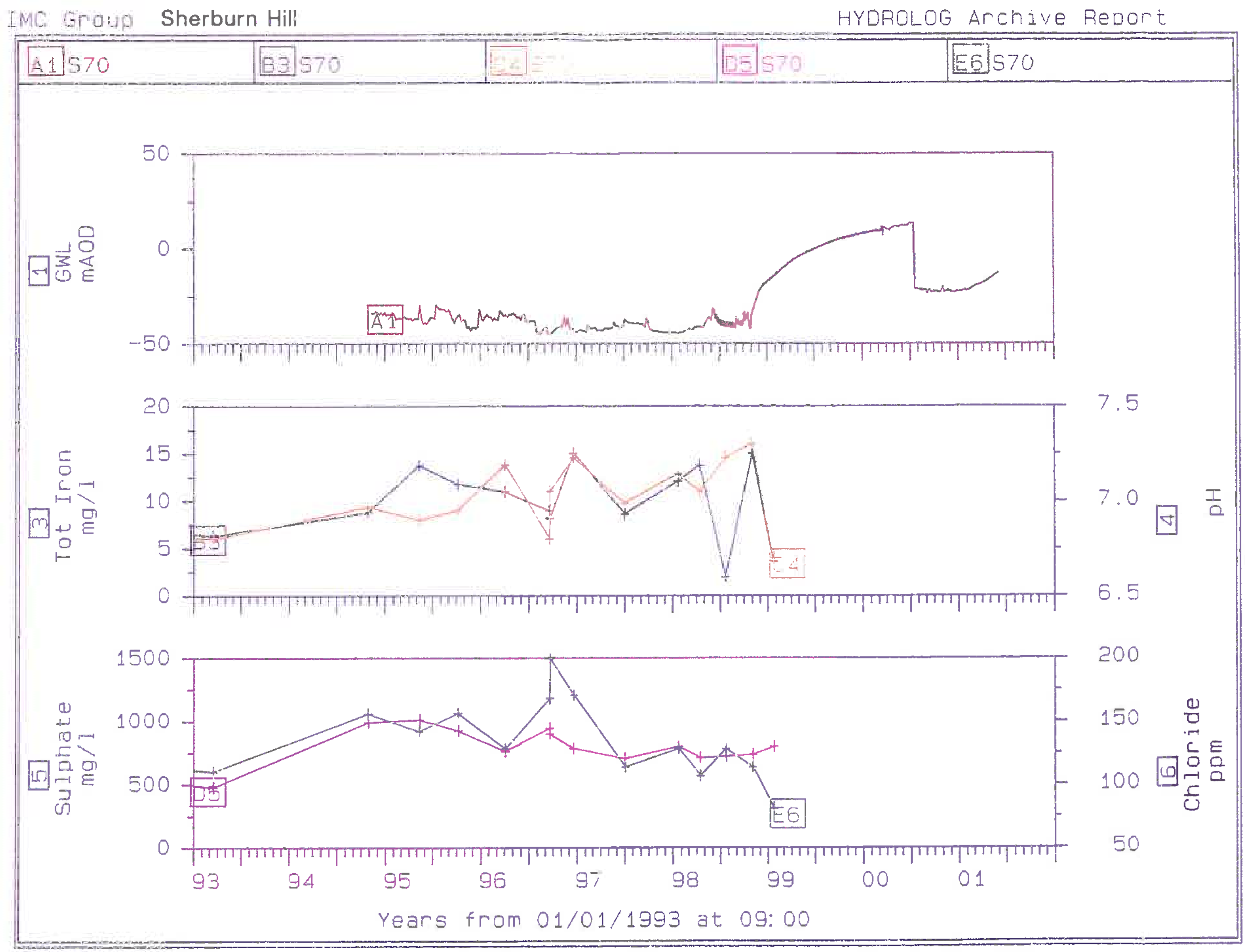
FIGURE 3

MINE WATER QUALITY TRENDS AT SHERBURN HILL

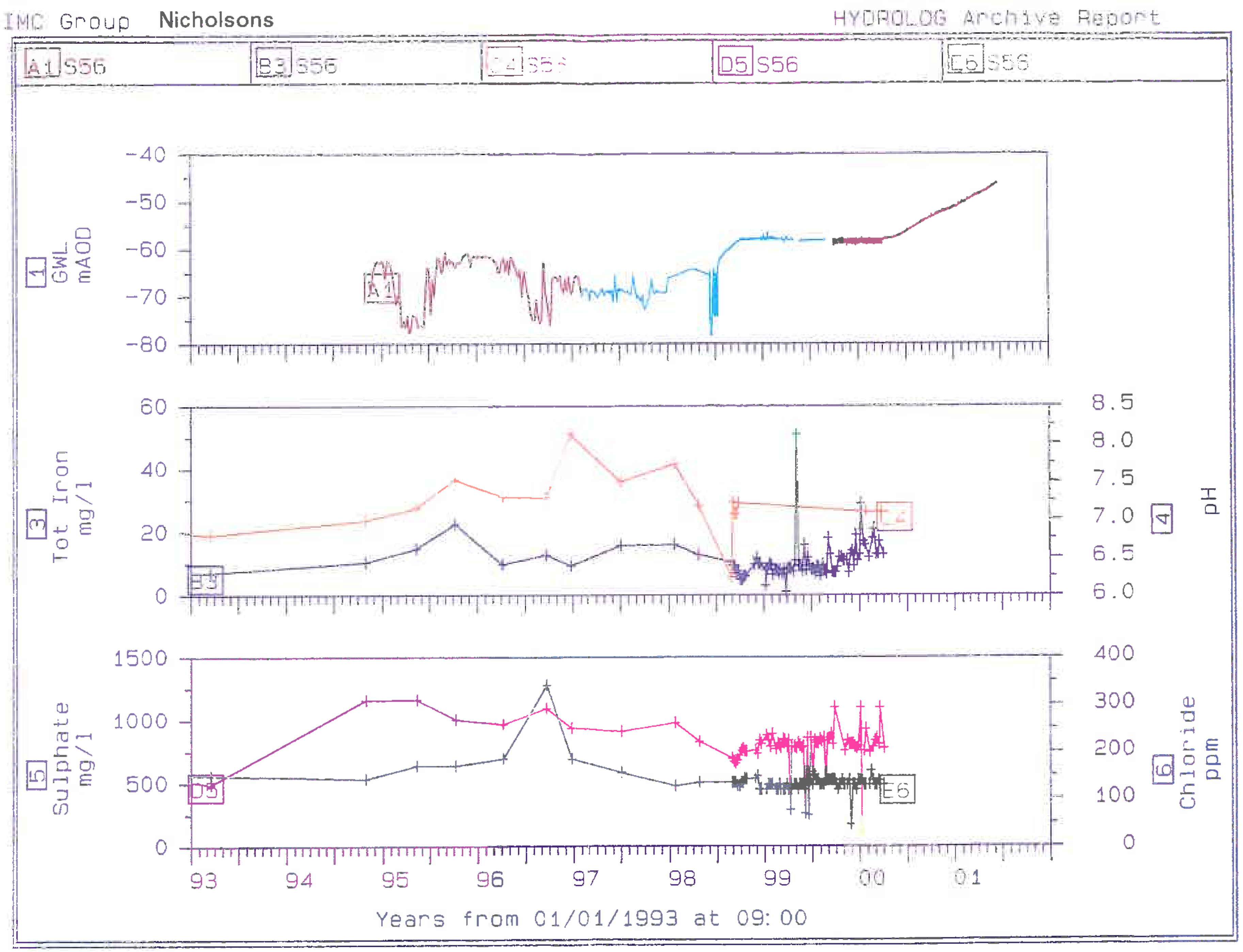


PROJECT	Options for the Control of Minewater East of the River Wear - The Coal Authority 7208	ENGINEER KRW	IMC
TITLE	Minewater quality trends at Sherburn Hill	TRACED BY JG	
		CHECKED BY	DATE AUGUST 2001
		APPROVED BY	DRG. No. Figure 3

Heatherbank B1388

FIGURE 4

MINE WATER QUALITY TRENDS AT NICHOLSONS



PROJECT	Options for the Control of Minewater East of the River Wear - The Coal Authority 7208	ENGINEER KRW	IMC
TITLE	**Minewater quality trends at Nicholsons**	TRACED BY JG	
		CHECKED BY	DATE AUGUST 2001
		APPROVED BY	DRG. No. Figure 4

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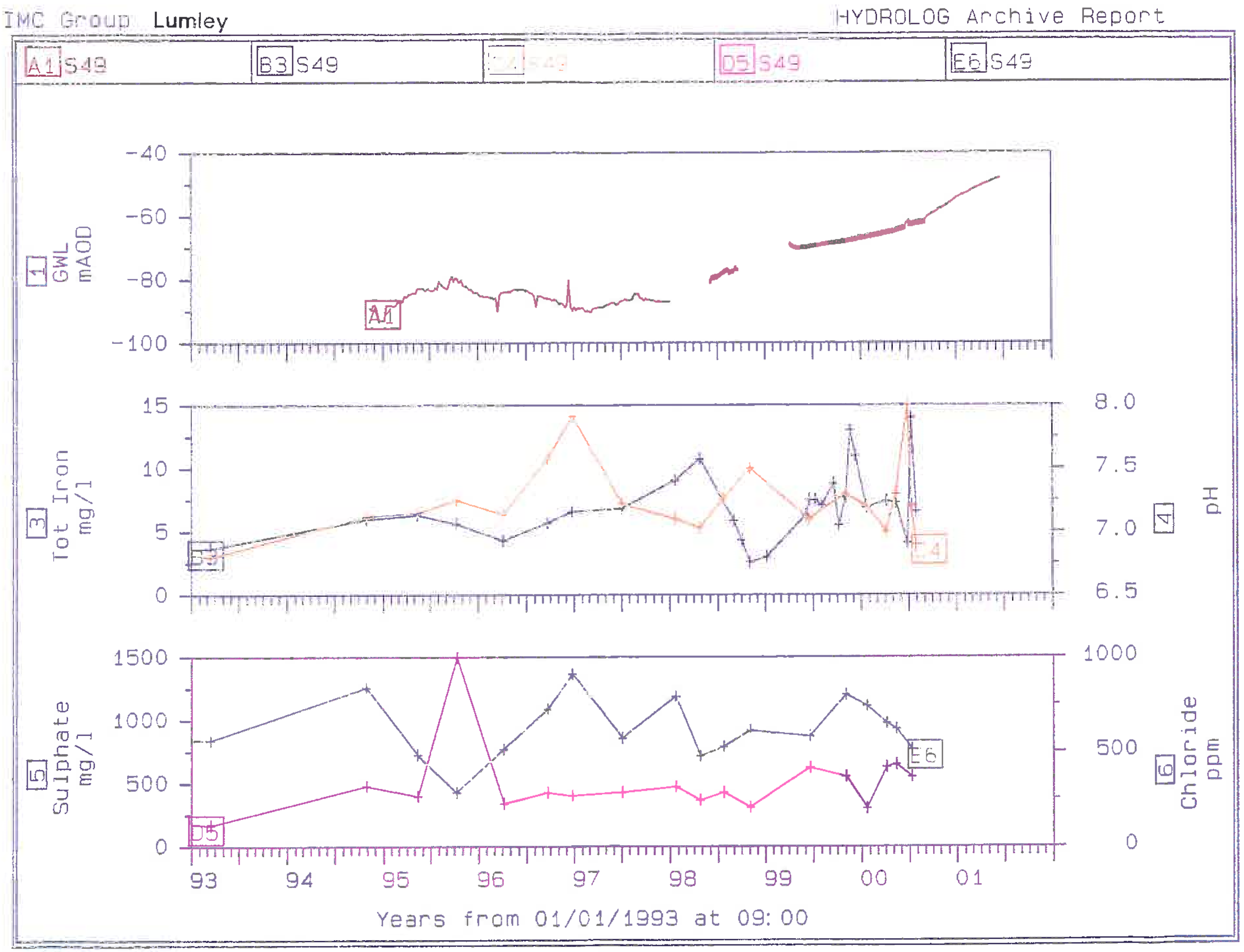
FIGURE 5
MINEWATER QUALITY TRENDS AT LUMLEY 6^{TH}



PROJECT	Options for the Control of Minewater East of the River Wear - The Coal Authority 7208	ENGINEER KRW	IMC
TITLE	Minewater quality trends at Lumley 6th	TRACED BY JG	
		CHECKED BY	DATE AUGUST 2001
		APPROVED BY	DRG. No. Figure 5

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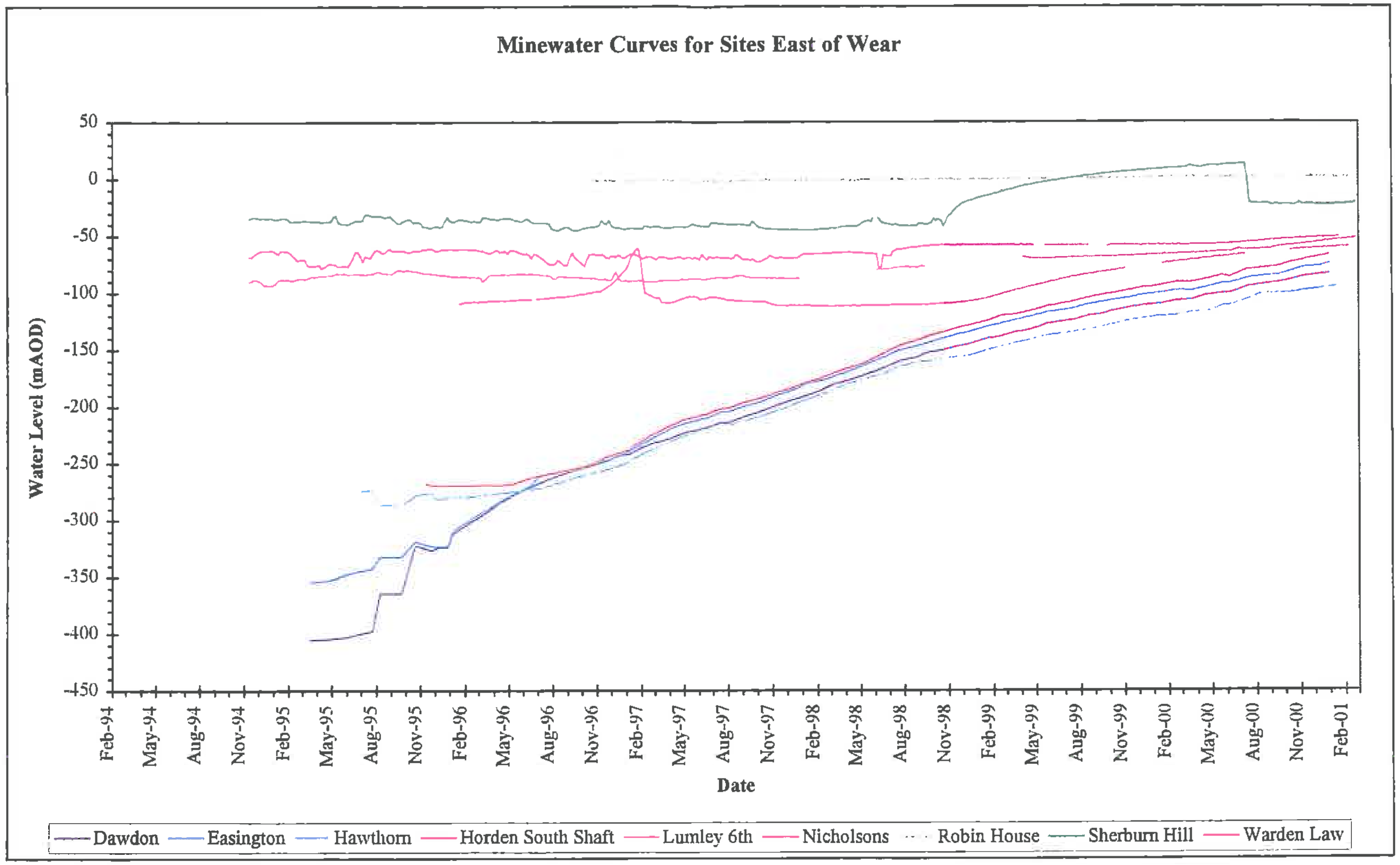
FIGURE 6

MINE WATER RECOVERY EAST OF THE RIVER WEAR SINCE 1994



PROJECT	Options for the Control of Minewater East of the River Wear - The Coal Authority 7208	ENGINEER KRW	IMC
		TRACED BY JG	
TITLE	Minewater recovery East of the River Wear since 1994	CHECKED BY	DATE AUGUST 2001
		APPROVED BY	DRG. No. Figure 6

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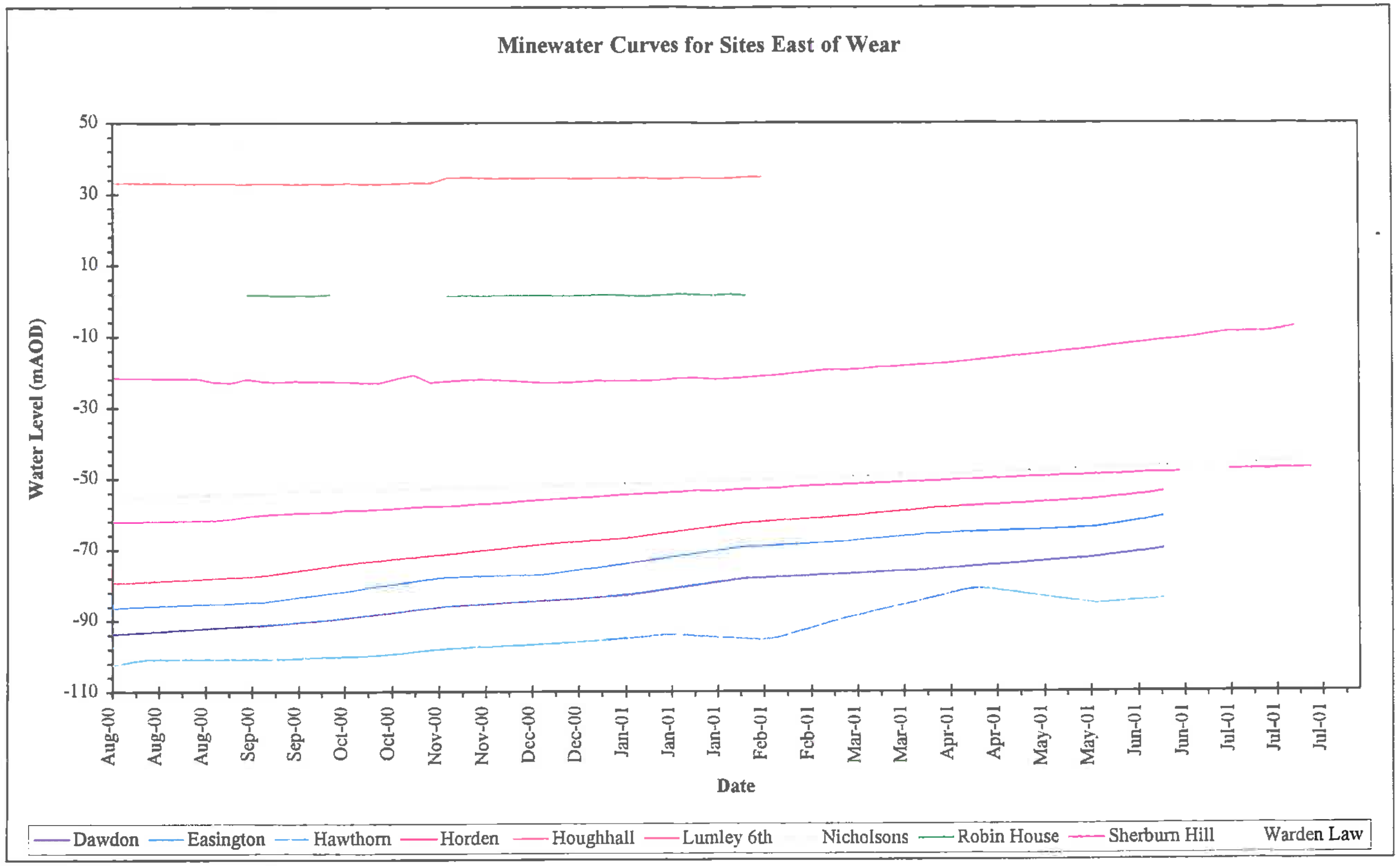
FIGURE 7

MINE WATER RECOVERY EAST OF THE RIVER WEAR FOR THE LAST YEAR



PROJECT	Options for the Control of Minewater East of the River Wear - The Coal Authority 7208	ENGINEER KRW	IMC
TITLE	Minewater recovery East of the River Wear for the last year	TRACED BY JG	
		CHECKED BY	DATE AUGUST 2001
		APPROVED BY	DRG. No. Figure 7

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FIGURE 8

PROBABLE DIRECTIONS OF MINE WATER FLOW AND HYDRAULIC GRADIENTS EAST OF THE RIVER WEAR

PO Box 18
Mill Lane
Huthwaite
Sutton in Ashfield
Nottinghamshire NG17 2NS
Tel: Mansfield (01623) 441444

INTERNATIONAL MINING CONSULTANTS LIMITED

NOTES

REV	DATE	BY	CHKD	APPRVD	MODIFICATIONS	STATUS
2	Oct. 2000				Water Levels for August 2000 unless otherwise stated Water Levels for June 2001 unless otherwise stated	

Options for the Control of the Minewater East of the River Wear

DRAWN/DATE	CHECKED/DATE	APPROVED/DATE	SCALE
JG / AUG 2001	KRW/AUG 2001	AUGUST 2001	1 : 50,000

For
The Coal Authority

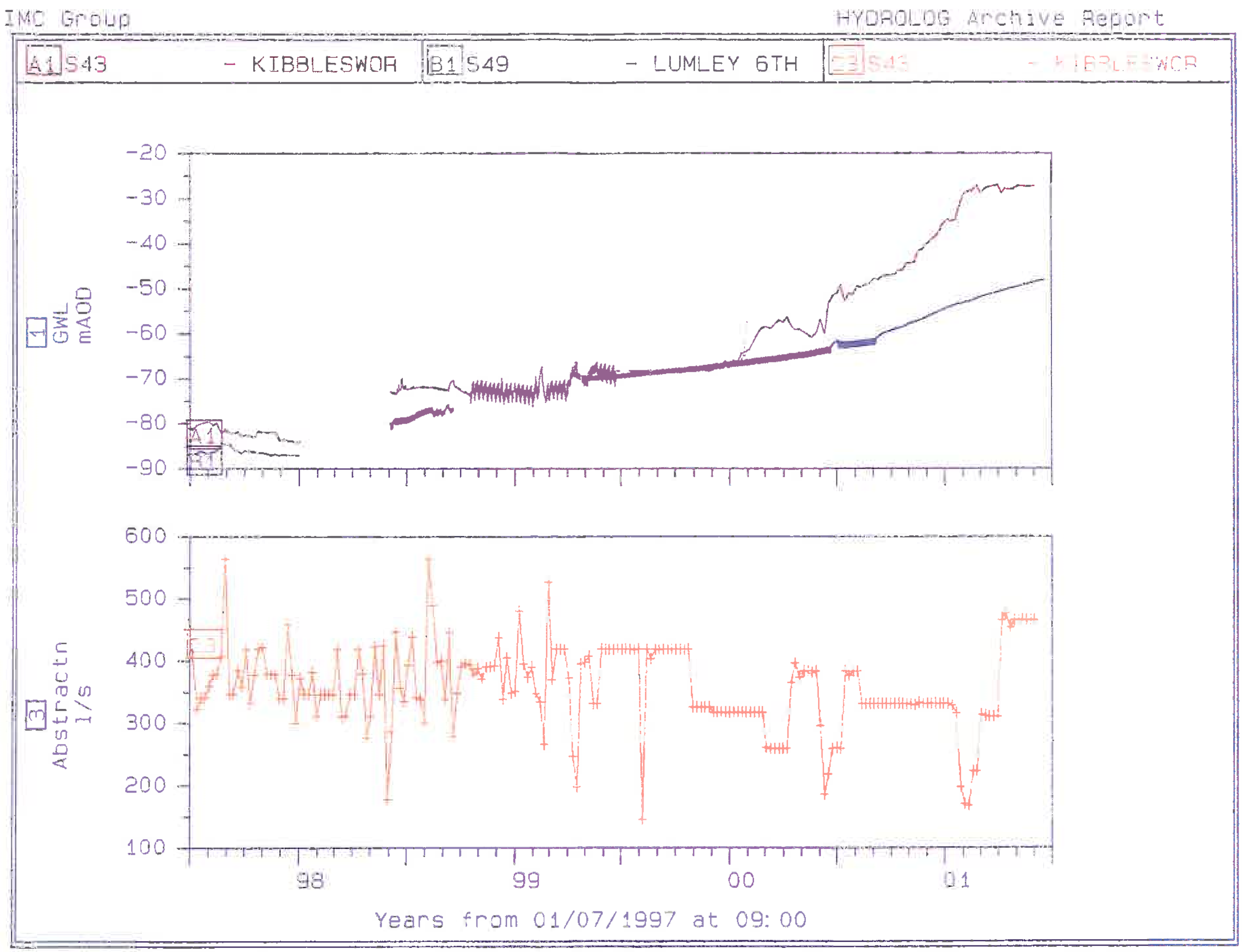
INTERNATIONAL MINING CONSULTANTS LIMITED

Probable directions of minewater flow and hydraulic gradients East of the River Wear

PROJECT	STATUS	NUMBER	REV
	/	/	Figure 8

FIGURE 9

WATER LEVELS AND ABSTRACTION AT KIBBLESWORTH PUMPING STATION



PROJECT	Options for the Control of Minewater East of the River Wear - The Coal Authority 7208
TITLE	Water levels and Abstraction at Kibblesworth Pumping Station

ENGINEER	KRW
TRACED BY	JG
CHECKED BY	
APPROVED BY	
DATE	AUGUST 2001
DRG. No.	Figure 9

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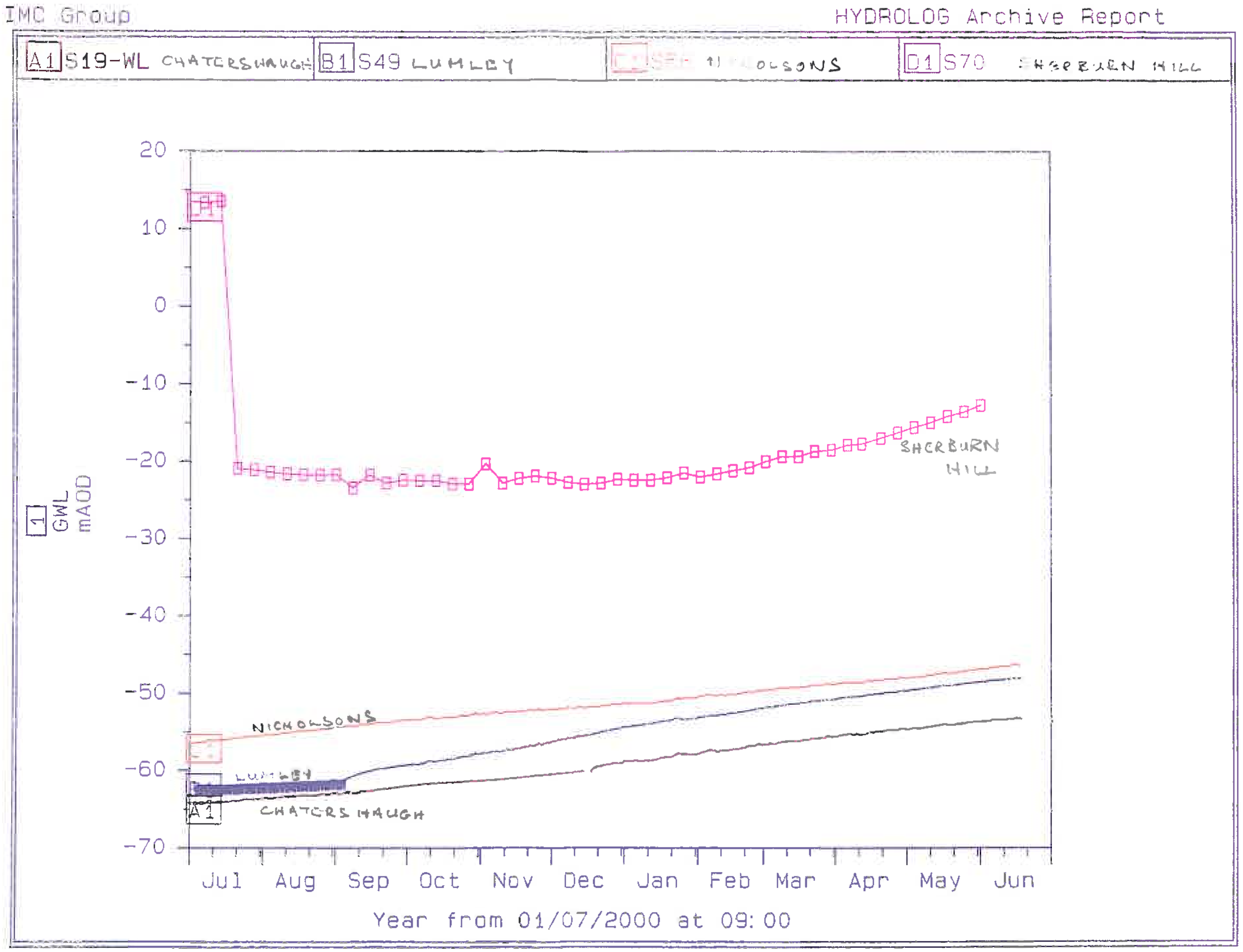
FIGURE 10

MINE WATER RECOVERY AT SHERBURN HILL, NICHOLSONS, LUMLEY 6TH AND CHATERSHAUGH FOR THE LAST YEAR



PROJECT	Options for the Control of Minewater East of the River Wear - The Coal Authority 7208
TITLE	Minewater recovery at Sherburn Hill, Nicholsons, Lumley 6th and Chatershaugh for the last year

ENGINEER	KRW
TRACED BY	JG
CHECKED BY	
APPROVED BY	
DATE	AUGUST 2001
DRG No	Figure 10

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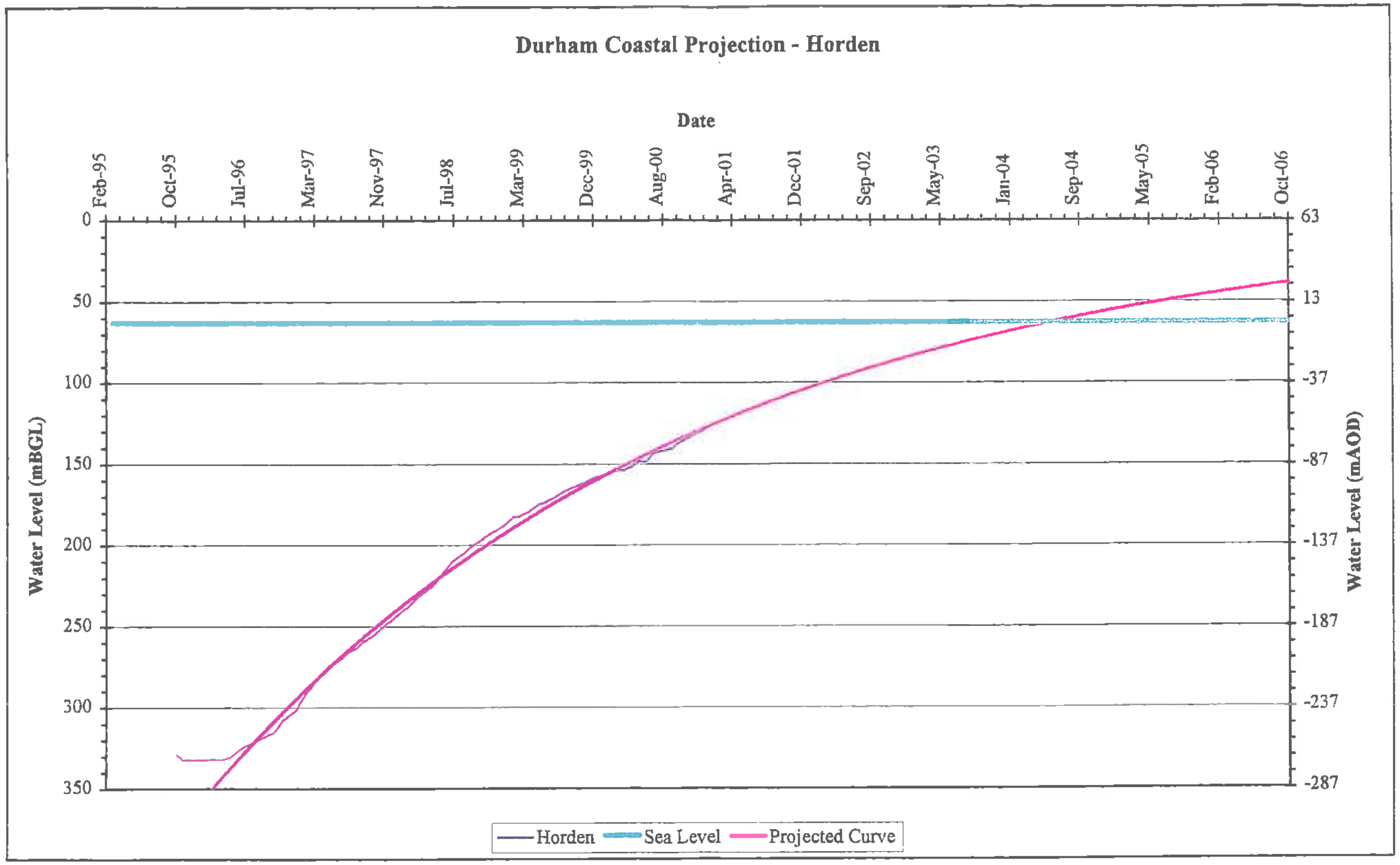
FIGURE 11

PROJECTED MINE WATER RECOVERY CURVE AT HORDEN COLLIERY (MINIMUM RECOVERY PERIOD)



PROJECT	Options for the Control of Minewater East of the River Wear - The Coal Authority 7208	ENGINEER KRW	IMC
TITLE	Projected Minewater Recovery curve at Horden Colliery (minimum recovery period)	TRACED BY JG	
		CHECKED BY	DATE AUGUST 2001
		APPROVED BY	DRG. No. Figure 11

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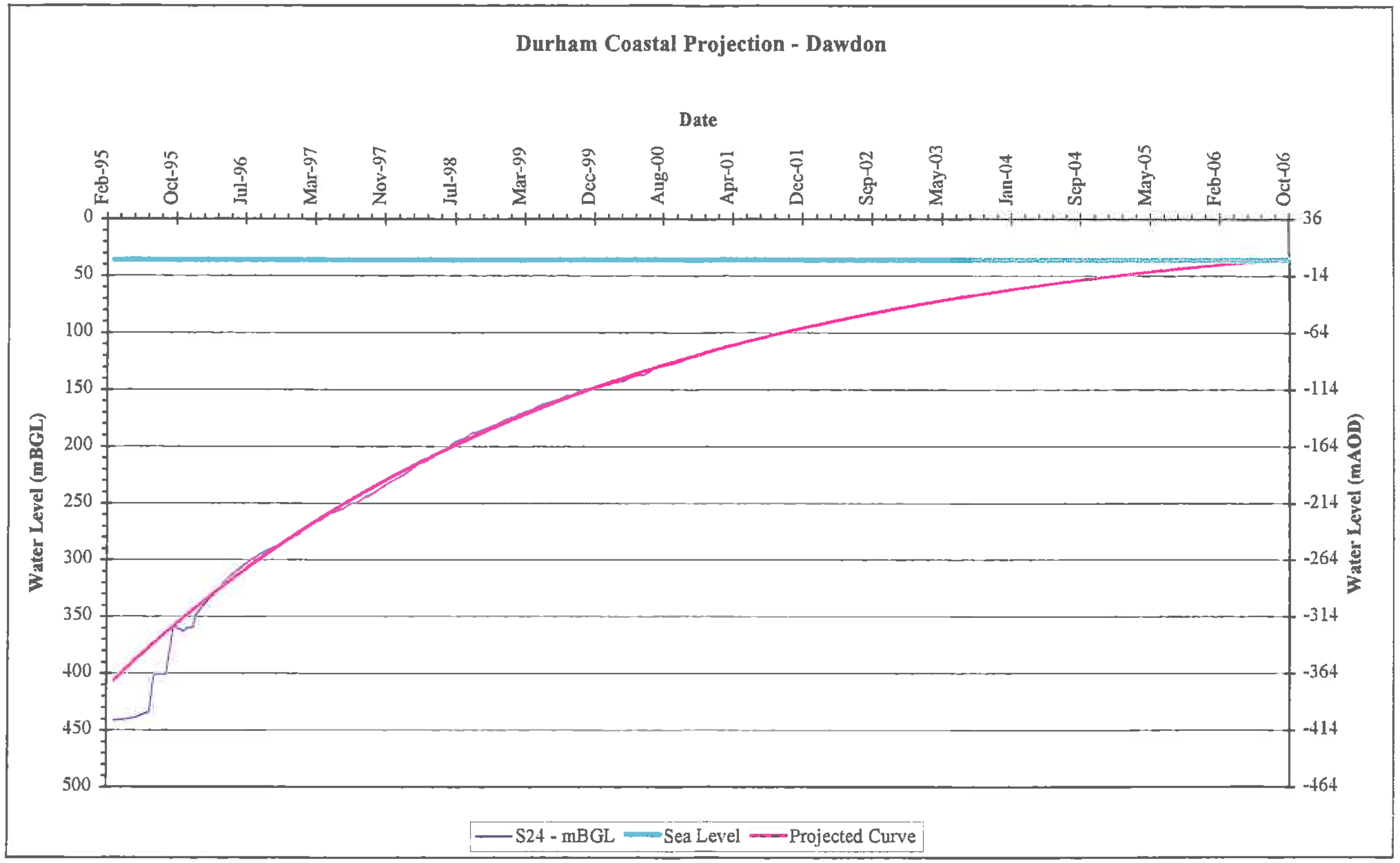
FIGURE 12

PROJECTED MINE WATER RECOVERY CURVE AT DAWDON COLLIERY (MINIMUM RECOVERY PERIOD)



PROJECT	Options for the Control of Minewater East of the River Wear - The Coal Authority 7208	ENGINEER KRW	IMC
TITLE	Projected Minewater Recovery curve at Dawdon Colliery (minimum recovery period)	TRACED BY JG	
		CHECKED BY	DATE AUGUST 2001
		APPROVED BY	DRG. No. Figure 12

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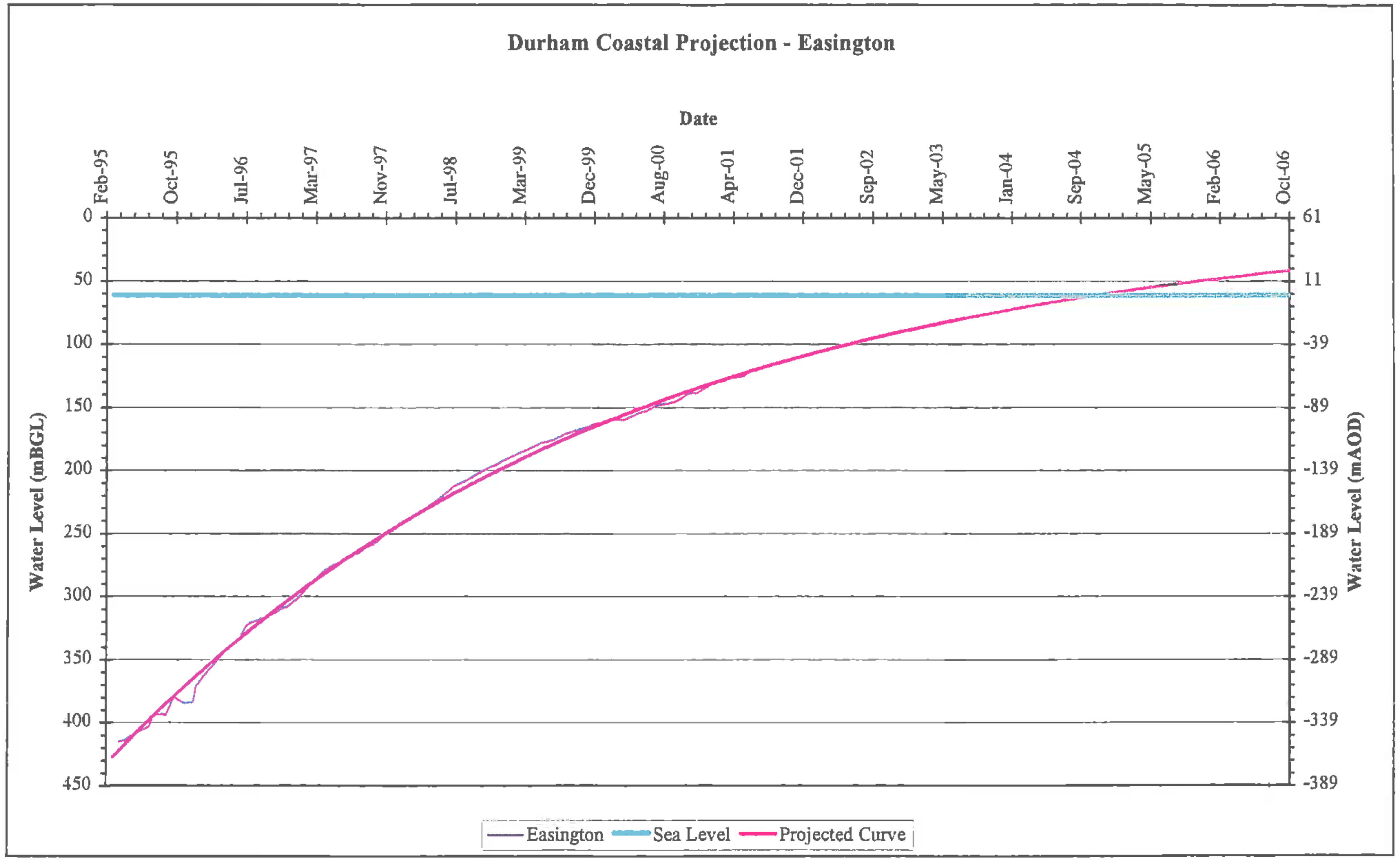
FIGURE 13

PROJECTED MINE WATER RECOVERY CURVE AT EASINGTON COLLIERY (MINIMUM RECOVERY PERIOD)



PROJECT	Options for the Control of Minewater East of the River Wear - The Coal Authority 7208	ENGINEER KRW	IMC
TITLE	Projected Minewater Recovery curve at Easington Colliery (minimum recovery period)	TRACED BY JG	
		CHECKED BY	DATE AUGUST 2001
		APPROVED BY	DRG. No. Figure 13

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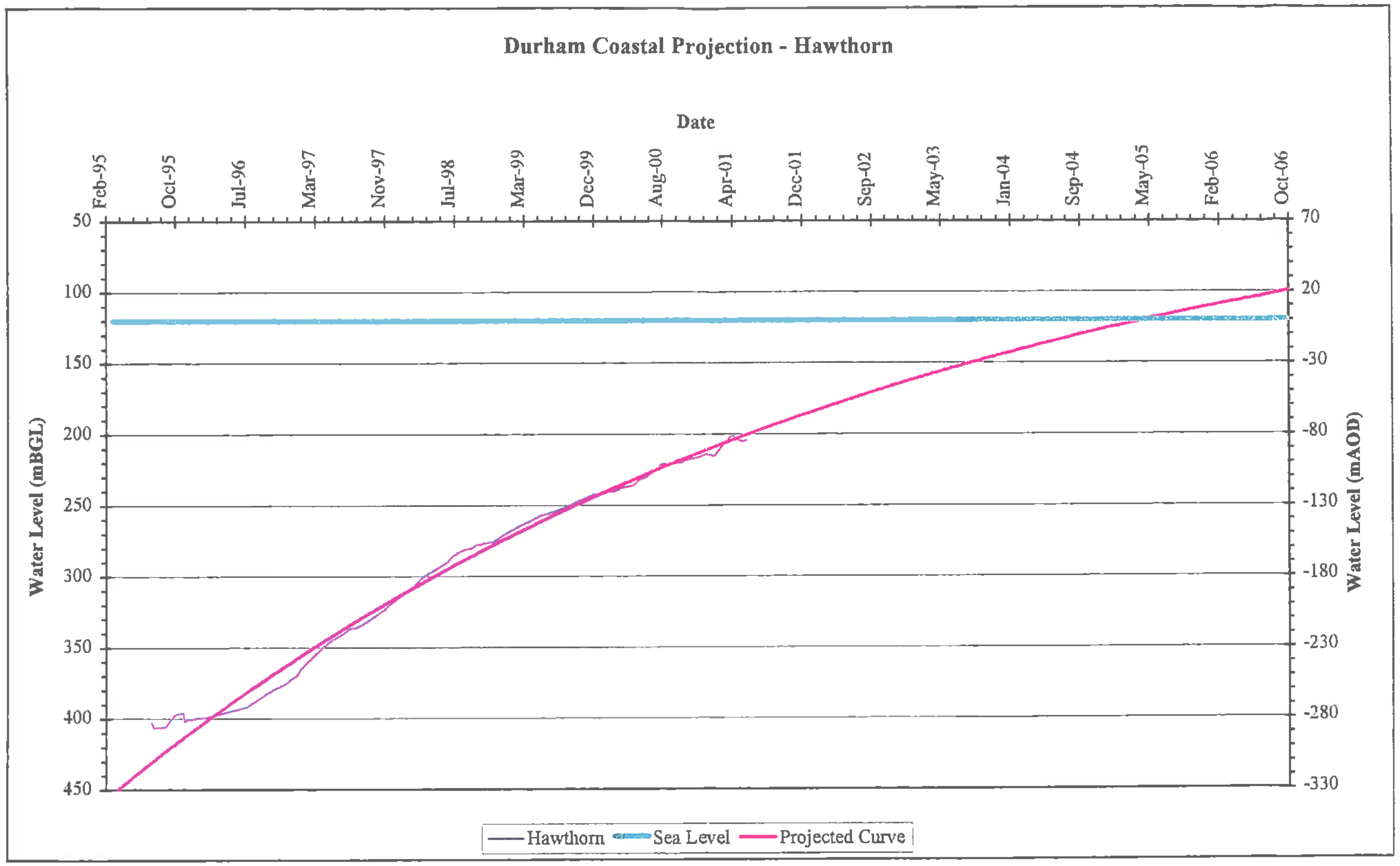
FIGURE 14

PROJECTED MINE WATER RECOVERY CURVE AT HAWTHORN COLLIERY (MINIMUM RECOVERY PERIOD)



PROJECT	Options for the Control of Minewater East of the River Wear - The Coal Authority 7208
TITLE	Projected Minewater Recovery curve at Hawthorn Colliery (minimum recovery period)

ENGINEER	KRW		IMC
TRACED BY	JG		
CHECKED BY		DATE	AUGUST 2001
APPROVED BY		DRG. No.	Figure 14

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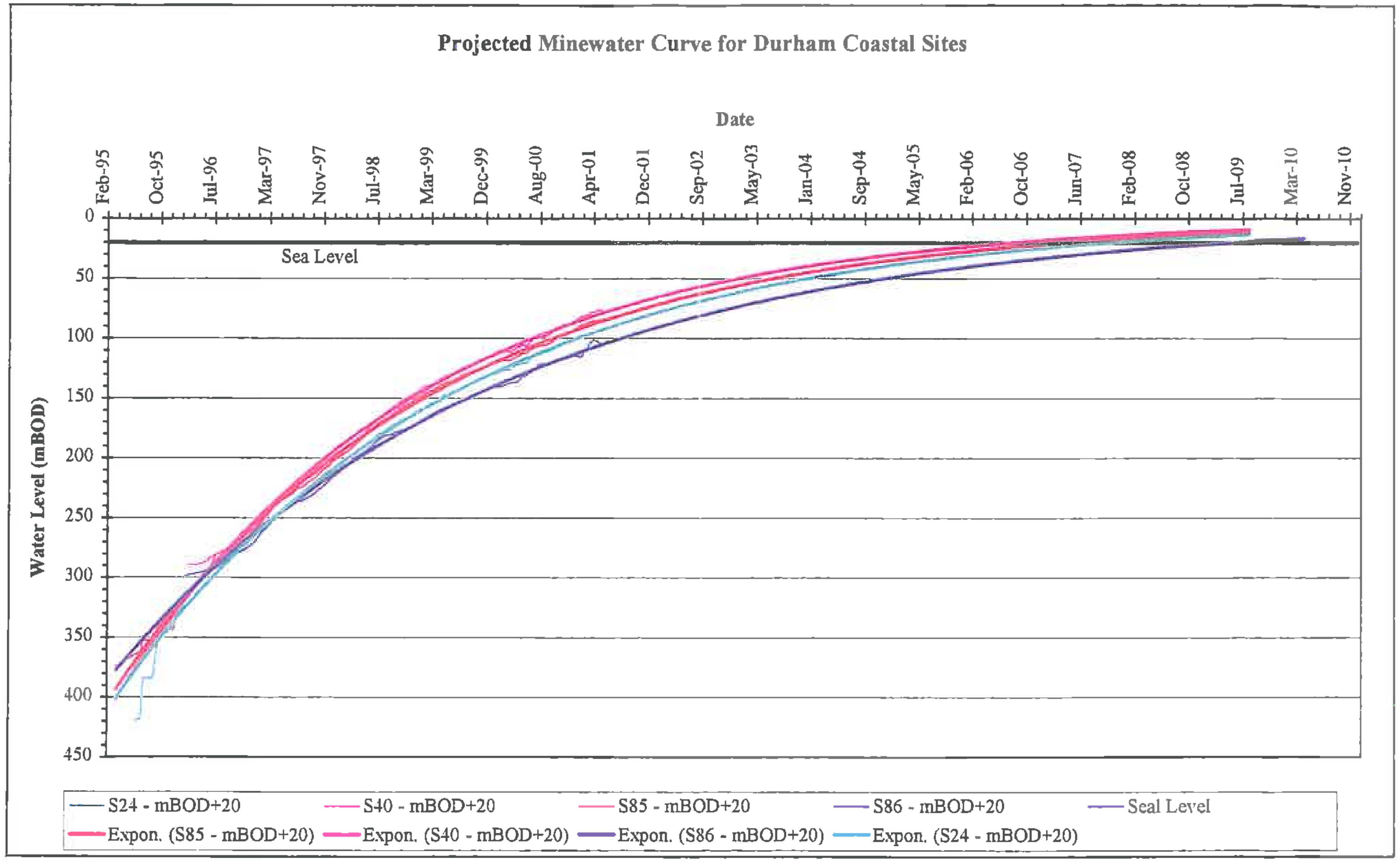
FIGURE 15

PROJECTED MINE WATER RECOVERY CURVES AT HORDEN, DAWDON, EASINGTON AND HAWTHORN (MAXIMUM RECOVERY PERIOD)



PROJECT	Options for the Control of Minewater East of the River Wear - The Coal Authority 7208	ENGINEER KRW	IMC
TITLE	Projected Minewater Recovery curves at Horden, Dawdon, Easington and Hawthorn (maximum recovery period)	TRACED BY JG	
		CHECKED BY	DATE AUGUST 2001
		APPROVED BY	DRG. No. Figure 15

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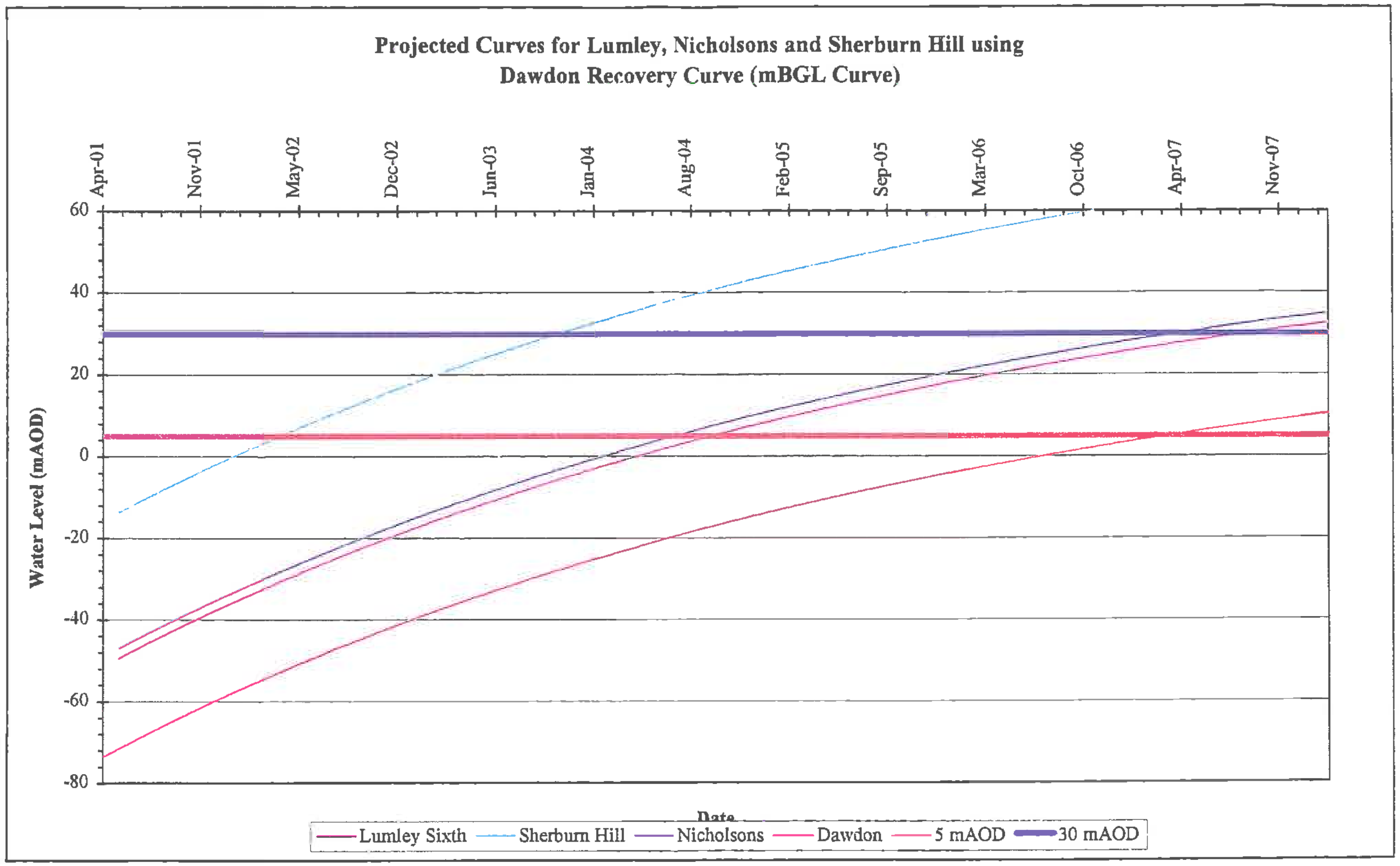
FIGURE 16

PROJECTED MINE WATER RECOVERY CURVES FOR LUMLEY 6TH, NICHOLSONS AND SHERBURN HILL BASED ON THE RATE OF RECOVERY AT THE COASTAL PITS (DAWDON)



PROJECT	Options for the Control of Minewater East of the River Wear - The Coal Authority 7208	ENGINEER KRW
TITLE	Projected Minewater Recovery curves for Lumley 6th, Nicholsons and Sherburn Hill based on the rate of recovery at the coastal pits (Dawdon)	TRACED BY JG
		CHECKED BY
		APPROVED BY

IMC

DATE AUGUST 2001

DRG. No. Figure 16

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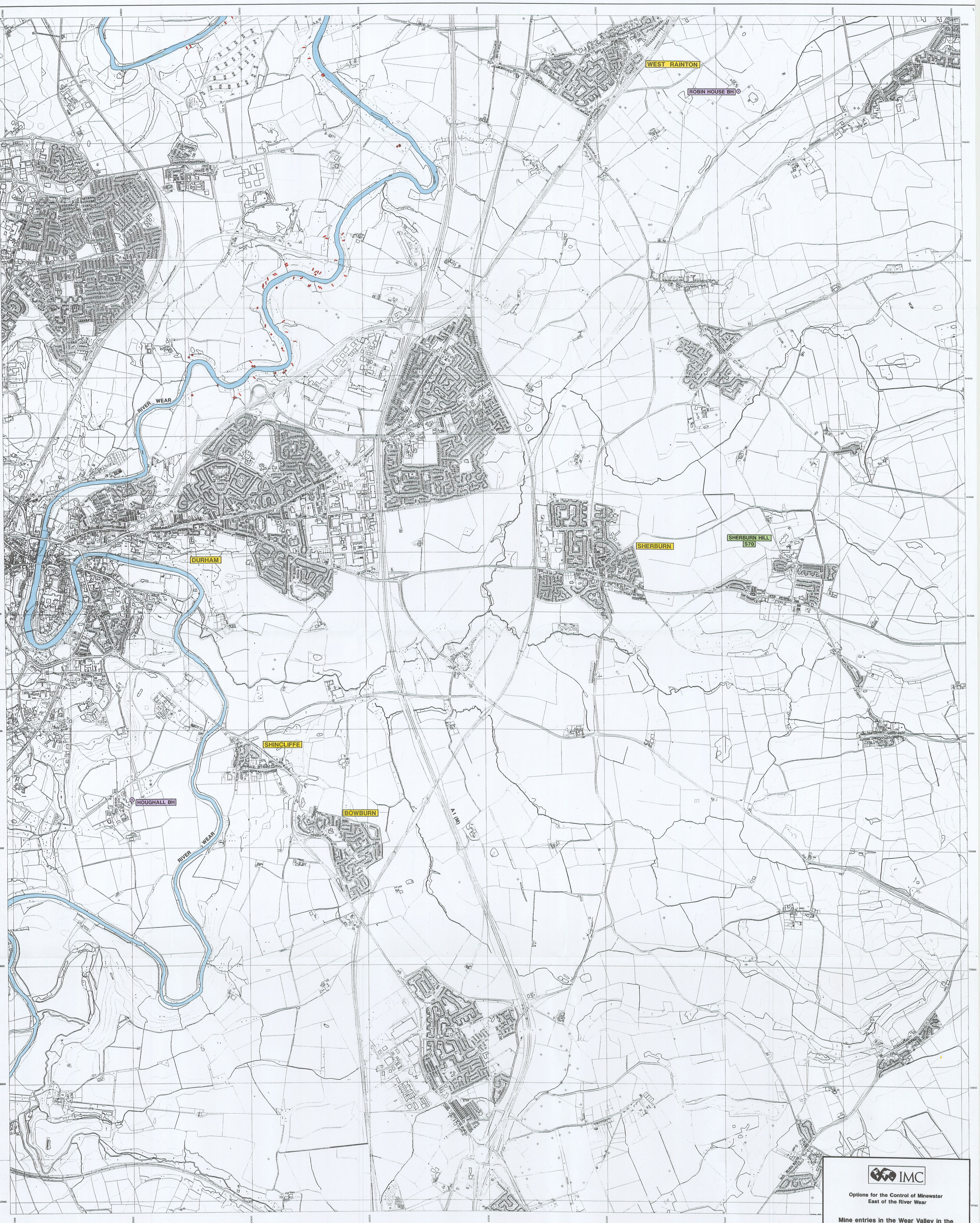
FIGURE 17

MINE ENTRIES IN THE WEAR VALLEY IN THE SOUTHERN PART OF THE STUDY AREA



COAL AUTHORITY MINING FEATURES CHECK PLOT
Scale: 1:10000

0.0 100.0 200.0 300.0 400.0 500.0 600.0 700.0 800.0
Metres

N

USER: interprd DATE: 16/JUL/2001 TIME: 14:03

IMC

Options for the Control of Minewater East of the River Wear

Mine entries in the Wear Valley in the southern part of the study area

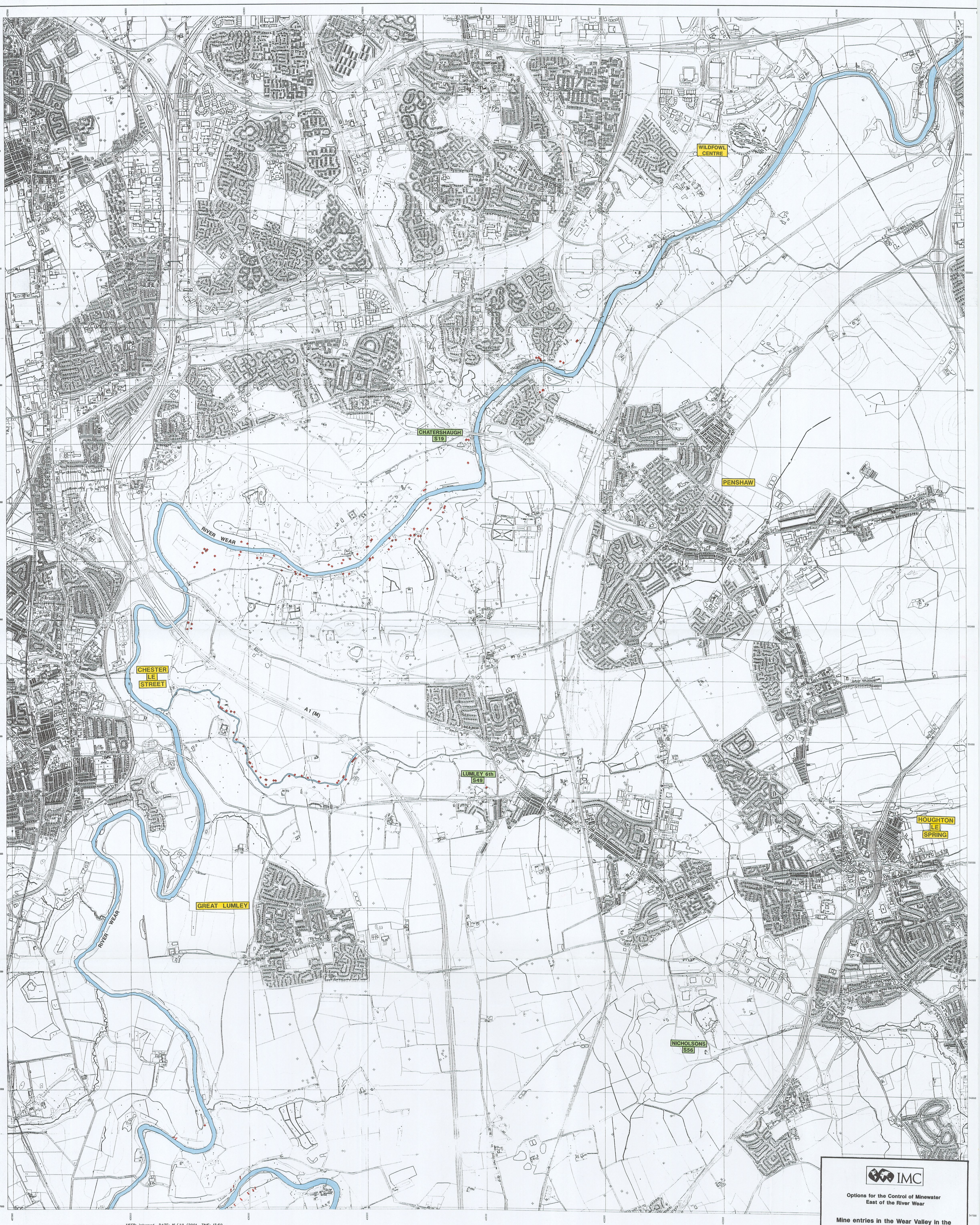
Scale 1:10,000

August 2001

Figure 17

FIGURE 18

MINE ENTRIES IN THE WEAR VALLEY IN THE NORTHERN PART OF THE STUDY AREA



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Options for the Control of Minewater
East of the River Wear

Mine entries in the Wear Valley in the northern part of the study area

Scale 1:10,000

August 2001

Figure 18

COAL AUTHORITY MINING FEATURES CHECK PLOT

Scale: 1:10000

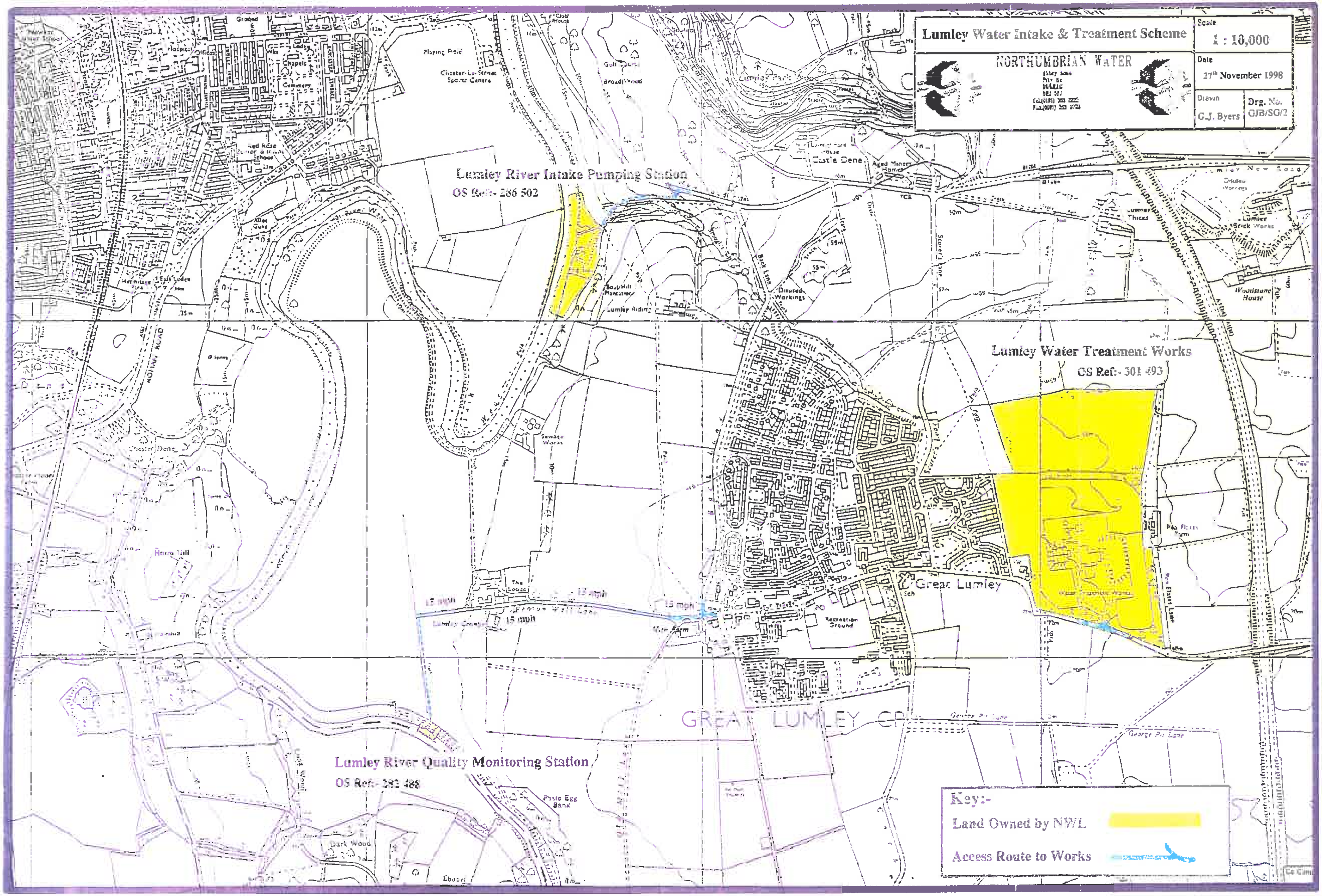
0.0 100.0 200.0 300.0 400.0 500.0 600.0 700.0 800.0
Metres

N

USER: interprd DATE: 16/JUL/2001 TIME: 13:59

FIGURE 19

NORTHUMBRIAN WATER RIVER WEAR ABSTRACTION SITE AT LUMLEY



PROJECT	Options for the Control of Minewater East of the River Wear - The Coal Authority 7208	ENGINEER KRW	IMC
TITLE	Northumbrian Water River Wear Abstraction site at Lumley	TRACED BY JG	
		CHECKED BY	DATE AUGUST 2001
		APPROVED BY	DRG. No. Figure 19

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APPENDIX A

FLUID CONDUCTIVITY; TEMPERATURE AND FLOW LOGS FOR SHERBURN HILL, DAWDON, EASINGTON, HORDEN, HAWTHORN AND NICHOLSONS

Factual Report

On the Geophysical Logging of 6 Mine Shafts

In County Durham

For International Mining Consultants

JN: 98534

Status	Prepared	Date	Checked	Date	Approved	Date
Factual Report	HCB	08/02/00	[signature]	08/02/00	[signature]	08/02/00

Introduction

Six mine shafts were geophysically logged between 24–28 January 2000. The Shafts were located in various sites in east County Durham.

The shafts were logged with a	temperature / conductivity tool (9042)
	Impeller Flow meter (9710)
And water samples were taken	Wire-line 1litre water sampler (9751)

The specifications for these tools can be found in appendix A

The shafts investigated were: Dawdon
Easington South
Hawthorne
Hordon South
Nicholson
Sherburn Hill

The shafts varied in depth between 550m (Dawdon) and 150m (Nicholson). None of the shafts were logged to full depth as installations and possible debris in the base of the shaft made this inadvisable. The depth of investigation was based on the IMC Geophysicist's decision in relation to the construction plans of each shaft.

1.5litre water samples were collected for each shaft excluding Easington and Nicholson where no water samples were taken. The depth and frequency of the sampling was based on IMC geophysicist's decision in relation to the information provided by the temp/cond and flow logs.

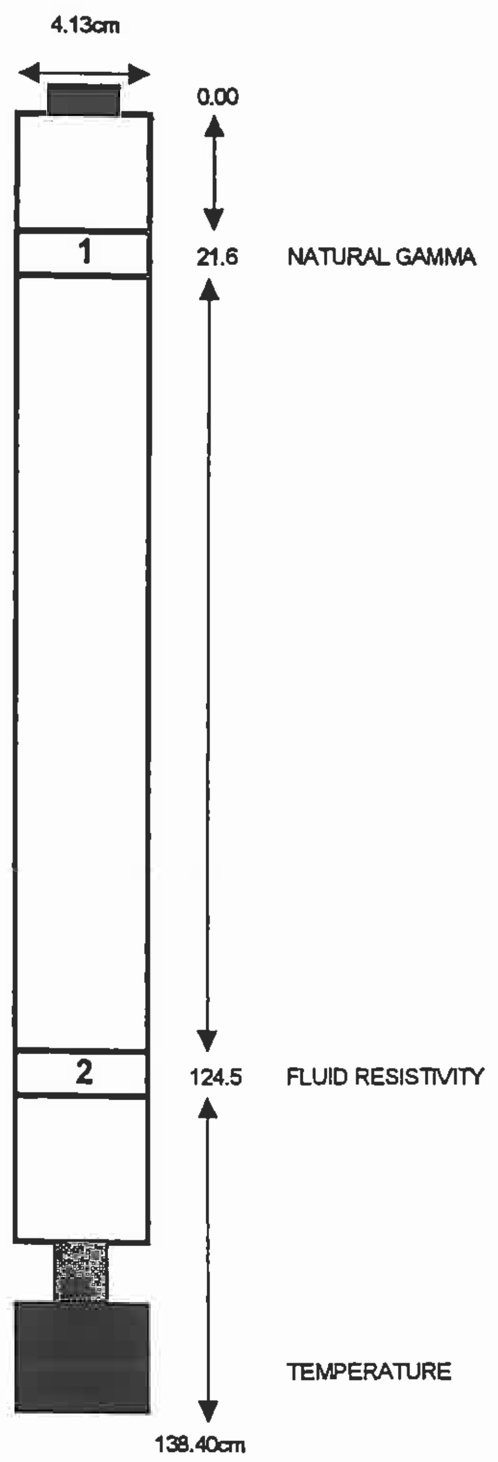
All the shafts had been left at least 24hrs before the geophysical logging was undertaken with the exception of Nicholson, which had been pumped 2 hours before.

Schedule

T/C Temperature Conductivity sonde
Flow Impeller Flow
WS Water Sample

Shaft	Shaft depth	Water Depth	Tool	Date Logged	Log/Sample depth	Comments
Sherburn Hill	250m	110m	T/C	24/01/00	230.22m	
			Flow	25/01/00	230.12m	
			WS 1	24/01/00	125.30m	
			WS 2	25/01/00	150.50m	
Dawdon	550m	140m	T/C	25/01/00	520.10m	
			Flow	25/01/00	520.10m	
			WS 3	25/01/00	510.30m	Sample came out as thick coaly slurry
			WS 4	25/01/00	164.70m	
			WS 5	26/01/00	470.10m	
			WS 6	26/01/00	383.20m	
			WS 7	26/01/00	310.20m	
Hawthorne	455m	247m	T/C	26/01/00	430.12m	
			Flow	26/01/00	430.02m	
			WS 8	26/01/00	390.30m	
			WS 9	27/01/00	350.20m	
			WS 10	27/01/00	290.10m	
			WS 11	27/01/00	255.10m	1Litre only
Hordon South	439m	157m	T/C	27/01/00	416.12m	Probe got stuck at 400m.
			Flow	27/01/00	390.23m	
			WS 12	27/01/00	380.20m	
			WS 13	27/01/00	350.20m	
			WS 14	27/01/00	180.10m	1Litre only
Easington	460+m	162m	T/C	28/01/00	460.09m	
			Flow	28/01/00	460.01m	
Nicholson	150m	117m	T/C	28/01/00	141.52m	
			Flow	28/01/00	143.57m	

9042 LOGGING TOOL



9042 TEMPERATURE, CONDUCTIVITY LOGGING TOOL

BACKGROUND INFORMATION

The 9042 logging tool is a multi-parameter geophysical tool primarily used for water well logging and monitoring wells. The tool records five different parameters simultaneously in one pass of the borehole. The five parameters are the following: natural gamma, fluid resistivity, specific conductivity, and temperature and differential temperature. The tool is run in open hole applications and can also be used in boreholes lined with slotted plastic casing.

FEATURES

TOOL SPECIFICATIONS

Length : 139 cm (55 in)

Diameter : 4.13 cm (1.625 in)

Weight : 10 Kg (22 pounds)

Temperature : 90 C (194 F)

Pressure : 232 Kg/cc (3300 psi)

Logging Speed : 9 m/min (30 ft/min)

SENSOR RESPONSE RANGES

Sensor	Response Limits	Accuracy
Natural Gamma	0 to 10,000 api units	+/- 5%
Fluid Resistivity	0 to 100 ohm metres	+/- 5%
Temperature	0 to 50 degrees Celsius	+/-.25 C

ACCESSORIES

Not required

9710 LOGGING TOOL

9710 FLOWMETER LOGGING TOOL

BACKGROUND INFORMATION

The continuous velocity flowmeter logs are used to measure the fluid flow rates in open and cased wells. Logs are run in both the up and down direction. The probe uses a magnetic coupling between the sensing device and the electronics so that the borehole fluids can not enter the tool and injected oil is no longer necessary. Internally, a 256 pulse per revolution optical encoder records the impeller turns minimising statistical problems of other tools.

The 9710 logging tool can be used in open hole applications where borehole diameters are in excess of 12 cms, or in boreholes which are cased with slotted plastic.

FEATURES

TOOL SPECIFICATIONS

Length : 178 cm (70 in)

Cage Diameter : 11.4 cm (4.5 in)

Weight : 8 Kg (18 pounds)

Temperature : 75 C (167 F)

Pressure : 176 Kg/cm2 (2500 psi)

Logging Speed : .15 – 18 m/min (2 – 60 ft/min)

SENSOR RESPONSE RANGES

Sensor	**Response Limits**	**Accuracy**
Flow	2 to 200 ft/min	+/- 5%

ACCESSORIES

Allen key for cage removal

B.E.L. GEOPHYSICAL LTD

GEOLOG OUTPUT

Dawdon

MPANY	: IMC	OTHER SERVICES:			
WELL	: Dawdon	none			
CATION/FIELD	: Durham	None			
UNTY	: Northumbria	None			
STATE	: None				
CTION	: None	SCALE	: 1:500	RANGE	: None
TE	: 01/25/00	PERMANENT DATUM	: None		
PTH DRILLER	:			KB	: None
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G TOP	: 0.20	DRL MEASURED FROM:	None	GL	: None
CASING DIAMETER	:	LOGGING UNIT	: CENT		
SING TYPE	: PLASTIC	FIELD OFFICE	: TRANS		
SING THICKNESS:	0.5	RECORDED BY	: HCB/AW		
T SIZE	: 11.00	BOREHOLE FLUID	: H20	FILE	: ORIGINAL
GNETIC DECL.	: -6	RM	: 0	TYPE	: 9042C
MATRIX DENSITY	: 2.71	RM TEMPERATURE	: 0		
UTRON MATRIX	: Limestone	MATRIX DELTA T	: 140		
				THRESH:	2500
G TYPE	: 0.00=Installation top				
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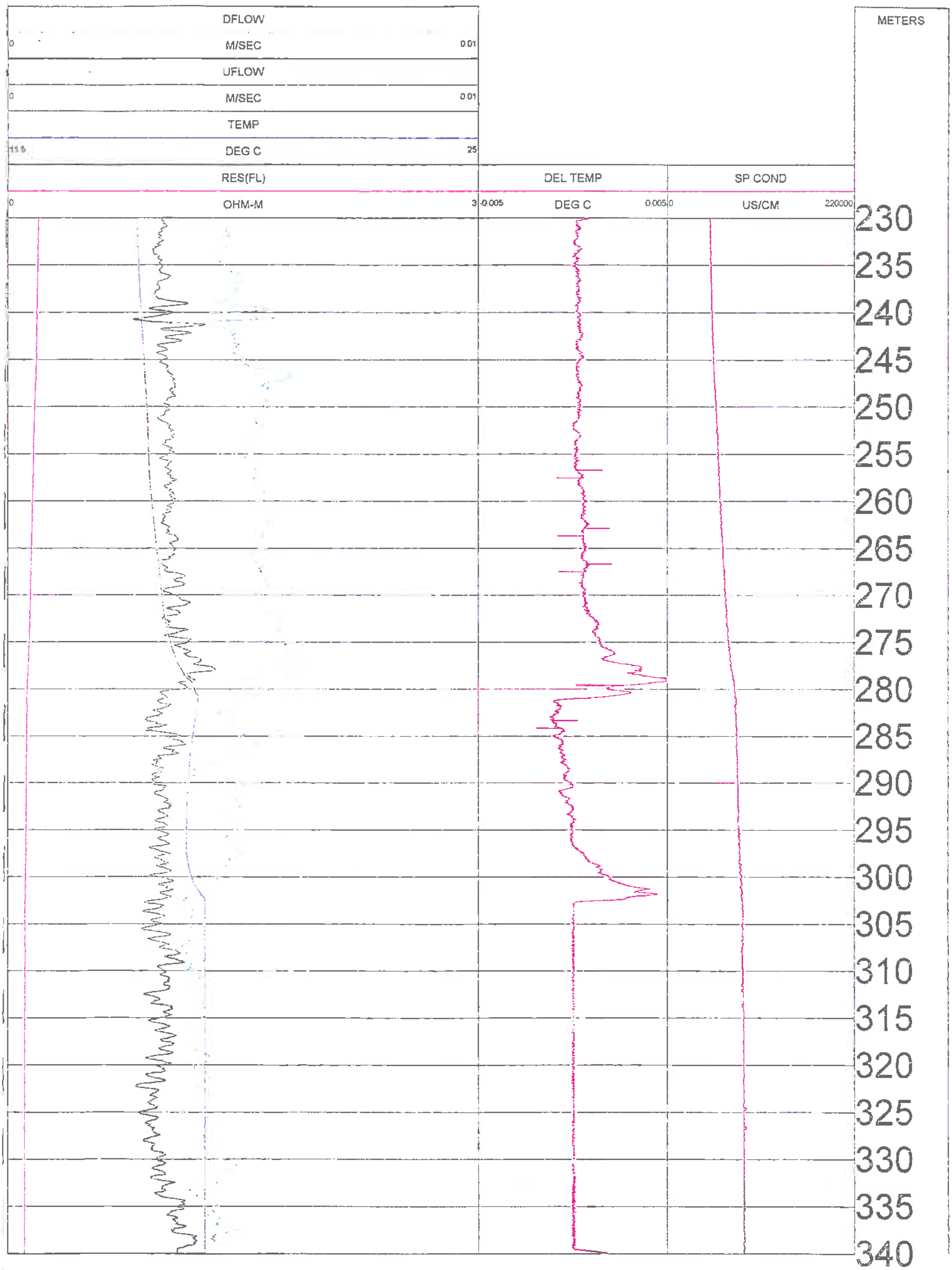

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SP COND
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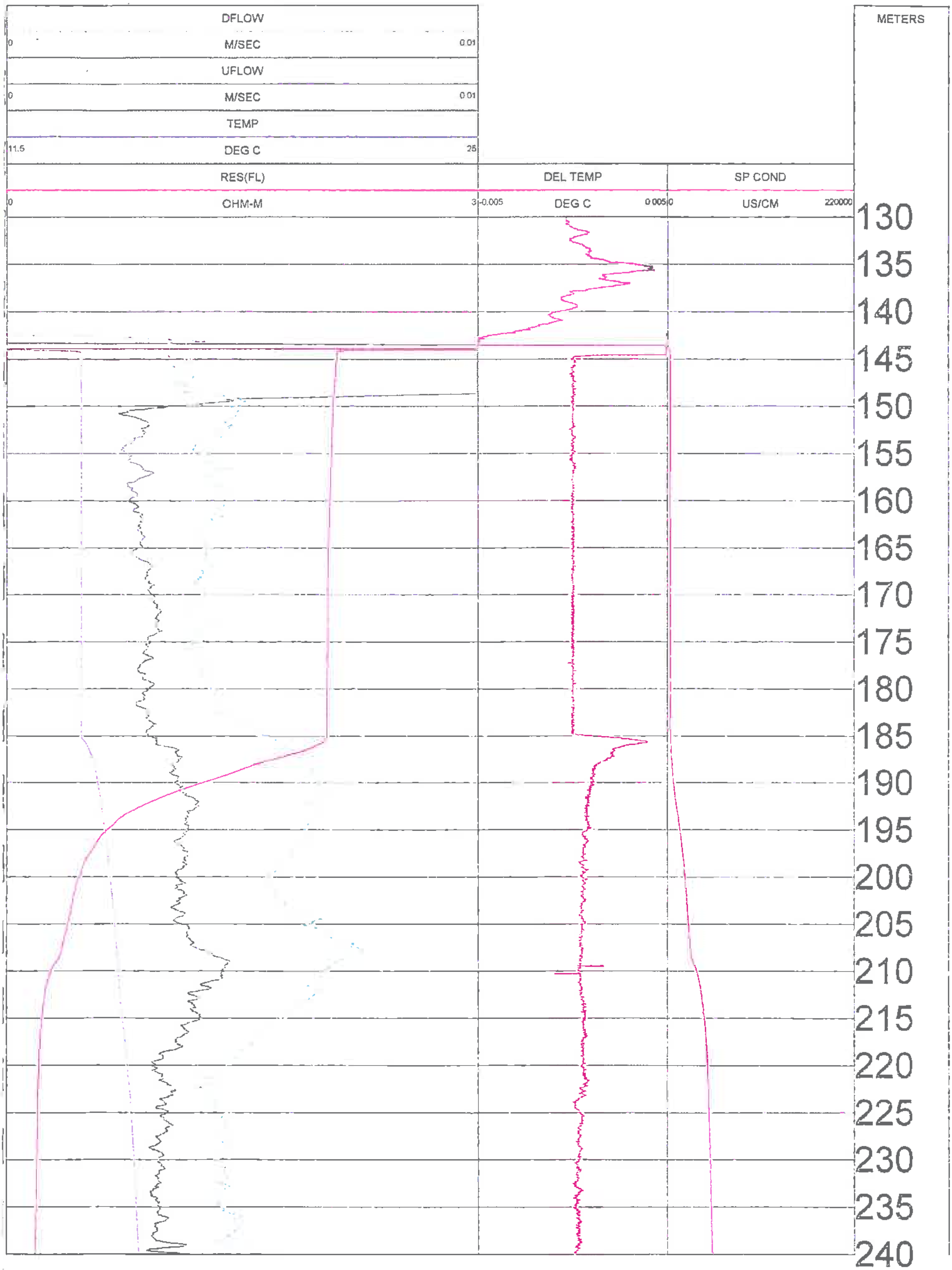

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SP COND
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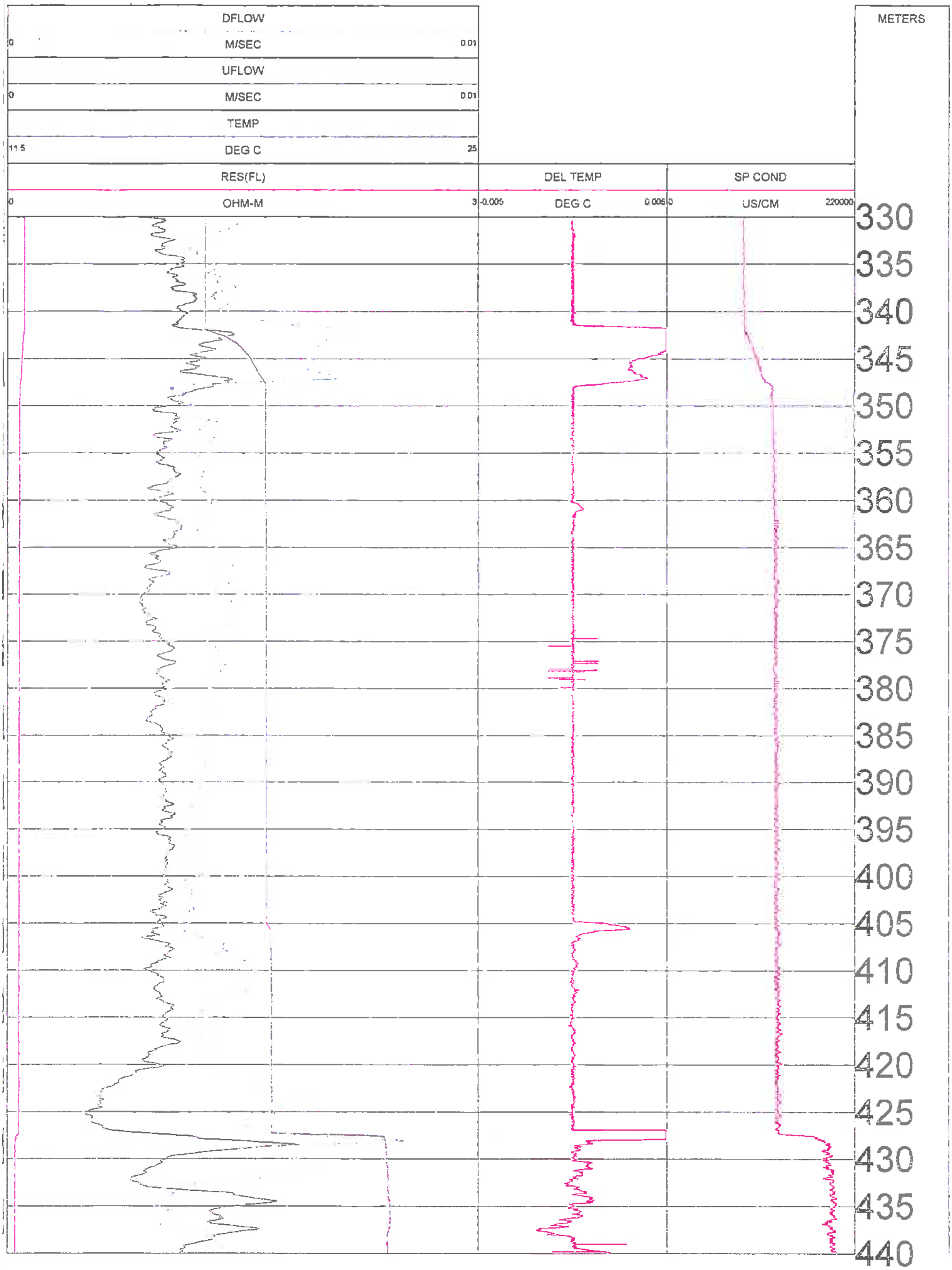

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M/SEC
0.01
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DEG C
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RES(FL)
0
OHM-M
3
DEL TEMP
-0.005
DEG C
0.005
SP COND
0
US/CM
220000
METERS
330
335
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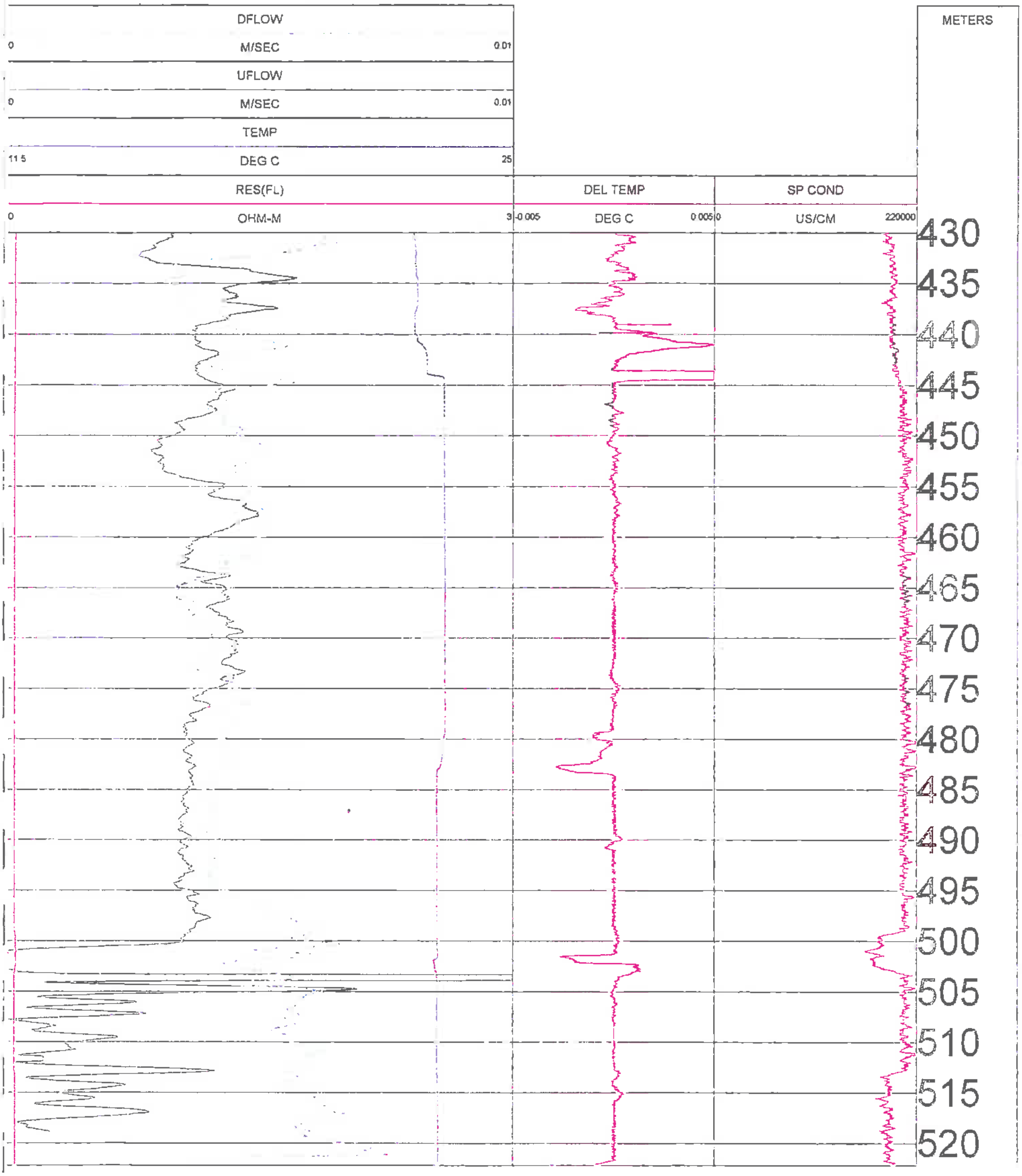
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METERS
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475
480
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490
495
500
505
510
515
520

B.E.L. GEOPHYSICAL LTD

GEOLOG OUTPUT

Easington South

OMPANY	: IMC			OTHER SERVICES:	
WELL	: Easington South			none	
CATION/FIELD	: Durham			None	
COUNTY	: Northumbria			None	
STATE	: None				
ECTION	: None	SCALE	: 1:500	RANGE	: None
ATE	: 01/28/00	PERMANENT DATUM	: None		
EPTH DRILLER	:			KB	: None
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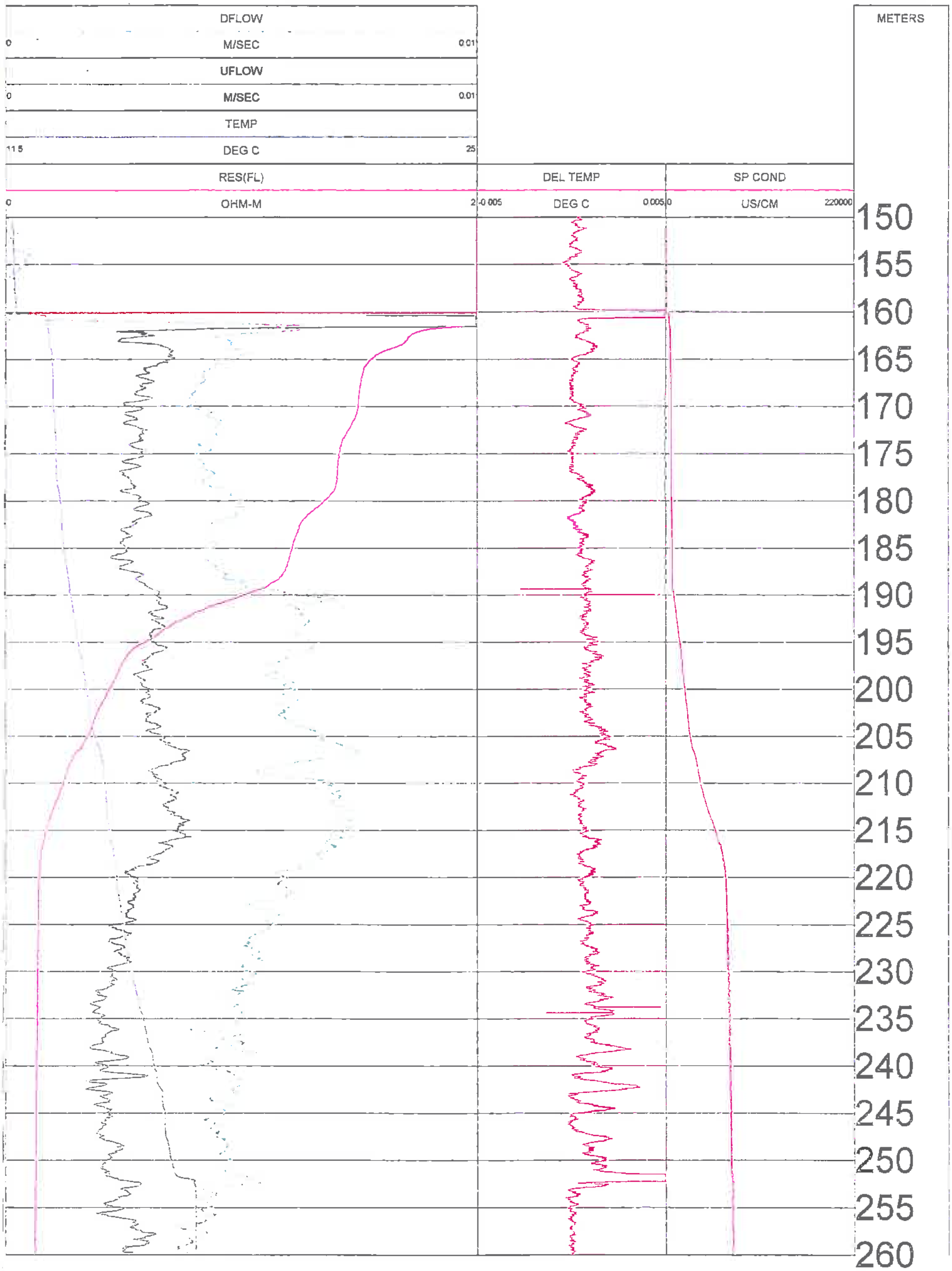
OG TOP	: 0.20	DRL MEASURED FROM:	None	GL	: None
CASING DIAMETER	:	LOGGING UNIT	: CENT		
ASING TYPE	: PLASTIC	FIELD OFFICE	: TRANS		
ASING THICKNESS:	0.5	RECORDED BY	: HCB/AW		
T SIZE	: 11.00	BOREHOLE FLUID	: H20	FILE	: ORIGINAL
AGNETIC DECL.	: -6	RM	: 0	TYPE	: 9042C
MATRIX DENSITY	: 2.71	RM TEMPERATURE	: 0		
EUTRON MATRIX	: Limestone	MATRIX DELTA T	: 140		
				THRESH:	2500

OG TYPE : 0.00=Installation top
None

ALL SERVICES PROVIDED SUBJECT TO STANDARD TERMS AND CONDITIONS



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RES(FL)
0 OHM-M 2
DEL TEMP
-0.005 DEG C 0.005
SP COND
0 US/CM 220000
METERS
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155
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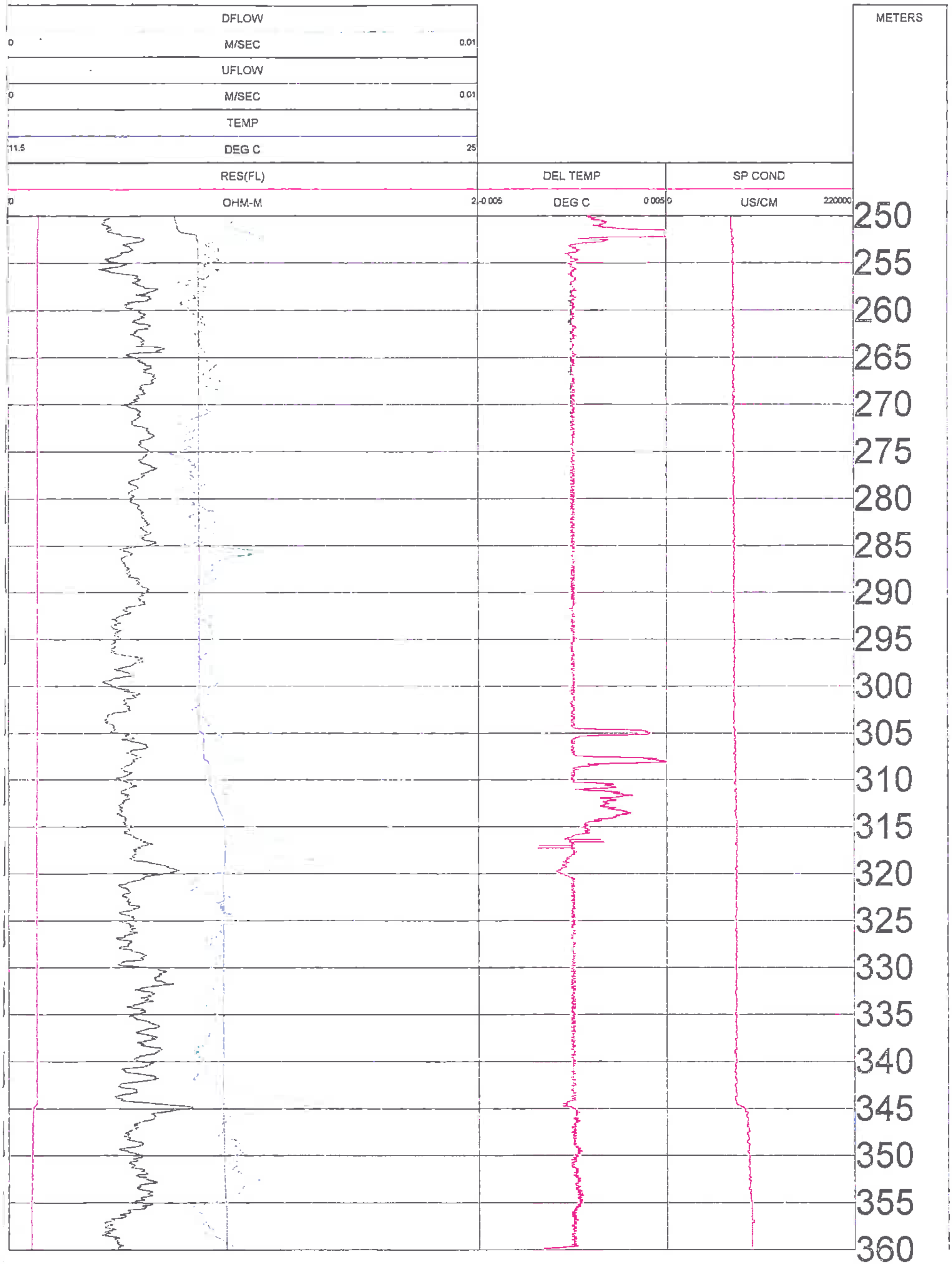
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RES(FL)
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OHM-M
2
DEL TEMP
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DEG C
0.005
SP COND
0
US/CM
220000
METERS
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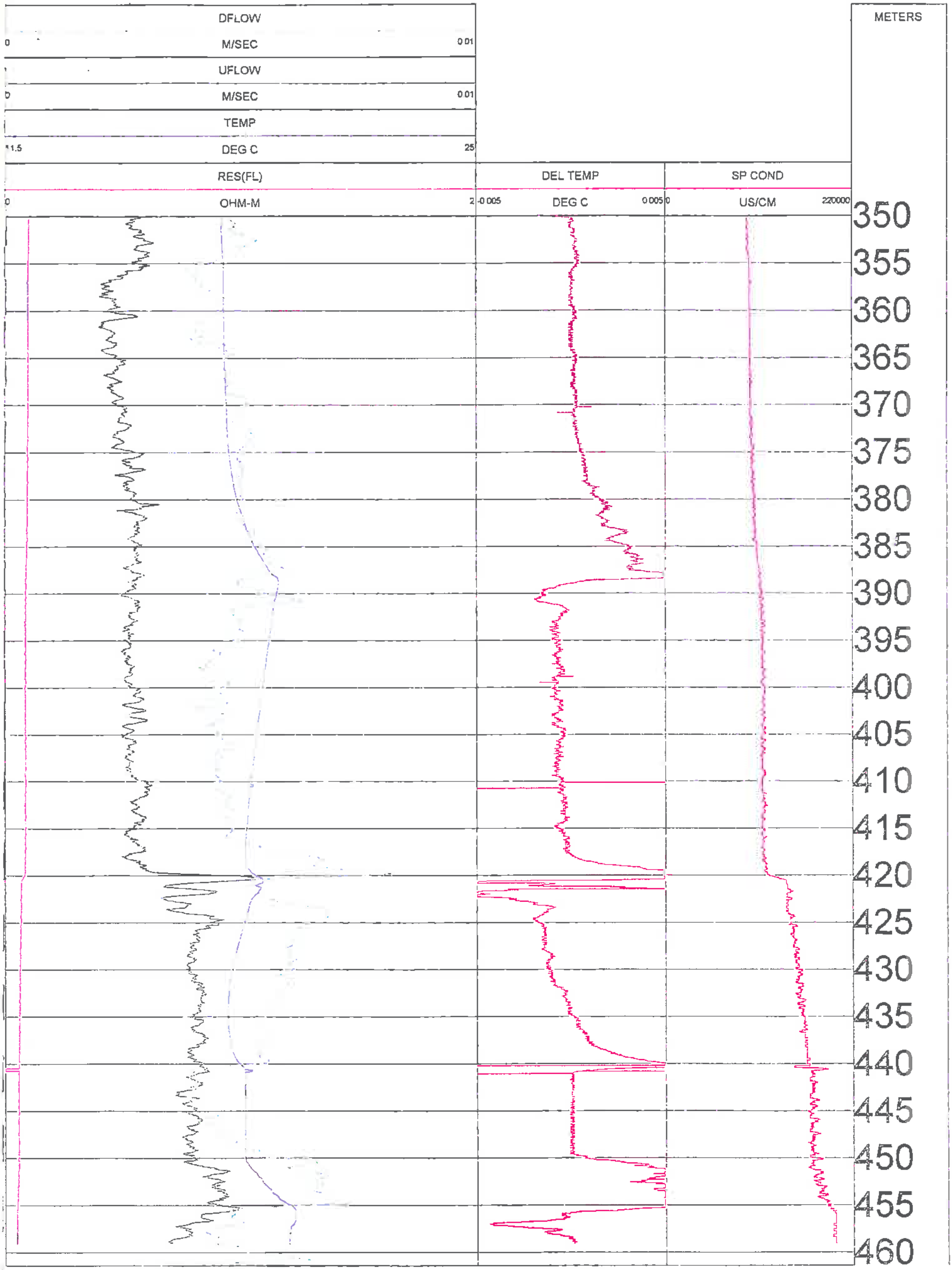
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DEL TEMP
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SP COND
0 US/CM 220000
METERS
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395
400
405
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415
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445
450
455
460

B.E.L. GEOPHYSICAL LTD

GEOLOG OUTPUT

Hawthorne

MPANY	: IMC			OTHER SERVICES:	
WELL	: Hawthorne			none	
CATION/FIELD	: Durham			None	
COUNTY	: Northumbria			None	
STATE	: None				
CTION	: None	SCALE	: 1:500	RANGE	: None
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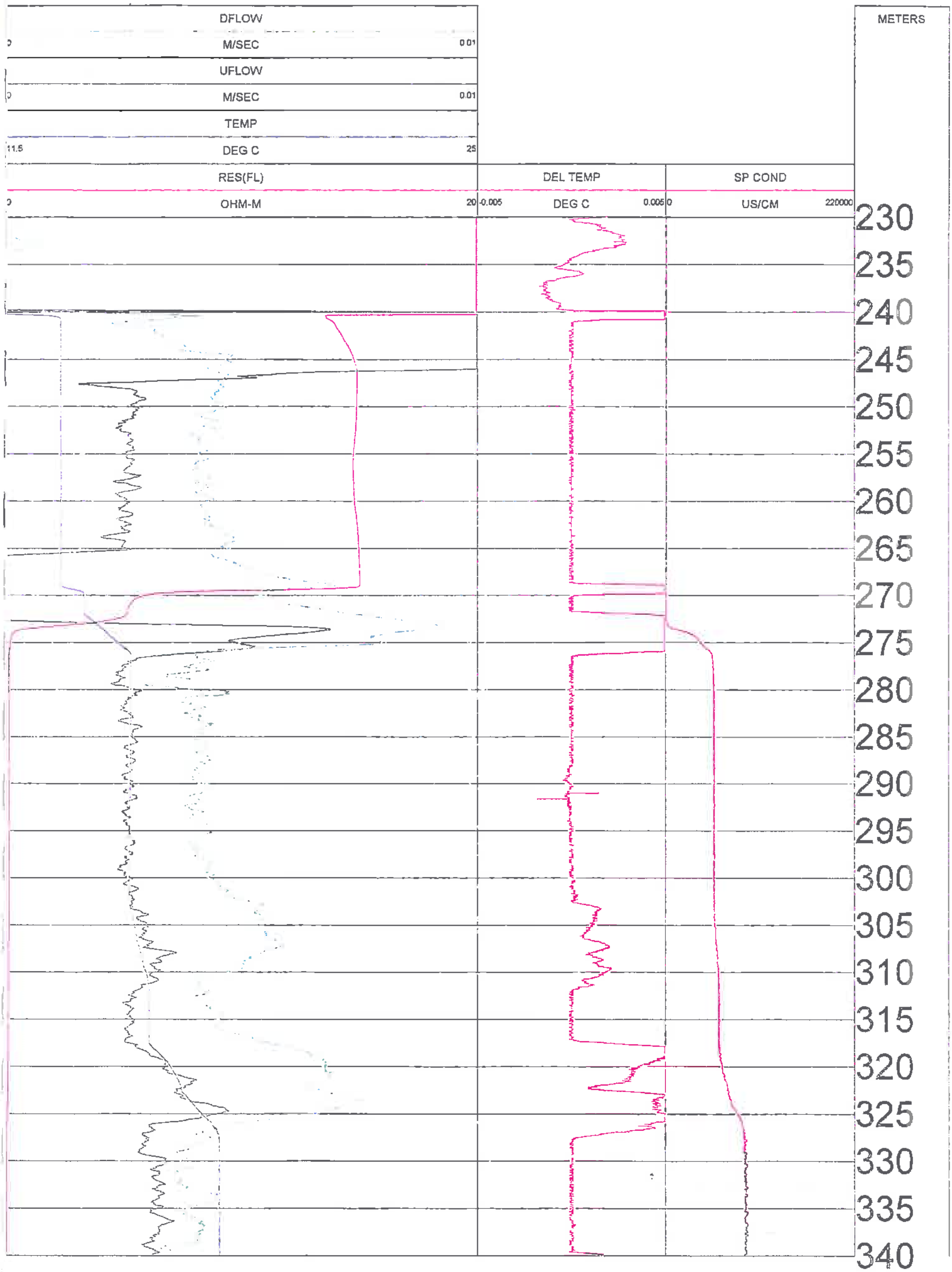
SING THICKNESS:	0.5	RECORDED BY	: HCB/AW		
T SIZE	: 11.00	BOREHOLE FLUID	: H20	FILE	: ORIGINAL
MAGNETIC DECL.	: -6	RM	: 0	TYPE	: 9042C
MATRIX DENSITY	: 2.71	RM TEMPERATURE	: 0		
EUTRON MATRIX	: Limestone	MATRIX DELTA T	: 140		
				THRESH:	2500

OTES : 0.00=Installation top
PLEASE NOTE SCALE CHANGE IN RES(FL) FROM PAGE 2

ALL SERVICES PROVIDED SUBJECT TO STANDARD TERMS AND CONDITIONS



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SP COND
0 US/CM 220000
METERS
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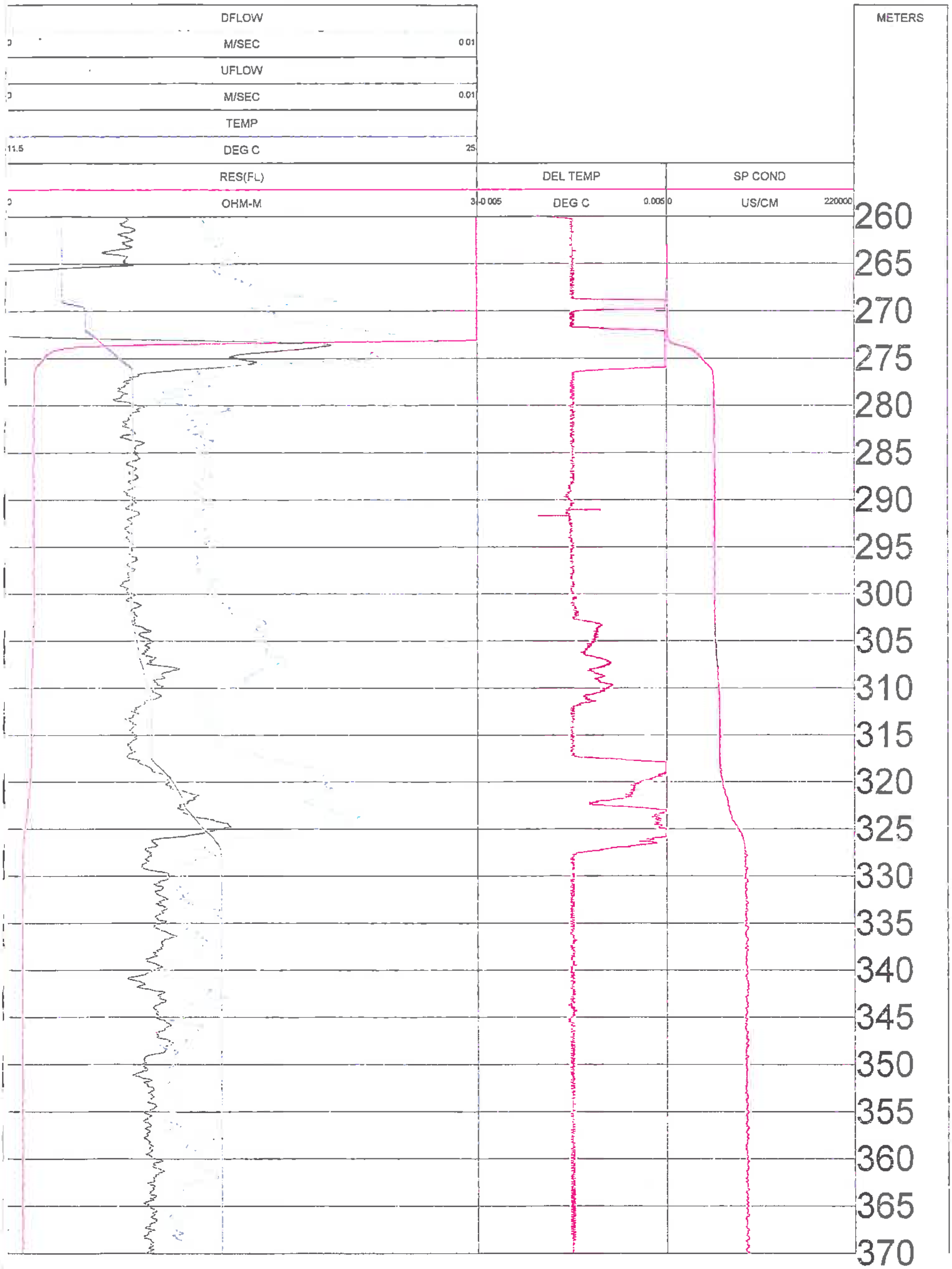
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RES(FL)
OHM-M
DEL TEMP
DEG C
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0.005
SP COND
US/CM
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220000
METERS
260
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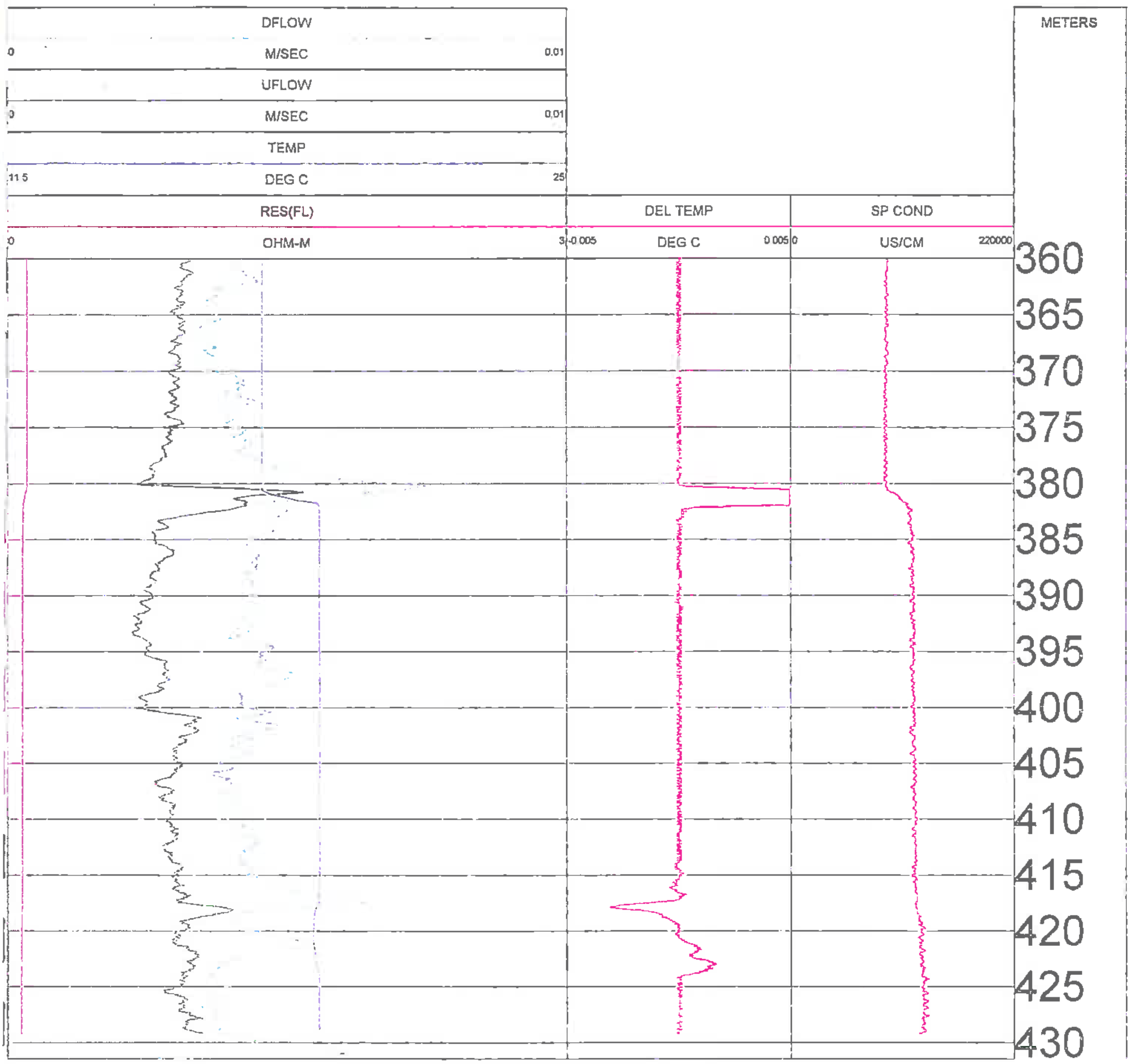
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OHM-M
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DEL TEMP
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DEG C
0.005
SP COND
0
US/CM
220000
METERS
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375
380
385
390
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400
405
410
415
420
425
430

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BG

GEOLOG OUTPUT

Hordon South

COMPANY	: IMC			OTHER SERVICES:	
WELL	: Hordon South			none	
LOCATION/FIELD	: Durham			None	
COUNTY	: Northumbria			None	
STATE	: None				
SECTION	: None	SCALE	: 1:500	RANGE	: None
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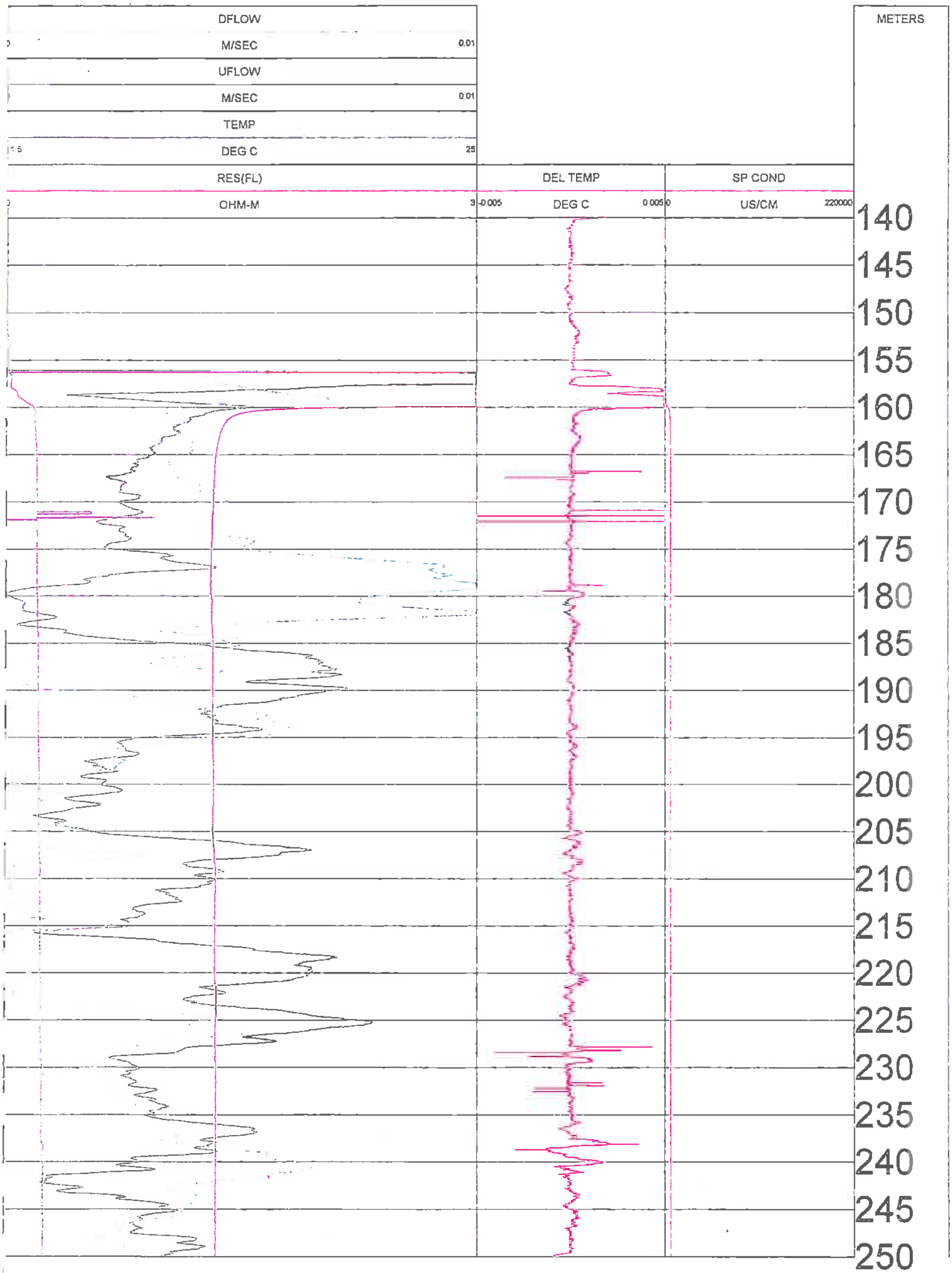
CASING TYPE	: PLASTIC	FIELD OFFICE	: TRANS		
CASING THICKNESS:	0.5	RECORDED BY	: HCB/AW		
BIT SIZE	: 11.00	BOREHOLE FLUID	: H20	FILE	: ORIGINAL
MAGNETIC DECL.	: -6	RM	: 0	TYPE	: 9042C
MATRIX DENSITY	: 2.71	RM TEMPERATURE	: 0		
NEUTRON MATRIX	: Limestone	MATRIX DELTA T	: 140		
				THRESH:	2500

NOTES : 0.00=Installation top
None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OHM-M
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DEL TEMP
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DEG C
0.005
0
SP COND
US/CM
220000
METERS
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145
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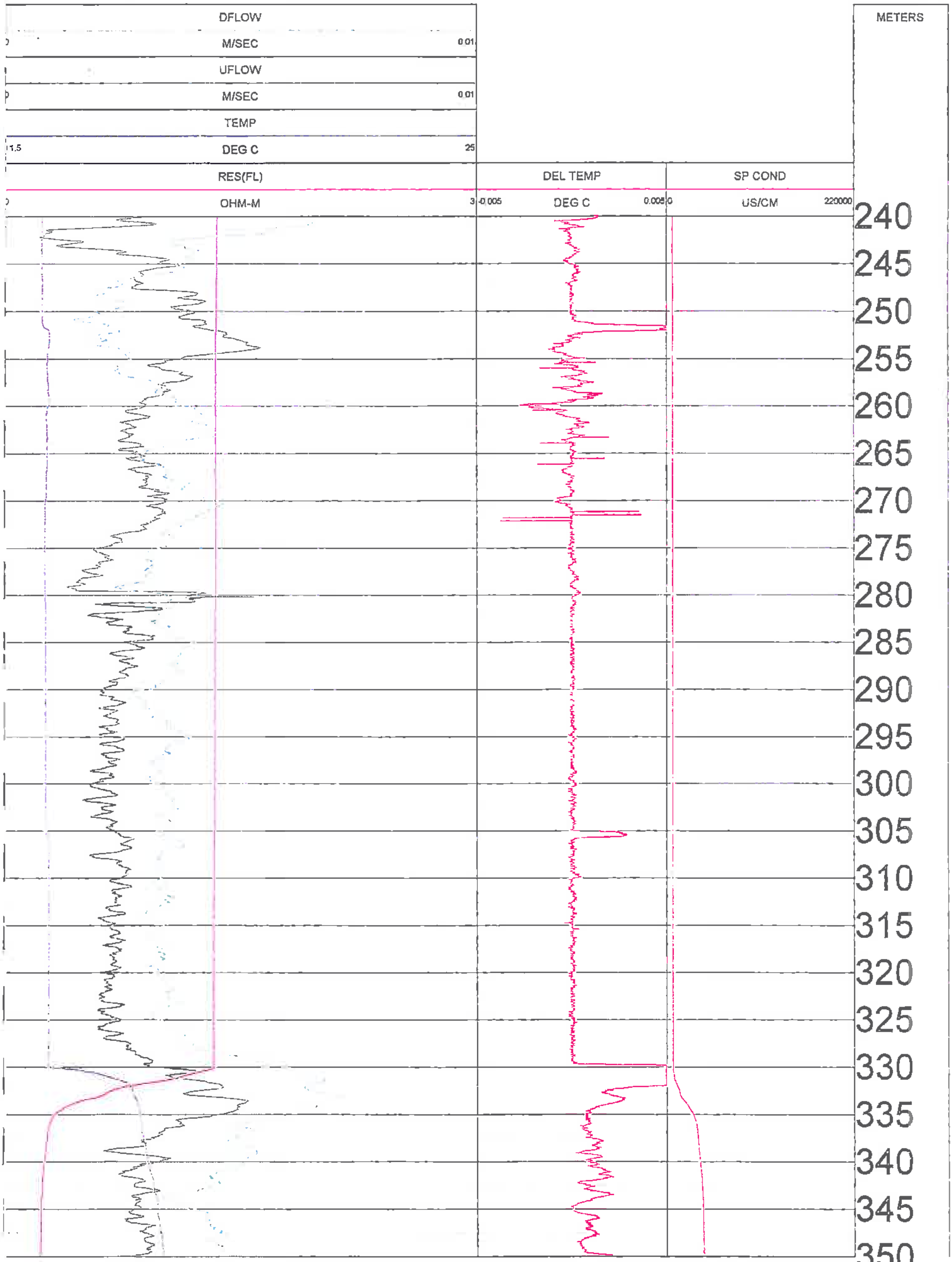

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SP COND
0 US/CM 220000
METERS
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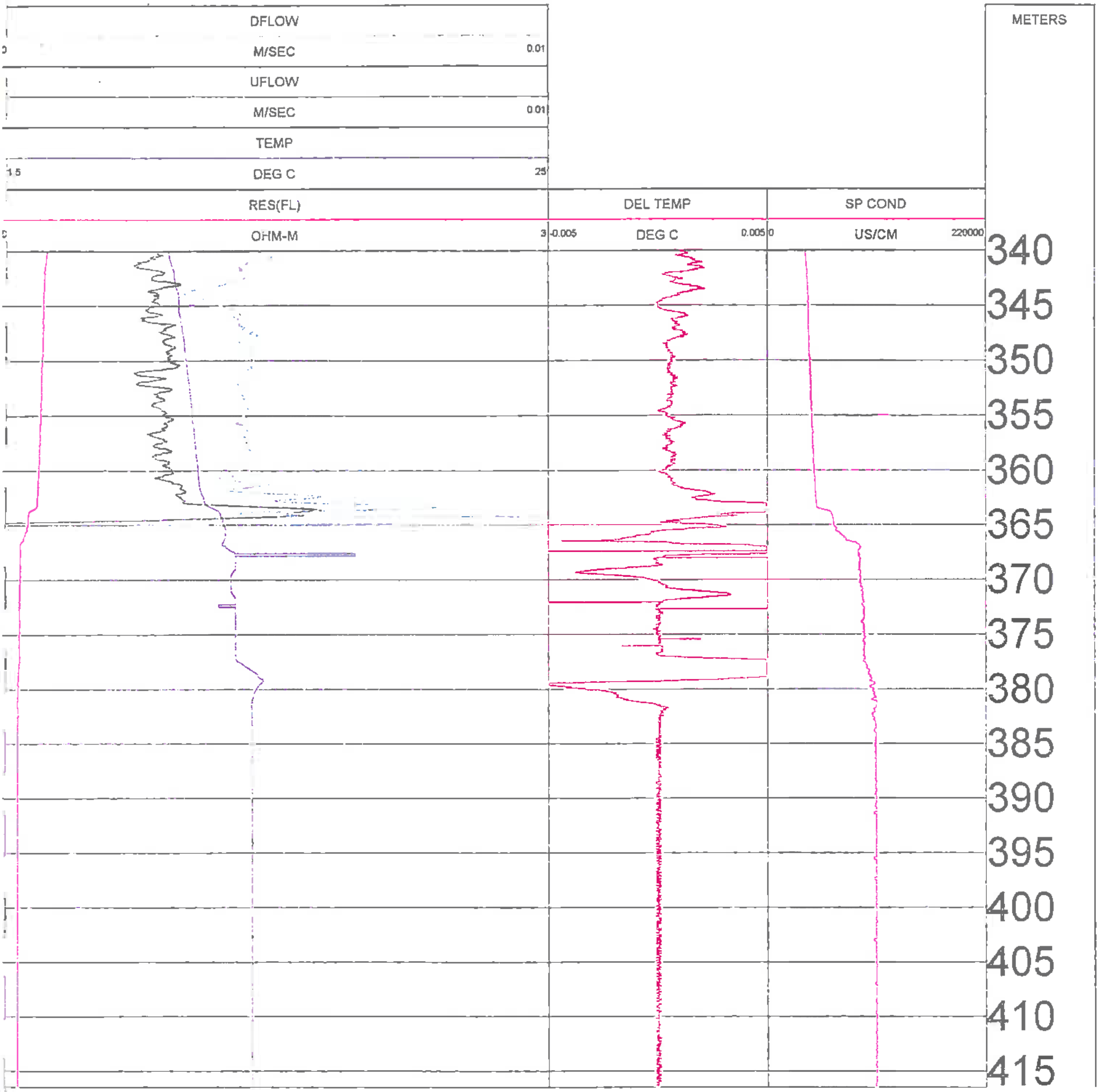

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OHM-M
3
DEL TEMP
DEG C
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0.005
SP COND
US/CM
0
220000
METERS
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410
415

BG

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GEOLOG OUTPUT

Nicholson

COMPANY	: IMC			OTHER SERVICES:	
WELL	: Nicholson			none	
LOCATION/FIELD	: Durham			None	
COUNTY	: Northumbria			None	
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CASING TYPE	: PLASTIC	FIELD OFFICE	: TRANS		
CASING THICKNESS:	0.5	RECORDED BY	: HCB/AW		
BIT SIZE	: 11.00	BOREHOLE FLUID	: H20	FILE	: ORIGINAL
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MATRIX DENSITY	: 2.71	RM TEMPERATURE	: 0		
NEUTRON MATRIX	: Limestone	MATRIX DELTA T	: 140		
				THRESH:	2500

NOTES : 0.00=Installation Top
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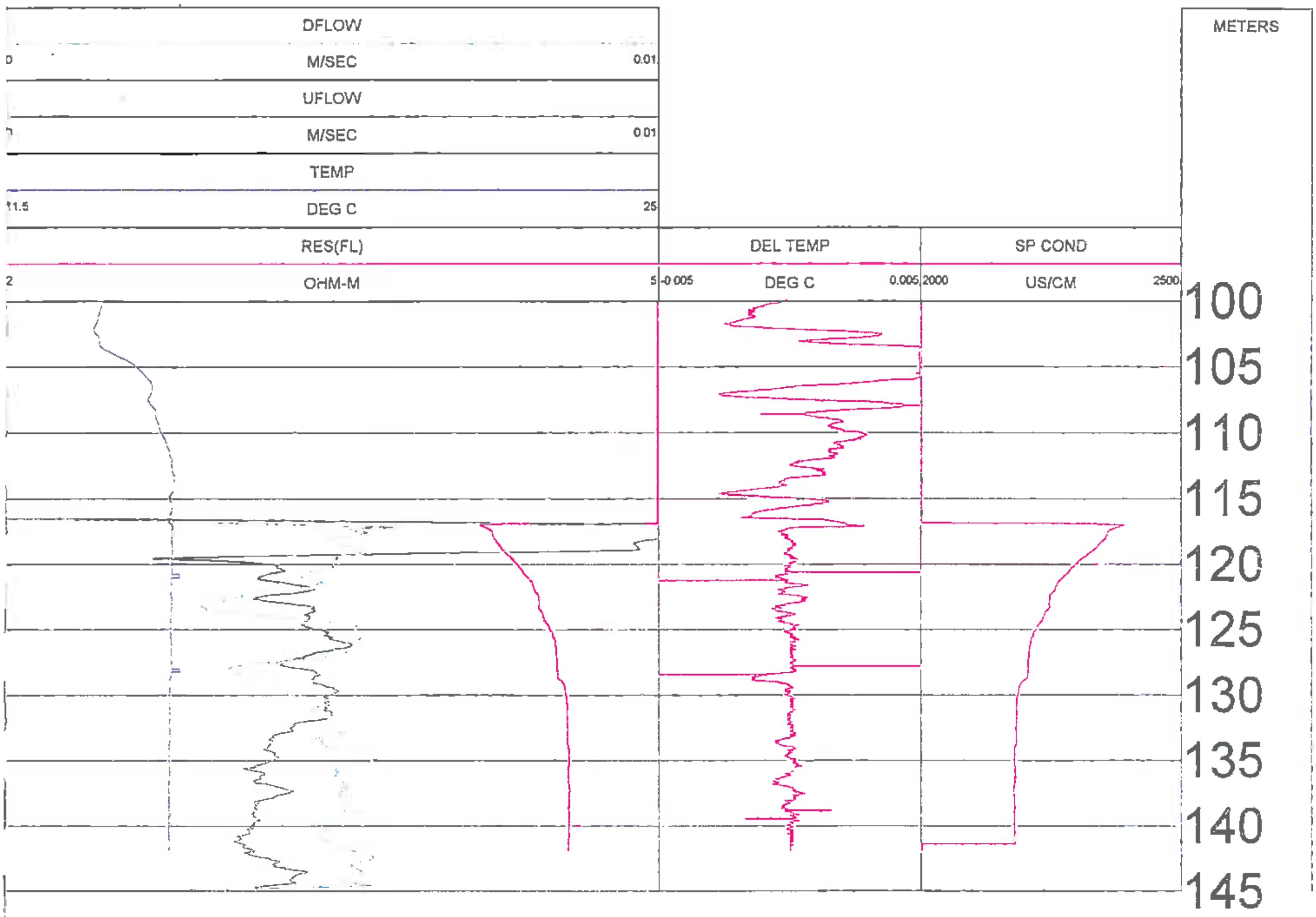
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2
OHM-M
5
DEL TEMP
-0.005
DEG C
0.005
SP COND
2000
US/CM
2500
METERS
100
105
110
115
120
125
130
135
140
145

B.E.L. GEOPHYSICAL LTD

GEOLOG OUTPUT

Sherburn Hill

COMPANY	: IMC			OTHER SERVICES:	
WELL	: Sherburn Hill			none	
CATION/FIELD	: Durham			None	
COUNTY	: Northumbria			None	
STATE	: None				
CTION	: None	SCALE	: 1:500	RANGE	: None
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SING TYPE	: PLASTIC	FIELD OFFICE	: TRANS		
SING THICKNESS:	0.5	RECORDED BY	: HCB/AW		
T SIZE	: 11.00	BOREHOLE FLUID	: H20	FILE	: ORIGINAL
MAGNETIC DECL.	: -6	RM	: 0	TYPE	: 9042C
MATRIX DENSITY	: 2.71	RM TEMPERATURE	: 0		
EUTRON MATRIX	: Limestone	MATRIX DELTA T	: 140		
				THRESH:	2500

OTES : 0.00=Installation top
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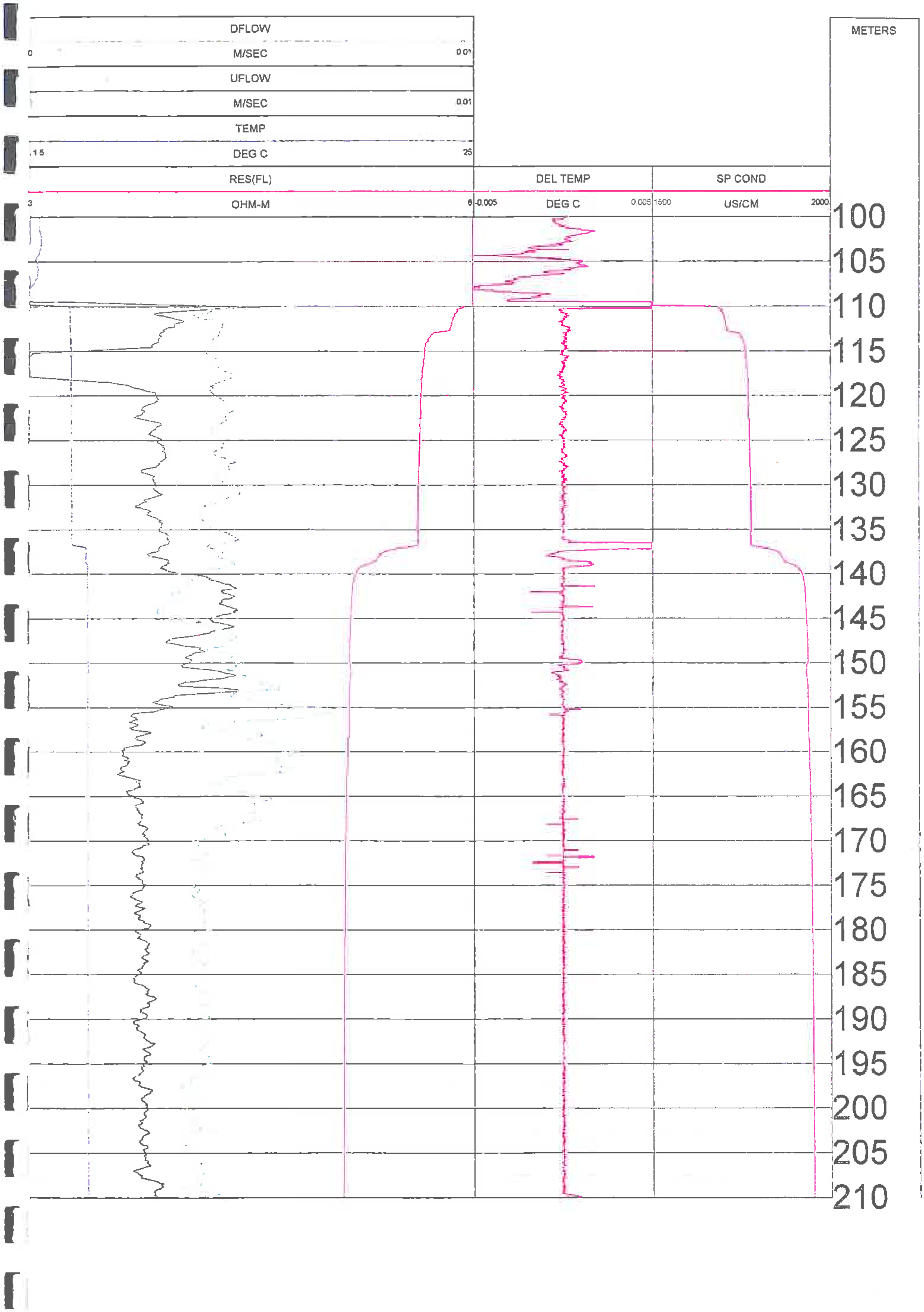
ALL SERVICES PROVIDED SUBJECT TO STANDARD TERMS AND CONDITIONS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SP COND
1500 US/CM 2000
METERS
100
105
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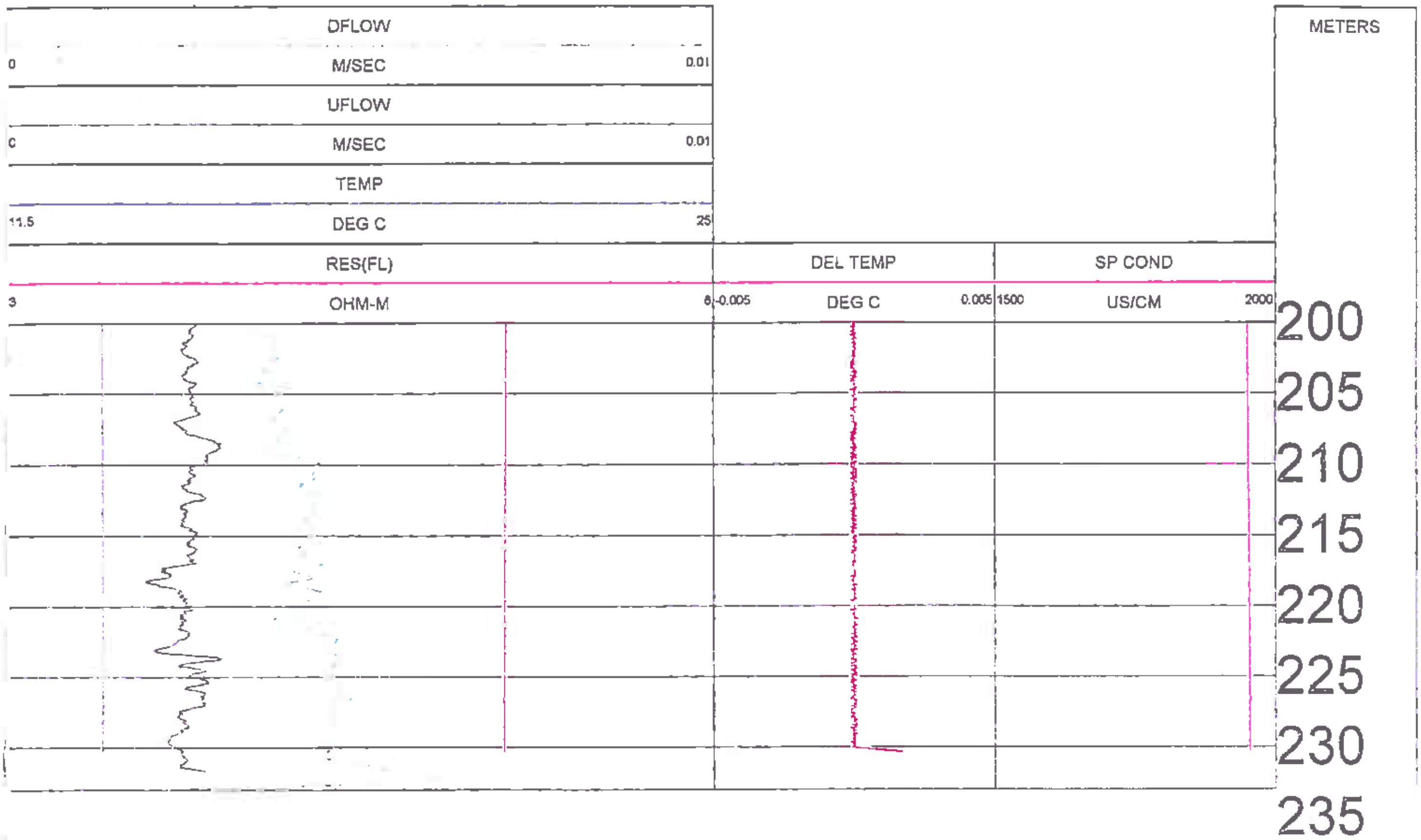
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SP COND
1500 US/CM 2000
METERS
200
205
210
215
220
225
230
235

APPENDIX B

PLANS OF ROADWAYS DRIVEN IN THE MAGNESIAN LIMESTONE AT EASINGTON, HORDEN, DAWDON AND BLACKHALL COLLIERIES

SCALE : 1/2500

16534

WEST SHAFT		EASINGTON COLLIERY NORTH SHAFT		SOUTH SHAFT	
443735	544141	443704	544169	443791	544153
SURFACE LEVEL	10207·54	SURFACE LEVEL	10197·44	SURFACE LEVEL	10195·04
INSET	10033·27	INSET	10029·95	INSET	10020·92
DEPTH OF SHAFT	143·7yds	DEPTH OF SHAFT	520·67yds	DEPTH OF SHAFT	527·65yds
BOTTOM OF SHAFT	9776·40	BOTTOM OF SHAFT	9811·40	BOTTOM OF SHAFT	9811·50

—SCALE — 1/2500—

DATUM FOR LEVELS
10000 feet below ORDNANCE DATUM

ROADWAYS IN LIMESTONE

45/4243/500 500

DATE OF CONSTRUCTION 6-3-73

EASINGTON COLLIERY

WEST PIT		NORTH PIT		SOUTH PIT	
SURFACE LEVEL	10207·54	SURFACE LEVEL	10197·44	SURFACE LEVEL	10195·04
INSET	10008·27	INSET	10029·95	INSET	10020·92
DEPTH OF SHAFT	143·7 YDS	DEPTH OF SHAFT	528 67 YDS.	DEPTH OF SHAFT	527·85 YDS.

—SCALE — 1/2500—

DATUM FOR LEVELS
10,000 feet below ORDNANCE DATUM

ROADWAYS IN LIMESTONE

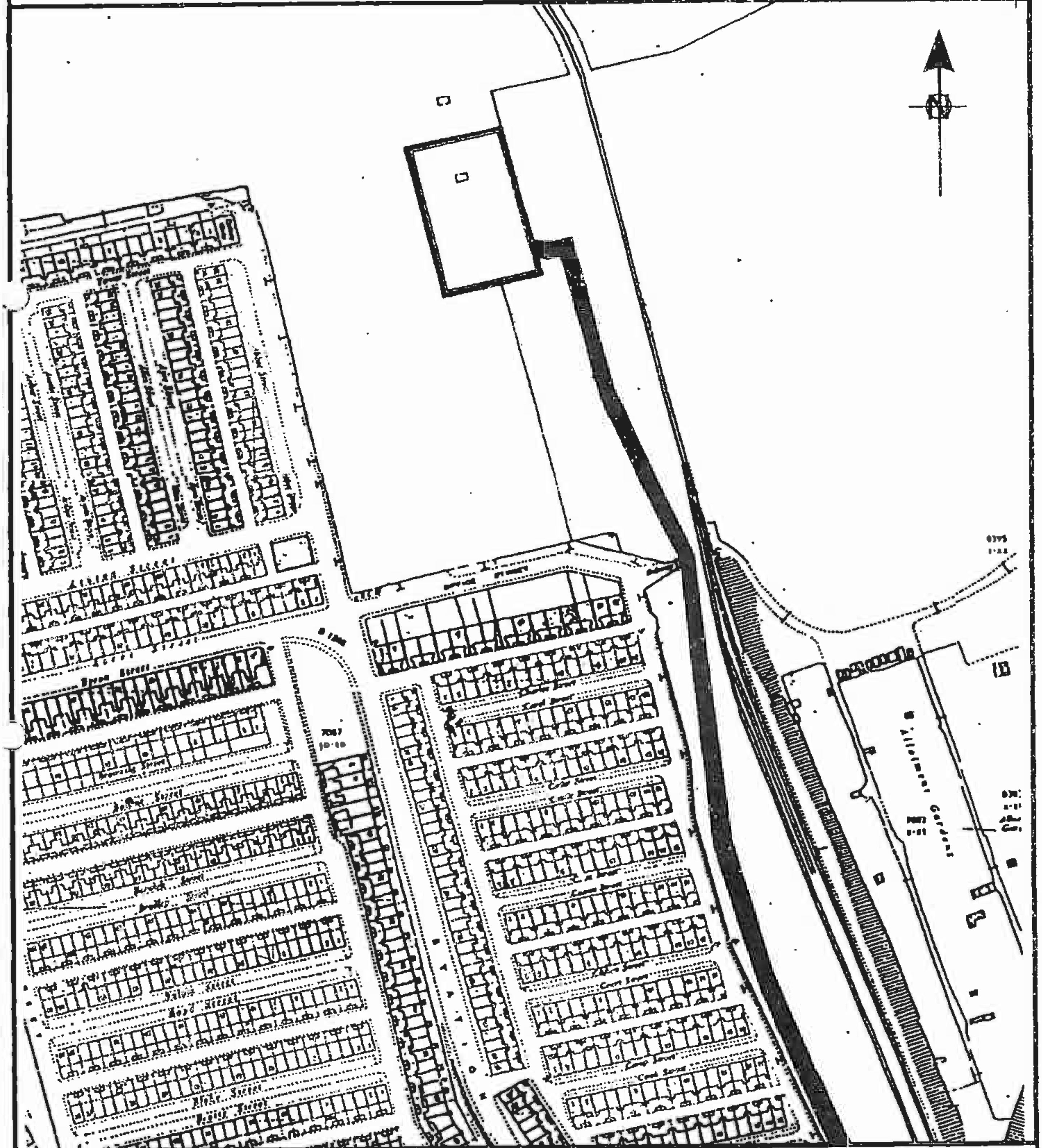
DATE OF CONSTRUCTION 9th April 1965

S85

APPENDIX B

PLANS OF ROADWAYS DRIVEN IN THE MAGNESIAN LIMESTONE AT EASINGTON, HORDEN, DAWDON AND BLACKHALL COLLIERIES

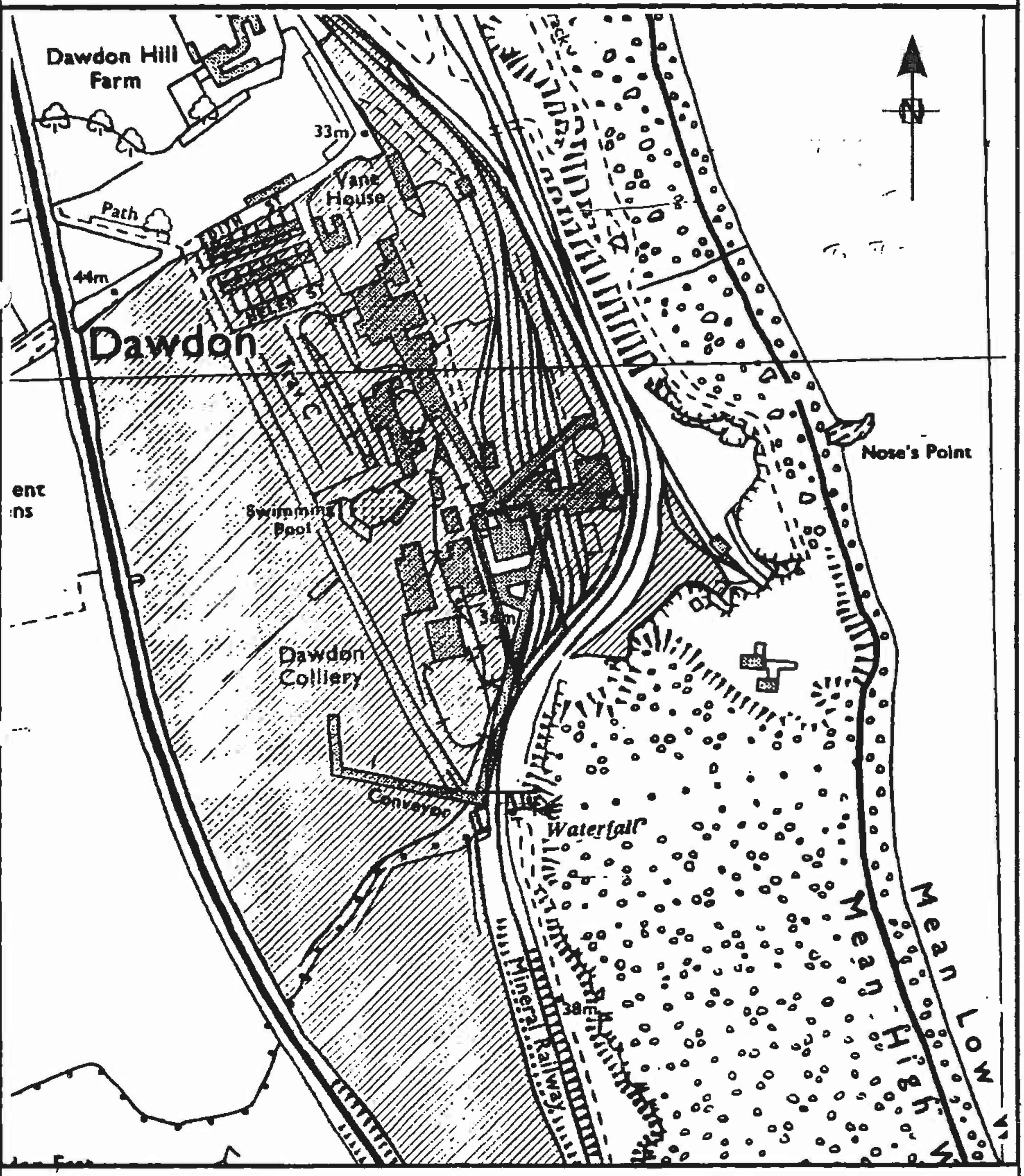
Durham Minewater
Coal Authority Ownership
Easington



Do Not Scale

IMC 7208

Durham Minewater
Coal Authority Ownership
Dawdon



Do Not Scale

IMC 7208

L24
(Adit)

DAWDON COLLIERY MINEWATER DISCHARGE ADIT (BEACH TUNNEL) SEALING DETAILS FOLLOWING CESSATION OF UNDERGROUND PUMPING

Prior to the cessation of underground pumping at Dawdon Colliery, it was considered that the water from the mine would have to be controlled by submersible pumps in the Dawdon Shafts to prevent it migrating to Easington Colliery.

A submersible pumping station was thus designed, which included the installation of a 204 mm O.D. steel minewater discharge range down a new 900 mm diameter surface borehole and along the previous "free flow" beach tunnel.

Following the closure of the colliery and the cessation of underground pumping, this work was undertaken and the pipes were installed to within four metres of the mouth of the tunnel in the cliff face.

It was also decided to build temporary stoppings in the beach tunnel to prevent "accidental entry". These consisted of one 18 inch thick blockwork wall built across the tunnel approx 5 metres from the new borehole on the shaft side and one 9 inch blockwork wall built across the tunnel at the entrance.

Vandals however later demolished the 9 inch wall at the entrance whilst the mortar was still green and the entrance was re-sealed by lifting into place, with a machine, one very large concrete block which was then covered with tons of colliery shale.

This as previously stated is only a temporary seal which will be replaced with a permanent one when it is decided that Dawdon will not, or no longer be, required as a pumping station.

T B DIXON
Dep. Group Surveyor
17th December 1992

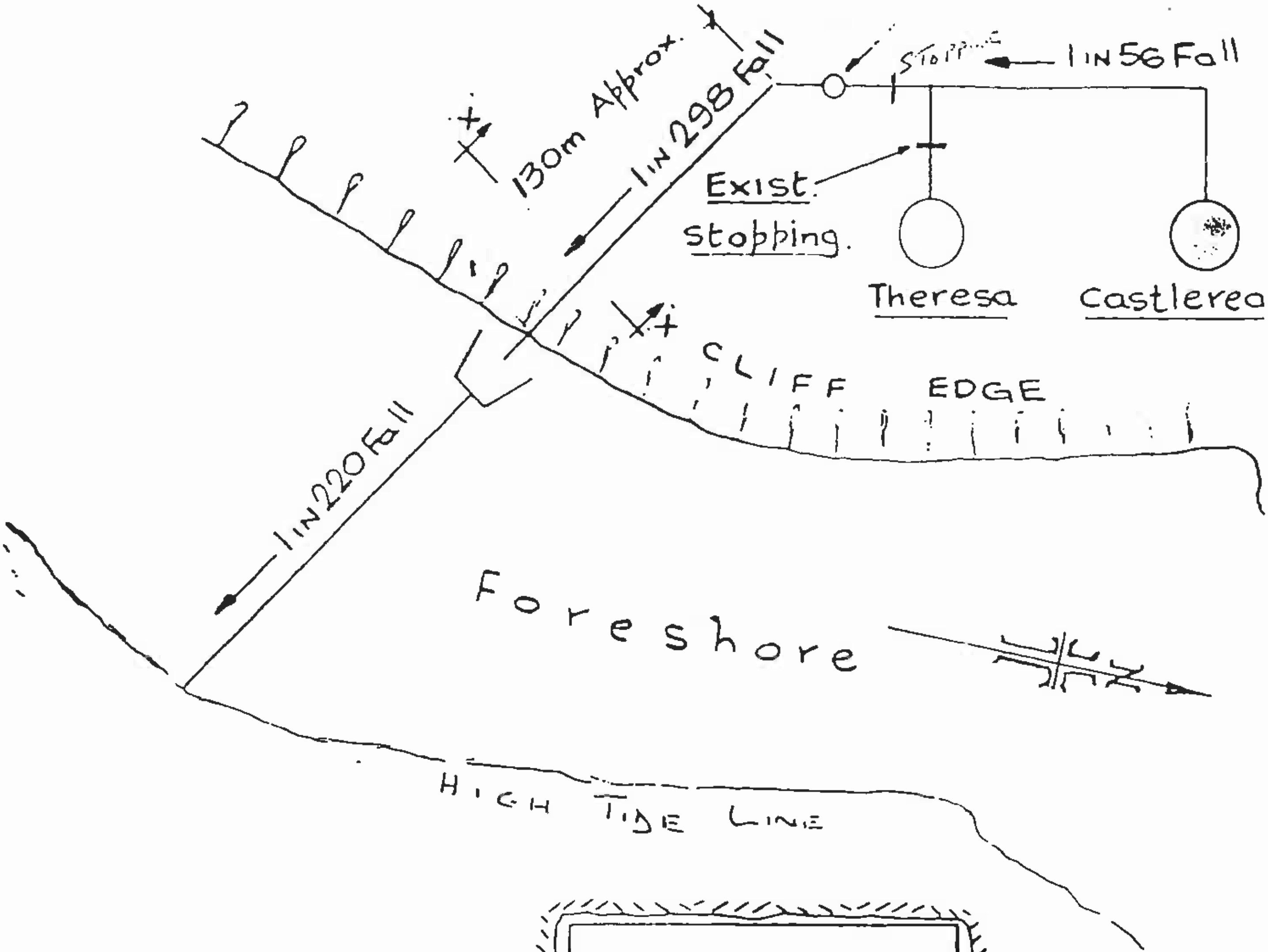
App 2(i)

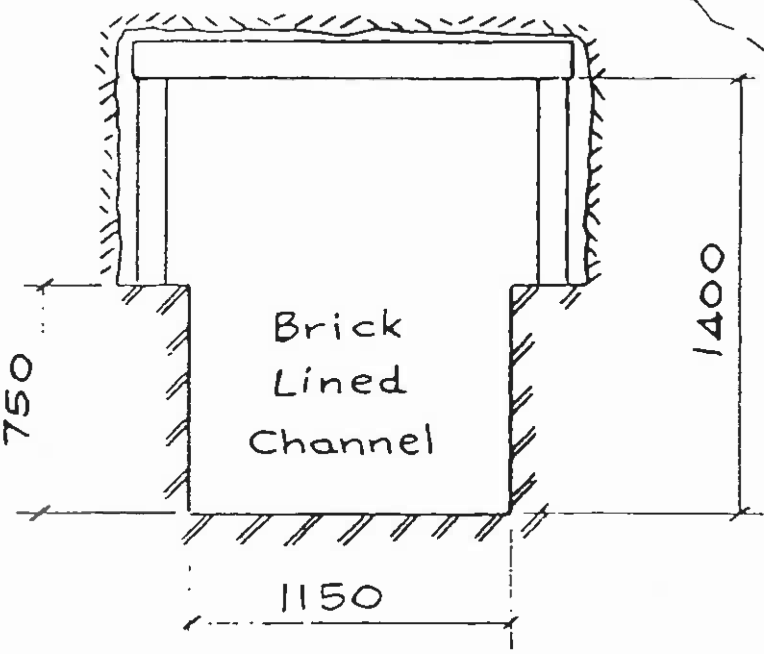
L24

(ADIT)

DAWDON COLLIERY

Pumping Adit Details





Section 'X-X'

SHAFT AND OUTLET RECORD

Shaft/Outlet Record No NZ 44 NW 13

Name/s DAWDON COLLIERY MINEWATER ADIT (BEACH TUNNEL)

Geological Record No

NG Co-ordinates NZ 43694 47738

Source of Information (Location) SURVEYED N.C.B.

Total Depth/Length and Gradient with Source of Information
195 m to Castlereagh Shaft
157 m to Theresa Shaft
Rising from beach to shafts 1 in 230

Diameter/Dimensions 1·2 m wide x 1·6 m high (Approx)

Filling Details (Date, Material Condition)

Lining Details Brick lined up to 0·75 m from floor

Capping/Sealng Details and Date
0·5 m thick block wall in tunnel
5 m from new borehole on shaft side. +
Large conc block covered in shale at beach end

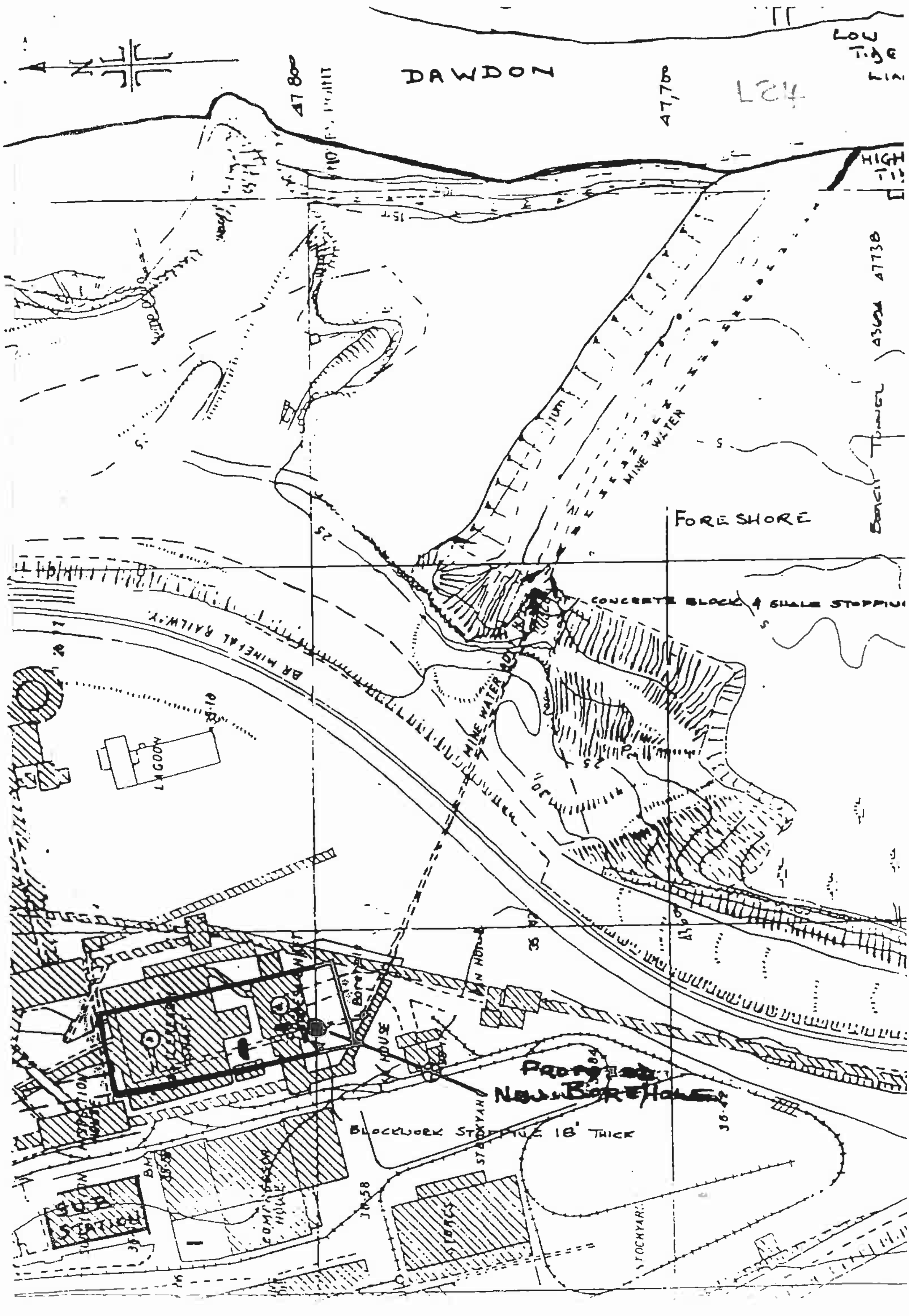
Nature and Thickness of Superficial Deposits Sunk/Driven through

Date of Sinking/Driving

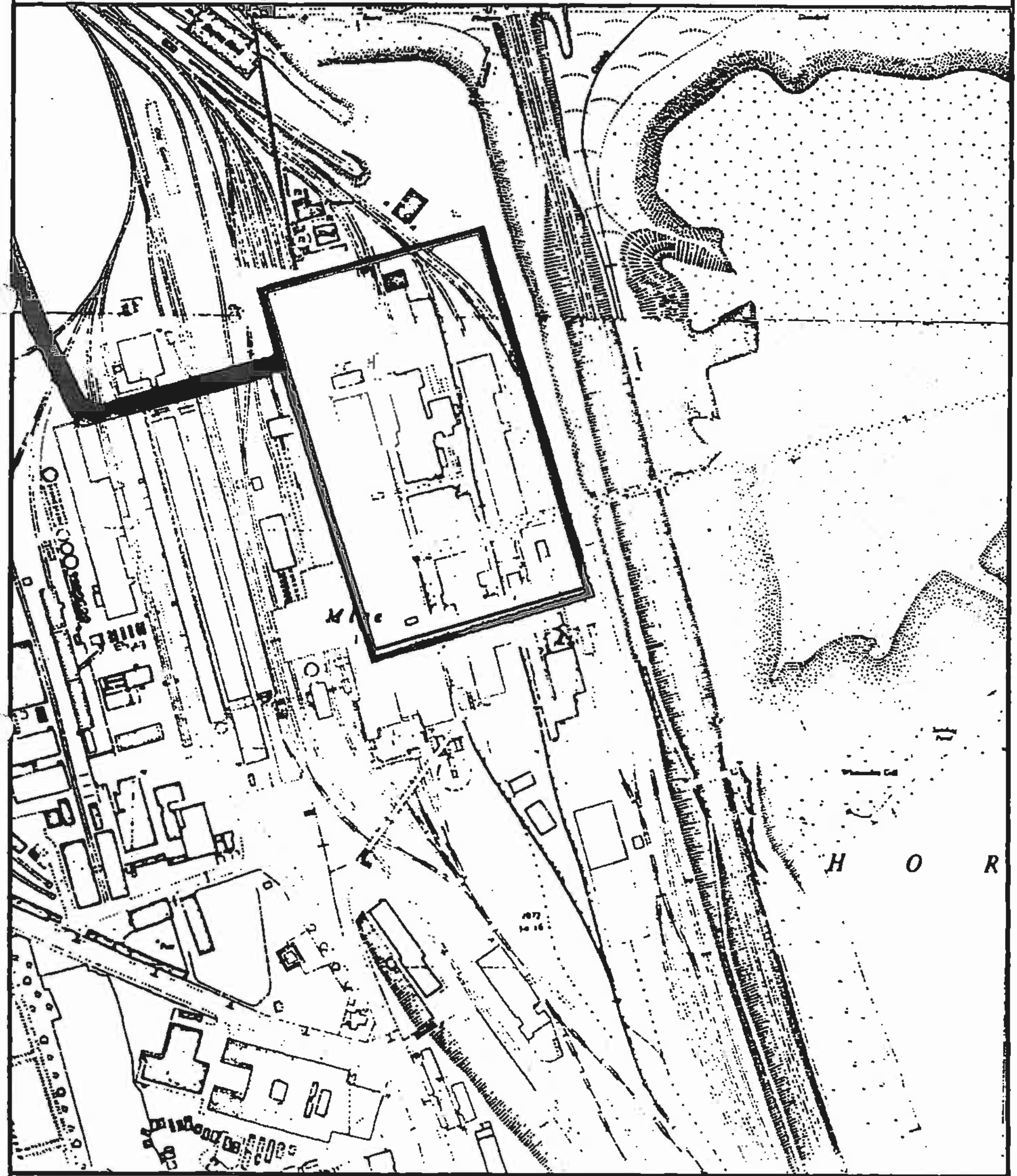
Details of Ownership

Other Remarks (incl Inset Horizons)

WCE6PJ/1

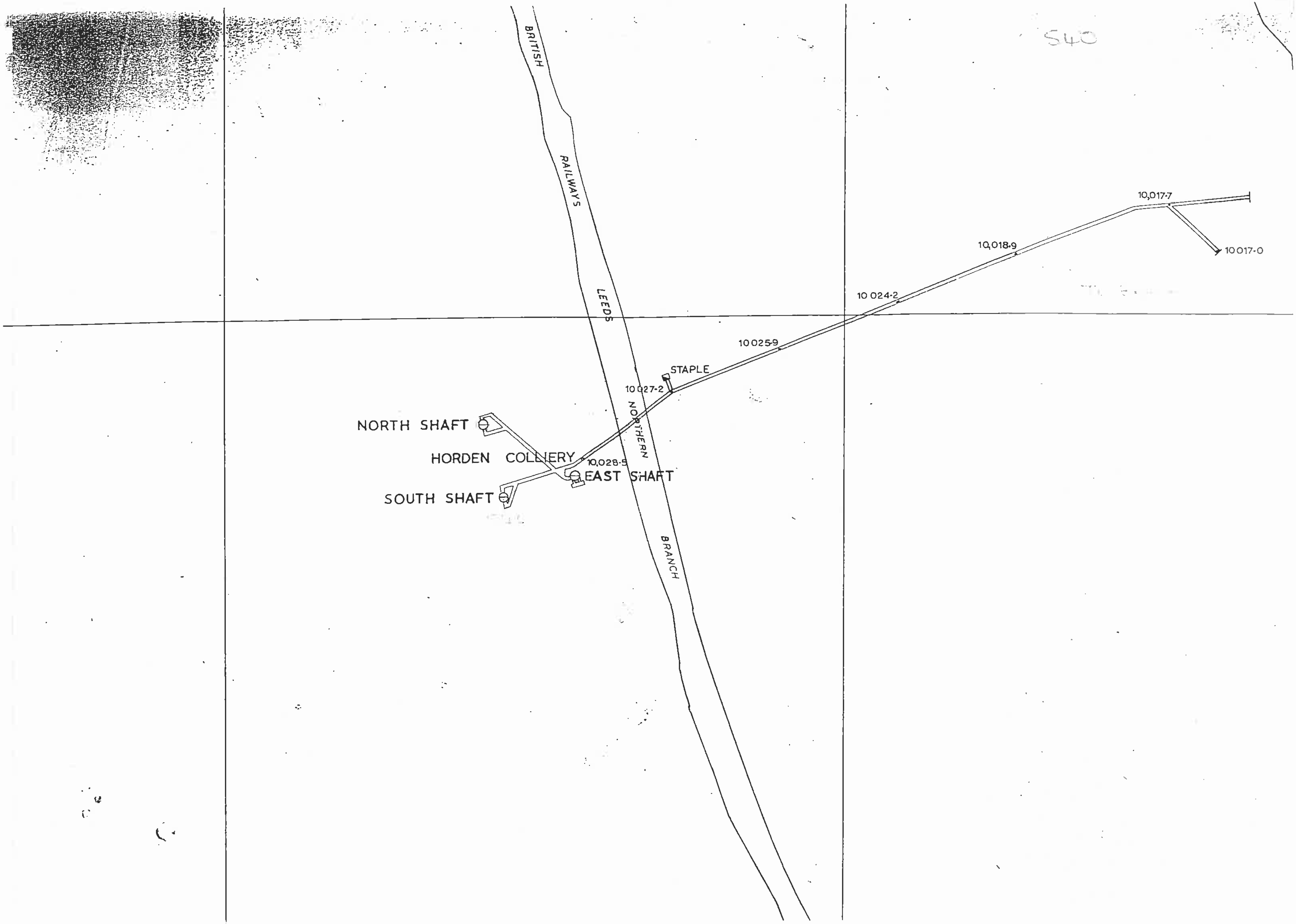

DAWDON
LOW TIDE LINE
HIGH TIDE
L24
A7,800
A7,700
A7738
FORESHORE
MINE WATER
CONCRETE BLOCK & SHALE STOPPING
BR MINERAL RAILWAY
MINE WATER
LAGOON
PROPOSED NEW BOREHOLE
BLOCKWORK STOPPING 18' THICK
SUB STATION
COMPRESSOR HOUSE
STORES
STOCKYARD

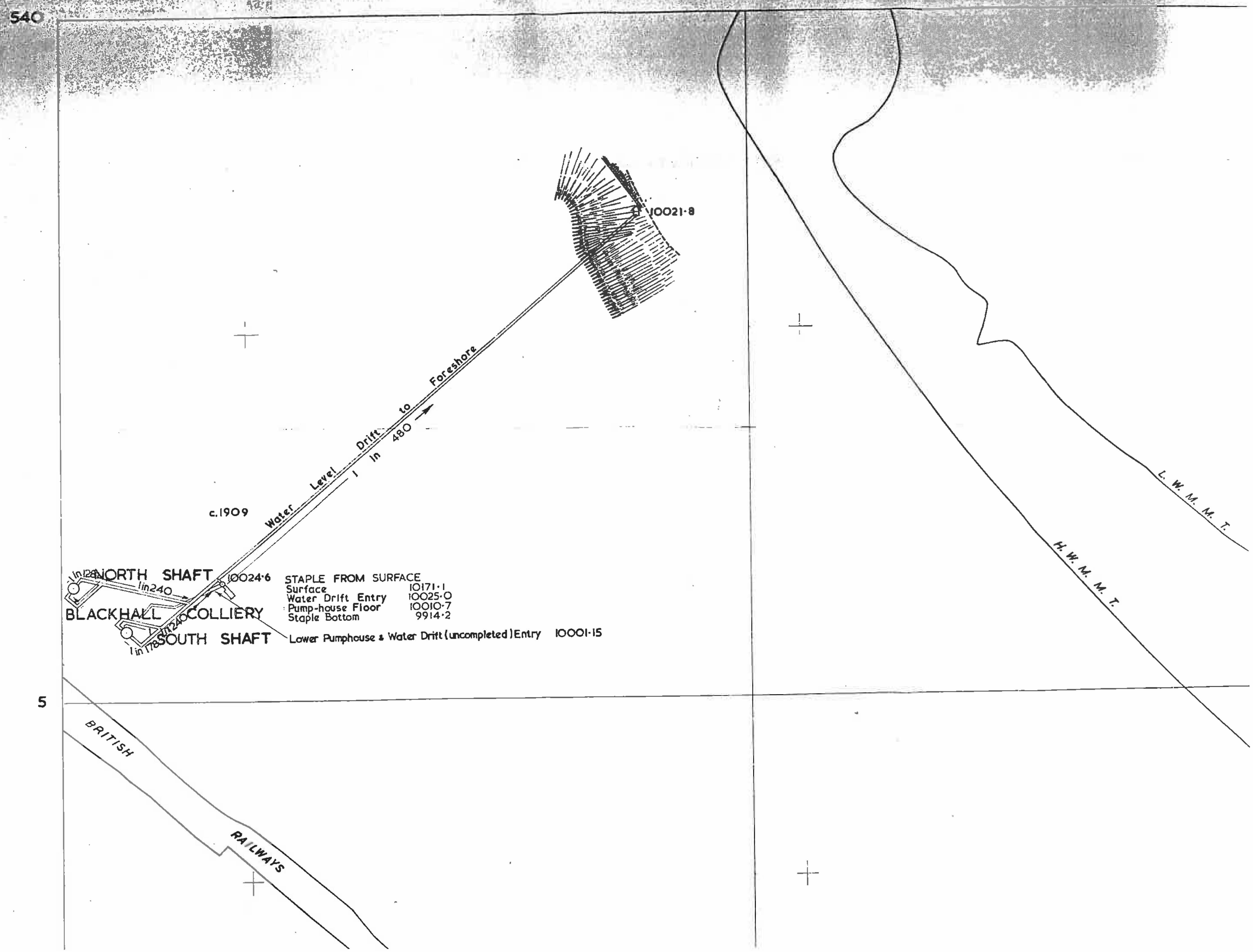
Durham Minewater
Coal Authority Ownership
Horden



Do Not Scale

IMC 7208


S40
BRITISH
RAILWAYS
LEEDS
NORTHERN
BRANCH
10,017·7
10017·0
10,018·9
10 024·2
10025·9
STAPLE
10027·2
NORTH SHAFT
HORDEN COLLIERY
10,028·5
EAST SHAFT
SOUTH SHAFT



540
5
10021·8
Water Level Drift to Foreshore
1 in 480
c.1909
1 in 128
NORTH SHAFT
1 in 240
10024·6
BLACKHALL COLLIERY
1 in 240
1 in 178
SOUTH SHAFT
STAPLE FROM SURFACE
Surface 10171·1
Water Drift Entry 10025·0
Pump-house Floor 10010·7
Staple Bottom 9914·2
Lower Pumphouse & Water Drift (uncompleted) Entry 10001·15
L. W. M. M. T.
H. W. M. M. T.
BRITISH RAILWAYS

APPENDIX C

HAWTHORN SHAFT, PLANS AND SECTION

Hawthorn Shaft Section.
HAWTHORN SHAFT
DEMARCATION Between HAWTHORN — MURTON
DEMARCATION Between HAWTHORN — ELEMORE
MAIN COAL GOAF CONTACTED IN FLOOR OF HORIZON
1 in 1 Rise Drift from Top Horizon Bored 20ft. to prove L.M. workings.
to MURTON Sq. Five Quarter
to ELEMORE
SOUTH HETTON COLLIERY
NAT. GRID NORTH
LEVELS RELATIVE TO 10,000 FEET BELOW ORDNANCE DATUM
HAWTHORN MINE
SPOIL HEAP PLAN
SEAM OVERLAY
TOP HORIZON
SCALE 1/2500.
SCALE OF METRES
PLAN CONSTRUCTED JUNE 1972