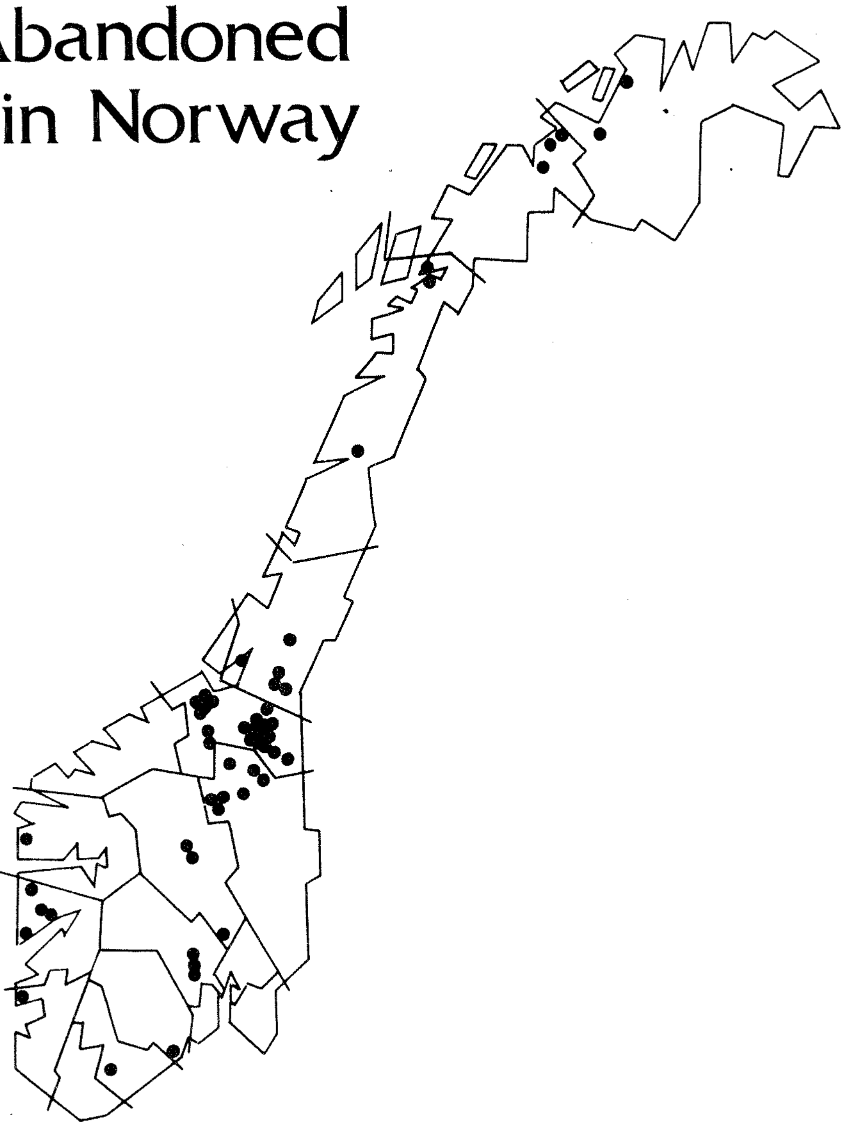
O-87048

Water Pollution from Abandoned Mines in Norway



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Abstract: The report provides a country-wide overview of abandoned pyrite mines where operations have been fairly extensive. The water pollution situation is assessed on the basis of reported investigations, inspections and chemical analyses from the individual areas. In cases where larger watercourses (Orkla, Gaula), and the upper stretch of the Glåma) are affected, the situation appears to be adequately described. However abandoned mine areas may also cause local pollution problems, and here documentation is rather sparse. Possible counter measures must be evaluated with respect to user interests in the area.

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WATER POLLUTION FROM ABANDONED MINES

Oslo, 8 September 1987

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P E R F A C E

The background for this report is the wish to provide an overview of the information NIVA has accumulated over a considerable period of time on the pollution situation in abandoned mining areas. The report collates data from samples collected by mine supervisors, as well as data from other NIVA projects and investigations. Where no such documentation exists, a general evaluation of the situation is given, based on the recipient conditions, the operating life of the mine and the production level.The project was financed by the Norwegian State Pollution Control Authority (Industrial Division) and the Ministry of Industry (Mines Office).

The English version has been translated from the Norwegian report "0-82068 Vannforurensning fra nedlagte gruver" by mrs. Jeniffer Follestad. Responsible at NIVA for this English edition of the report has been Rolf T. Arnesen.

INTRODUCTION AND STATEMENT OF PROBLEM

In his 1925 overview of Southern Norway's mines and ore deposits, Foslie reports a total of some 1414. The majority of these are located on pyretic deposits containing iron, copper, zinc, lead and nickel in varying proportions. Most of these mines and claims are small, and many have only been in trial operation for short periods of time. Such small scale deposits probably do not have a significant effect on the quality of water in the area. In the following report, the assessment of the pollution situation in various districts is confined to mines which have had a production of over 200,000 tons of crude ore. A provision visional overview of these pyrite mines, based on surveys carried out by mine supervisors, is given in Appendix 1. Additionally, smaller mine areas where there is specific knowledge of water conditions are also included, as well as areas where a number of mines drain into the same river system. Operative pyrite mines such as Grong, Skorovass, Bleikvassli, Folldal/Hjerkinn, and in part, Løkken and Sulitjelma, are not treated in the report. This selection of material will ensure that regions where abandoned mines cause signigicant pollution problems are dealt with. However, there may also be more local effects at smaller mines without this being registered at the present time. Even though production has been relatively modest and of short duration, drainage may affect the local water course to such an extent that a conflict with user interests is inevitable.

Figure 1 gives an overview of the more sizeable deposits of pyrites known to exist in 1925 (Foslie 1926).These pyrite deposits are found in conjunction with the Caledonian belt. Furthermore, a number of new mine areas have been developed in recent years in the same geological formations.

Southern Norway's pyrite deposits can be classified in three main groups: the Hardanger-Karmøy district, the Trondheim district (Røros), and the Grong district. In the North of Norway the most important deposits occur within smaller districts. This classification corresponds to the division into regional mining districts, and the data in this report are similarly organised. In addition, the mines within each district are classified according to the water course they drain into.

From early times it was primarily the copper ores than were mined, and a number of deposits were worked as early as the first half of the seventeenth century. At that time sulphur was valueless, and the ore was smelted on site to extract the copper. In approximately 1840, the

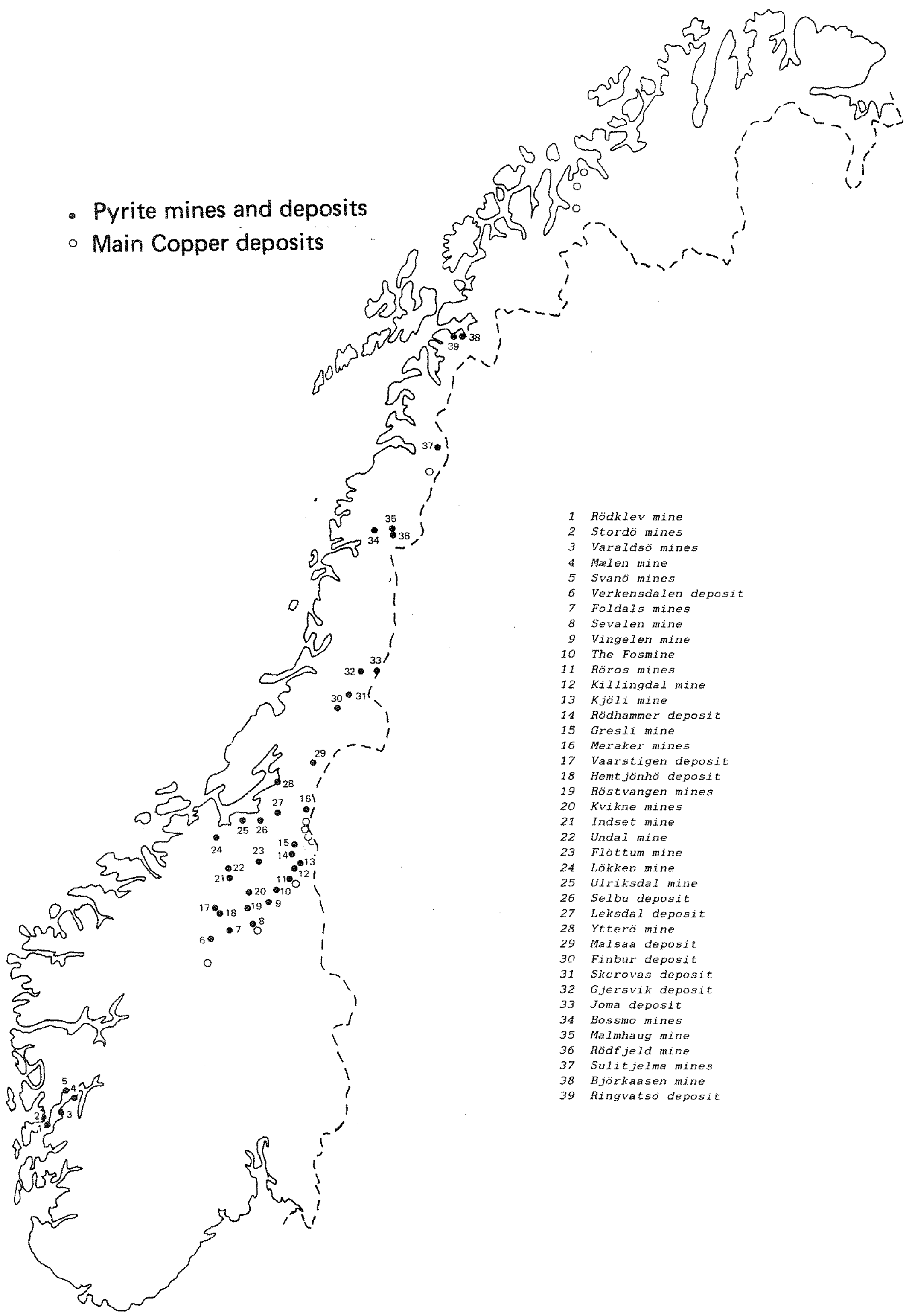

Fig. 1. Pyrite deposits in Norway as known in 1926. (Foslic 1926).

smelting of these relatively low-grade copper ores became unprofitable due to a fall in copper prices. This resulted in the exploitation of the sulphur in the ore for the production of sulphuric acid. There was an increase in production towards the end of the nineteenth century with export of ore as well as sulphuric acid. About 1850 a number of nickel mines were also operative but these have been abandoned today.

Acid mine drainage is caused by the weathering action of moisture and air. This process can be ascribed to bacteriological and chemical conditions. Weathering leads to the production of sulphuric acid, and the resultant acid drainage brings about the release of heavy metal ions. Therefore, normally, the more acid the mine water, the greater the probability that the concentration of metal ions will also be elevated. When metalliferous acid mine water is deacidified, as, for instance, in its gradual dilution in the watercourse, the metal ions will be precipitated. The preupetation of iron gives a characteristic reddish-brown deposit (ochre precipitation), which often provides a clear indication of mine pollution in streams and water courses.

Previously ore and shale were sorted by hand, resulting in waste rock dumps with a fairly high pyrite content. Thus older dumps give relatively acid and metalliferous seepage, as is also frequently the case with mines that have an adit below the mine works.

The technical equipment available at the beginning of this century made it possible to crush fairly large quantities of ore. At the same time, dressing techniques were not as efficient as today's, so that mining operations may have resulted in waste rock and tailings with a high metal content. Modern dressing processes produce a finely ground waste with low metal content. In certain cases such deposits may contribute to an undesirable particle transport in the recipient waters. Waste is currently deposited in water where possible so as to reduce the danger of oxidation of sulphide minerals.

The flow of pollution from abandoned mines to larger rivers depends on the interaction of ore, water and air. Thus the fall of water table in the area is a significant factor. Mines that are flooded, for example, probably cause less pollution than mines with a draining drift. Another important factor is the size of the gangue piles and its location. An inspection of the site can provide a fair impression of the likelihood of there being a real danger of pollution. Furthermore, existing documentation shows that the type of rock in the mine area can affect the rate of weathering considerably in that basic rock tends to retard the weathering process. In mine areas where there is a predominance of basic rock, mine water and run-off have higher pH values than would normally be expected in conjunction with sulphide minerals. The concentrations and transport of heavy metals released from such areas is relatively limited.

In this report the various mine areas are evaluated on the basis of knowledge of the area, analyses of samples collected by mining supervisors and others, as well as reported investigations of larger watercourses. Map references are provided using UTM codes where the first three digits give the east/west coordinator and the last three the south/north coordinator. The map-sheet is given instead of the zone number.

A number of larger watercourses receive drainage from several mine areas of varying size. A tentative evaluation has been made of the principal sources and their effect on the main water course. The report also points to the need for a closer examination of conditions in a number of places.

Information on the pollution situation at abandoned mines is collated in the report. This information is derived from reports on particular areas compiled by NIVA and others.In addition, inspection reports and, in some cases, analysis results have also been included. In consequence, the results that are presented from the various areas are to some extent very different in character. The aim of this report, therefore, is to give an overall evaluation of the pollution situation based on data available from the various abandoned mines. Moreover it is recommended that closer investigations be carried out in abandoned mine areas that are potential sources of pollution problems.The future course of action in an area can be assessed by considering the pollution situation in relation to user interests.

2. OVERVIEW OF INDIVIDUAL ABANDONED MINES

2.1 The Western Norway Mining District

2.1.1 Vigsnes Copper Works

Map: 1113 I Haugesund 858853.

The mines are situated on the north west coast of the island of Karmøy. They have been in production intermittently since 1865, and were finally abandoned in 1968. The mining area drains to Lake Vigsnesvatn which has an outlet to the sea.

Lake Vigsnesvatn is extensively polluted due to seepage from the mine area.

Regular test samples are taken from Lake Vigsnesvatn by the National Pollution Control Authority. Individual analyses also show that the mine water has a low pH value and a high metal content. An inspection should be made in the catchment area to evaluate the situation more closely, since sporadic samples indicate high concentrations of heavy metals in small lakes in the area.

Analyses results:

Date	Sample	pH	Fe mg/l	Cu mg/l	Zn mg/l	SO_4 mg/l
820722	Lake Vignesvatn northern arm	3.05	14.2	0.39	3.9	-
790608	Mine water old mine	2.70	73.8	40.2	157	1570
750920	Mine water Rødklev mine	2.46	1960	378	880	-

2.1.2 Stordø Pyrites Mines

Map: 1114 I Fitjar.

The deposit was discovered in 1864, but production was marginal up to 1907.

From 1907 to the closing of the mines in 1968, a total of 8 million tons of crude ore were extracted. There are several mines in the area but the pollution situation is not known.

2.1.3 Other mines in Hardanger

In the mineralized belt northwest of the island of Stordø lies the Bømlo mine area as well as several other smaller mines further along the Hardanger Fjord. The two largest are the Ølve Mine (the Christiansgave Copper mine), and the Varaldsø mine where mining operations were carried on from 1867-88 and for a short period during the First World War. There are a number of mines further along the fjord including the Mølen mines. The pollution situation in these area is not documented but.

2.2 The Eastern Norway Mining District

2.2.1. Evje Nickel Mines

Map reference: 1512 III, Evje 344961.

The nickel mines at Evje are located to the east of the River Otra, close to the village. The mine was Norway's largest nickel mine with a combined total production of 2,700,000 tons, giving a production figure ten times larger than that of the Ertelien mine at Ringerike, for example.

The mine area drains to the River Otra. In the main river there is a sizeable stock of fish on this stretch, while no negative effects have been registered in the main water course as a result of drainage from the area. No closer inspection of the mine water and the small brooks in the area has been carried out.

2.2.2 Bamble Nickel Mines

There has been a considerable degree of activity in the Bamble mining field, but it has not been ascertained whether this has led to local pollution problems.

2.2.3 Ertelien Nickel Works

Operation

The mine was first opened in 1688 and closed finally in 1920. The gangue heaps in the area were established primarily in the years from 1688-1716 and 1849-1920, the period of greatest activity.

The most important minerals in the crude ore are magnetic iron sulphides, pyrite, copper sulhpides and pentlandite. Altogether a total of some 280,000 tons of ore containing approximately 0.8% Cu and 1% Ni were extracted.

Description of the area

Map Sheet: Hønefoss 1815 III.

The district is situated in the municipality of Modum on the west side of the Tyrifjord. Drainage from the mine area finds its way to Lake Åsterudtjern and to a stream from Lake Tjernslitjern which joins the brook from Lake Åsterudtjern just below the latter's outlet. The stream from Åsterudtjern flows into the River Henoa immediately prior to the rivers outlet at Henovika on the Tyrifjord. The size of the waste rock dump s is not known, and they are dispersed over the entire mining area. Some are extremely weathered and have the characteristics of sand. The mine water reaches Lake Åsterudtjern.

Test sampling and analysis

Several water samples have been taken in the area both by the mine supervisor and by NIVA. The results are given in the table below.

Sampling - grid site reference	Date	pH	Cond. mS/m	SO_4 mg/l	Fe µg/l	Cu µg/l	Zn µg/l	Cd µg/l	Ni µg/l	Co µg/l	Cr µg/l
The Åsterudbekk str. downstream of(its)confluence with(the)Tjernslibekk(str.)-582590	29/08-79	6.04	17.5	66	440	24	54	-	132	66	-
Seepage from tips -582590	20/10-81	3.95	89.7	590	440	474	490	5.1	1670	-	2.8
Stream Flowing into Lake Åsterudtjern -580597	20/10-81	4.88	14.6	62	2200	43	20	0.8	113	-	1.8
Outlet from Lake Åsterudtjern - 582591	20/10-81	6.46	14.3	56	610	16	30	3.1	67	-	0.6
- " -	18/10-83	6.51	14.7	55	590	16	30	0.1	57	24	-
- " -	24/10-83	6.50	15.1	100	620	17	20	0.1	57	-	-
Tjernslibekken stream - 583592	20/10-81	6.58	13.4	48	470	23	30	1.3	90	-	0.95
- " -	18/10-83	6.42	12.0	48	230	20	30	0.1	71	37	-

Evaluation of the pollution situation

The concentrations of copper and nickel in Lake Åsterudtjern are so high that fish cannot survive there. Attempts have been made to stock out fish but without success. It may well be the case that the outflow of heavy metals from the mine area is so great that the biological balance in the lower stretches of the River Henoa and the bay of Henovika may be affected. Input from the area has, however, no significance as far as water quality in the Tyrifiord is concerned.

Water from Lake Åsterudtjern is used for agricultural irrigation.

2.2.4 Langdalen mine

Map Sheet: 1815 III Hønefoss
Map reference: 567707.

Operation

There is no record of when the mine was first opened but mining activity was at its peak in the years from 1886 - 1920. The gangue piles in the mine area date from this period.

The most important minerals in the crude ore are iron sulphides, copper sulphides and pentlandite. A total of some 10,000 tonnes of hand-sorted ore with a content of roughly 0.8% Cu and 1% Ni was extracted. Two smaller mines, the Tysklands Mine 570702, and the Skaug Mine 571697, are also in this area, but their production was of minor significance compared to the main mine.

Description of the area

The area is located north of Holleia on the west side of the Tyrifjord. The mine and its gangue heaps are in steep terrain in the neighbourhood of Gruvåsen. Drainage from the haps merges with mine water, and drains to the brook from the Langdalen valley which flows into the inner reaches of Lake Langdalstjern. Runoff from the other two mines is rather dispersed but apparently disappears in the ground, and probably drains to the Sandtjernsbekken brook which runs into Lake Baksjø.

Drainage from the entire area passes through a number of smallish lakes draining to the River Væleren, which flows into the River

Skjærsdalselva and the Tyrifjord. A smelting works has previously been located at Væleren.

Test Samples and Analysis

Samples have been collected in the area by the mines supervisor and by NIVA. The results are shown in the table below:

Sampling - grid site refenence	Date	pH	Cond. mS/m	SO_4 mg/l	Cu µg/l	Zn µg/l	Fe µg/l	Ni µg/l	Co µg/l	Cd µg/l
Stream from Langdalen -566706	29/08-79	6.55	4.59	12	45	17	80	118	0.6	-
Mine water + drainage - 566706	18/10-83	6.09	3.14	7.3	18.5	<10	130	31	-	<0.1
" " "	24/10-83	6.67	3.92	9.0	21.5	<10	95	47	-	<0.1
Mine water	18/10-83	4.81	35.0	150	2270	190	160	3010	190	1.6
Outlet from Lake Langdalstjern - 566703	18/10-83	5.49	2.78	5.9	10	<10	180	12	-	<0.1
" "	24/10-83	5.80	2.85	6.5	10	<10	164	17	-	<0.1
Sandtjernbekk stream - 572695	24/10-83	6.89	3.76	6.9	2.3	<10	178	7	-	<0.1

Furthermore samples have been taken from the larger watercourses in the area to determine the effect of metal inputs on the Tyrifjord. The following table presents data gathered in 1978 from the River Skjørdalselva close to its outlet in the Tyrifjord (The Tyrifjord Commission, unpublished):

River Skjærdalselva	1978 24/4	12/6	21/6	26/6	10/7	31/10	20/11	11/12
pH		6.90	6.55	6.85	7.15	7.25	7.20	7.00
cond. mS/m		36.5	56.0	49.7	43.1	65.2	39.7	39.7
Sulphate mg SO_4/l	9.0	6.6	17.4	13.0	7.3	7.2	10.6	6.7
Copper µg Cu/l	119	9	19	19	22	16	4	2
Zink µg Zn/l	10	13	5	12	10	<10	<10	<10
Iron µg Fe/l	190	160	415	280	470	410	160	120

Assessment of the pollution situation

Pollution inputs from the Langdalen mining area can only be described as modest, and have almost certainly no effects on the watercourse below.

The situation in Lake Langdalstjern is not known. Concentrations of copper and nickel at the outlet are higher than might be expected on the basis of the natural background values. Fish have been observed in Lake Langdalstjern. Drainage from the other two smaller mines has no effect on the watercourse.

In contrast, samples from the River Skjørdalselva show that water quality is affected by inputs of heavy metal. This may well originate from the former smelting works at Væleren.

2.2.5 Eiker Copper Works

The mine was probably opened originally round about 1600, although at that time there was most likely very little activity. Production was at its peak in years from 1875-78 and 1885-89, and the gangue heaps were established during these two periods. The ore was hand-sorted and dispatched, while in the final years of operation the ore was dressed by means of washing.

The mine was abandoned on 17/4-1889.

Production figures

Year	Dressed ore tons	% Cu	Ore mined m^3
1875	885	4,5	
76	1175	4	-
77	1665	4	-
78	400	4	-
85	2273	-	1330
86	2633	-	3602
87	4385	-	3442
88	4826	-	4290

Description of the area

The area lies in the municipality of Øvre Eiker on the west side of the River Drammenselva.

Map: Hokksund 1714 I.

The mine area consists of three mines:

a) Bergsgruva Mine (the main mine), map reference 456249.
b) Map reference 460260.
c) " " 464264.

It is estimated that areas b) and c) are of minor importance, both as far as the pollution situation is concerned, and in comparison with a) the main mine.

The mine area drains to the Grorudbekken stream, a tributary of the River Honselva which flows into the River Drammenselva at Hokksund. Part of the mining area at the main mine also drains to a network of streams leading to the River Vestfosselva which also has its outlet in the River Drammenselva at Hokksund.

Sampling and analysis

In the course of an inspection carried out on the 18/10-83 three samples were taken at the following map references:

1. Seepage from gangue heaps and mine water - 464263

2. Seepage from gangue heaps at the main mine - 457251

3. The Grorudbekken stream by the road barrier (accumulated drainage to the Grorudbekken stream) - 473262

An analysis of the samples produced the following results:

Sample	Estimated water flow	pH	Cond. mS/m	Sulphate mg SO_4/1	Iron µg/1	Copper µg/1	Zink µg/1	Cadmium µg/1
1	< 1	4.49	5.46	11	550	580	200	0.59
2	1 - 5	3.04	13.5	740	39500	6430	27700	40
3	5 - 20	4.75	9.89	32	560	210	1120	1.6

Assessment of the pollution situation

The inputs from the area are heavily dependent on precipitation conditions. In times of drought, drainage is most probably limited. The principal drainage of heavy metals originates in the area around the main mine. Weather conditions were good when samples were taken on 18-X-83, but there had been heavy precipitation just a few days earlier.

Effluent from the area is so extensive that the Grorudbekken brook can only be described as severely polluted, and it may be the case that concentrations here are so high that they may also affect biological conditions in the lower stretches of Honselva.

No samples were taken of drainage in the direction of the River Vestfosselva, but this was also assessed as being fairly considerable, with ochre precipitation along the stream.

Overall, however, the pollution problem in the area must be said to be relatively modest since the drainage is diluted to a very large extent in the larger watercourses. User interests in these local streams which may have a fair degree of pollution are not known. The use of mine wastes in road construction along the Grorudbekken brook has been a contributory factor in the increase of heavy metal outflow from the area.

2.2.6 Modum Cobalt Works

Map: 1714 I Hokksund

The mine area lies on the west bank of the River Drammenselva between its tributaries, Simoa and Snarumselva.

The cobolt mines were in operation in the years from 1776-1889, with a total of forty mines.

The area has not been systematically surveyed so as to establish the effects of heavy metals, but random samples were taken on an inspection by NIVA on the 20/10-1980.

Results of analysis

Grid ref	Name	pH	Cond.- mS/m	SO_4 mS/l	Fe mg/l	Cu µg/l	Zn µg/l	Cd µg/l	Ni µg/l	Cr µg/l	Co µg/l
492460	Str.from Lake Overntjern	6.57	4.55	10	230	1.7	<10	11	<5	<0.5	7.0
492507	Str.from Lake Nordgruvtjern	6.76	7.37	17	370	58	40	23	41	2.8	63
494506	Str.from Dam Stulldammen	6.88	5.83	7	340	7.3	10	2.2	<5	1.5	8.0

All the samples show varying degrees of heavy metal pollution. In particular, the relatively high cadmium values should be noted. This area should be kept under observation and further samples taken to assess the significance of the pollution situation.

2.2.7 Konnerud mining field

Map: 1814 III Drammen.

The field is to be found on the south side of the River Drammenselva and consists of a number of mines and prospects. Activity has been greatest in the area around Konnerudkollen. The earliest strikes of ore were made around 1640, but mining operations did not commence until 1730. Operations have been sporadic, though from time to time they have been fairly extensive when considered in relation to the situation at the time. The field was abandoned in 1913.

Mining operations have concentrated on silver-bearing galena and sphalerite, but sulphur ore (pyrite) and copper sulphides are also found in this area.

Heavy metal pollution is minimal, and is dispersed in a number of smaller streams flowing either into the River Drammenselva or to the River Bremsa (Sande watercourse). The biggest problems arise from the discharge of heavy metals from spoil from former washeries along the River Verkenselva at the Svendse Dam. Not only have high metal values been reported in the ground water in this region, but also elevated lead and zinc values can be traced in the River Verkenselva (NIVA 1978). Mine water from the Kontaktstollen Mine at Konnerudkollen (the final period of operations) is slightly alkaline.

Results of analysis

Date	Name	pH	Cond. mS/m	SO_4 mg/l	Ca mg/l	Pb µg/l	Zn µg/l	Ag µg/l
801125	Mine water Kontakt-stollen	7.75	61.6	250	106	4.6	<10	<0.5

2.2.8 Hadeland Pit - Grua

Map 1815 I Gran.

The zinc mines at Grua drain to a network of streams that form part of the Vigga watercourse.

The area has been surveyed by NIVA several times, and samples have been taken from the stream which is the recipient of the entire drainage from the area.

Results of analysis

Grid ref.	Date	pH	Cond. mS/m	SO_4 mg/l	Cu µg/l	Zn µg/l	Fe µg/l	Cd µg/l	Ca mg/l
935819	801020	7.05	6.51	13	1.2	340	60	4.0	-
935819	831104	7.14	7.76	15	1.1	460	50	1.3	12.2

The results show that the brook which flows through the area is clearly contuminated by zinc and cadmium. The dilution that occurs further down the watercourse is sufficient to ensure that the effect of the drainage is unlikely to be noticeable in the main watercourse.

2.2.9 The Nickel Mines in Espedalen

Map reference: 1717 I Svatsum and 1717 IV Espedalen.

The mine area drains to Gausa, which is a subordinate watercourse on the west side of the River Gudbrandsdalslågen north of the Lillehammer.

High up in the Gråhø Massif on the steep slopes above Lake Espedalen lie the Espedalen mines. Experimental operations were commenced there as early as 1665, but these were abandoned by 1672. At that time nickel was unknown, and mining operations centered on the extraction of copper. In 1845 trial production of nickel was started and, in the heyday of nickel mining, some 700 people lived in Espedalen. However operations there were never particularly profitable, and they came to an end around 1858. Later on, in the years from 1874-78, production was resumed due to an increase in nickel prices. Close to Mount Nordre Gråhøy lies the Stangesgruve mine, parts of which are flooded today. The Evansgruven and Jørstadgruven mines are located higher up and both are flooded. At Lille Gråhøy there are four small claims, with Storgruven mine to the south. The smelting plant lay on the banks of the river, between Lake Busjøen and Lake Espedalsvann where slag heaps can still be seen today. Streams that receive runoff from the mines were sampled on 12/5-83, and showed the pH and specfic conductance values that are normal in unaffected areas. Extended analyses from the Storgruva Mine show low metal concentrations. There was a thaw when the samples were taken, and water flow was high. Any effect on the water quality may perhaps be detected when the water level is lower.

	pH	Cond.vity mS/m	
Storgruva	6.68	4.45	
Lauvåa	6.60	1.57	
Snuruhaugen	6.83	2.7	
Storfjellbekk	6.93	2.11	
Gammelseter	6.84	1.87	
	Fe µg/1	Cu µg/1	Zn µg/1
Storgruva	10	1.7	<10

2.2.10 The Fosgruva Mine

Map reference: Dalsbygda 1620 II, 009388.

Description

The mine is situated at a height of 800 metres above sea-level, in the municipality of Tolga-Os, approximately 10 kilometers from the village of Dalsbygda. It was opened in 1907, and remained operative till 1920. In this period a total of 17,000 tons of ore was produced for export. An analysis of the ore is given below:

S	:	47.4 %
Fe	:	43.4 %
Cu	:	1.1 %
Zn	:	1.1 %
Pb	:	0.003 %
As	:	0.01 %

The mine is flooded and the mine water and seepage from mine waste drain to a small brook which flows to the River Vangrøfta, a tributary of the River Glåma.

On several occasions surveys have been carried out by the mine supervisor and NIVA. Samples have been taken from the stream in the area (Map reference 008392). The analysis results are given in the table below:

Date	pH	Cond. mS/m	SO_4 mg/l	Fe µg/l	Cu µg/l	Zn µg/l	Pb µg/l	Cd µg/l
17/7 -79	4.88	10.2	40	1500	482	352	0.75	1.62
3/7 -80	4.41	10.7	38	2110	460	460	1.05	1.90
13/7 -81	4.59	9.7	38	1400	410	290	0.50	1.55
9/9 -81	5.15	13.1	52	860	400	320	1.05	1.25
6/10-83	3.49	29.2	80	10500	890	700	-	-

Even though the stream in the area must be described as substantially polluted, the quantity of water involved is so modest that it does not appear to affect conditions in the River Vangrøfta.

2.2.11 The Oscar II Mine or Mosen Mine

Map reference: 1619 I, Tynset.

<u>Description</u>

The mine was first opened in 1882, and abandoned in 1916, with activity at its peak in the years from 1889-91 and 1916-18. The waste heaps were established in the years 1882-84, 1889-91, and 1916-18.

The stream from the mining area receives seepage from mine waste and mine water and joins the River Vangrøfta about 10 kilometers downstream of the Fossgruva Mine.

Several samples have been taken from the stream at Map reference 1620 II, 0940328.

Date	pH	Cond. mS/m	SO_4 µg/l	Fe µg/l	Cu µg/l	Zn µg/l	Pb µg/l	Cd µg/l
17/7-79	3.58	41.4	142	1900	3560	823	<0.5	2.9
3/7-80	3.60	35.3	110	1880	3200	660	1.1	2.3
13/7-81	2.88	105.4	508	34700	14400	2730	3.3	10

Concentrations of heavy metals in the stream are considerably higher than at the Fossgruva Mine. However, because the amount of water involved here is relatively small (1-5 l/s), these outflows have presumably no real significance for water quality in the River Vangrøfta.

On several occasions samples have been taken from the River Vangrøfta just below the inflows from the Fossgruva and Mosenggruva mines.

Date	pH	Cond. mS/m	SO_4 mg/1	Fe µg/1	Cu µg/1	Zn µg/1	Pb µg/1	Cd µg/1
17/7-79	7.11	6.74	4.2	60	7.0	<10	<0.5	0.1
3/7-80	7.45	6.90	4.3	90	4.6	10	1.0	0.38

Although the natural concentrations, of heavy metals in the River Vangrøfta upstream of these tributaries is not known, it would appear from these results, that the quality of water in the river is not significantly affected by the outflows from the mine areas.

2.2.12 Folldal Works

Description

The Folldal Works are still operative, but operations are confined to the Tverfjell deposit at Hjerkinn. The old mine areas down in the valley of Folldal are therefore regarded as abandoned.

Ore was discovered in the centre of Folldal in 1745, and production began in 1748. The most important mine was the main mine at Folldal, but a fair quantity of ore has also been extracted from the Northern and Southern Geiterrryggen mines, the Grimsdal mine and the Nygruva mine.Operations at other mines such as the Alvdal, Rødal, Tron and Baugsberget mines, were on a lesser scale.

The pollution situation

The pollution situation in the Folla watercourse is well documented because of the surveys NIVA has carried out for Folldal Works. The principal inputs of heavy metals to the watercourse come from the mine area in the centre of Folldal. Although the area has not been studiedin detail, it is assumed that mine water from the main mine, and effluent from heaps and old tailings are the chief sources of pollution. The extent of pollutant inputs from the other mine areas is not known, but these have probably little significance for the main watercourses of Folla and Glåma. The average transport of pollutant components can be calculated indirectly from data analyses for the River Folla upstream and downstream of the centre of Folldal.

	Copper tons p.a	Zinc tons p.a.	Iron tons p.a	Sulphate tons p.a
Folldal Sentrum	6.6	25.2	120	1056

2.2.13 Other mines attached to Folldal Works

Grid ref.	Mine	Draining to
1619 III 818005	Sivildalen	Sivilla/Glåma
1619 III 864912	Tron (Tronslien)	Storbekken/Glåma
1619 III 817879	Baugsberget	Sølna
1619 II	Lille Tron	Tysta/Rena
1519 II 577898	Southern Geiteryggen	Folla
1519 II 567917	Norhtern Geitryggen	Svensbk./Folla
1519 II 473868	Nygruva	Sveabk./Folla
1519 II flere ref.	Grimsdalen	Grimsa/Folla Gåsåi/Folla
1619 IV 682069	Rødalen	Massjøåa/Einunna/ Folla/Savalen

On an inspection of the mines at Geitryggen in the autumn of 1983, pollution levels were estimated as being low, while little is known about the remaining mines in the table.

Drainage from	pH	Cond. mS/m	SO_4 mg/l	Cu mg/l	Zn mg/l	Fe mg/l
Northern Geit-ryggen	6.82	68.6	276	0.02	3.71	7.23
Southern Geit-ryggen	7.87	139	656	0.72	4.96	3.23

2.2.14 The Røstvangen Mines

Map reference: 1619IV Kvikneskogen 712179, 728179.

Description

The mine is situated 750-950 metres above sea-level at Lake Stubbsjøen, approximately 30 kilometres west of Tynset. Operations were terminated in 1920. In the period from 1906-1920 the total production amounted to 205,000 tons of pyrite for export. The pyrite's 43 mean composition was: 43 % S, 2.65 % Cu, 1% Zn and 0.01% As.

The mine area can be divided into an upper and a lower region. Pollution from the upper mine area, which comes from mine water and run-off from mine waste drained previously to the River Tunna. This outflow has now been diverted to the lower mining area which drains into a few small lakes, none of which have an outlet in any stream.NIVA carried out an investigation of the area in 1977- 78. Two smaller mines belonging to the same company but located 7 kilometresed further west were not includ in the investigation (the Børsjøhø and Finhaug Mines).

Following the diversion of all drainage from the area to lakes which have no surface outlet(?) DØDISGROPER, there have been no indications of abnormal metal concentrations in the two rivers which lie closest, the River Gløta and the River Tunna, or in Lake Stubbsjøen. - NIVAs 1979 report concluded that the unconsolidated material surrounding the lake retained heavy metals so effectively that further measures toe limit th outflows from the area were not necessary for the time being.

The annual mass transport of pollutant components is estimated as follows:

	Upper mine area	Lower mine area	Total
Copper tons p.a	0.4	0.8	1.2
Zinc tons p.a	0.3	0.6	0.8
Iron tons p.a	1.2	10	11
Sulphate tons p.a	23	58	81

2.2.15 Kvikne Copper Works

Map reference: 1620 III Kvikne.

Description

As far as is known, this mine is Norway's oldest pyrite mine, opened in 1631 and finally abandoned in 1912. Estimates put the total amount of ore extracted at 200,000 tons, while copper production has been in the region of 3000-3500 tons. The size of the waste heaps is calculated as being roughly 95,000 m^3. The mine itself is situated in the municipalich of Tynset, but drainage is northwards to the stream of Storbekken, which flows into the River Ya, a tributary of the River Orkla. The River Ya joins the River Orkla at the centre of Kvikne.

NIVA carried out a survey of the area in 1980-81.

The pollution situation

Drainage here is very widely dispersed, and it is difficult to decide whether inputs from waste heaps or mine water contribute most to material transport from the area. The waste heaps are extremely weathered and have generally the characteristics of sand heaps. Because the ore consists of copper-bearing sulphides and pyrite, the main constituents of the outflow are copper, iron, and sulphate.

The pollution has only a local significance, because the waters of the Storbekken stream are diluted very considerably at the stream's confluence with the River Ya. In the River Ya only the copper concentration can be described as being higher than the natural value. Inputs from the area have no effect on water quality in the River Orkla. The situation in the River Ya will deteriorate because hydroelectric power schemes will bring about a decrease in the flow of water. It is unlikely, however, that increased concentrations in the

River Ya will have any effect on fish life in the River Orkla. The River Ya is included in the National Surveillance Programme for Orkla.

NIVA's 1982 report gives the following figures for material transport from the area:

	Copper tons p.a	Zinc tons p.a	Iron tons p.a	Sulphate tons p.a	Sulphate tons p.a
Total Transport	1.0	0.18	4.0	1.1	54

2.2.16 Other mines in Eastern Norway

There has also been considerable mining activity in a number of other areas, where the pollution situation is not known, such as:

Area	Drans to:
Vingelen/Tolga	Glåma
Åsorden/Sel	Gudbrandswatercourse
Glomsrudkollen/Modum	Glitterwatecourse/Lierelva River
	Drammensfjord

2.3 The Trondheim Mining District

2.3.1 Mines belonging to Røros Copper Works

Description

When Røros Copper Mines were closed down in 1977 they were the oldest that were in operation in Norway; it is estimated that production started there in 1644. Only the mines surveyed by NIVA in 1978/79 are included in this section. There are a number of small mines in the area as well. These are mentioned in Par. 2.3.I E.

Over the years Røros Copper Works have exploited a large number of deposits dispersed over an extensive area draining to the main watercourses, Gaula and Glåma. The most important area east of Glåma is the Storwartz field with mines such as Gamle Storwartz (1655), Nyberget (1656), Hestkletten (1659), Solskinn (1673), Kvintus (1691), Ny-Storwartz (1708),and Olavsgruva (1936). West of Glåma the most important are the Arvedal (1657), Sextus (1723), Kongens (1736), and Leirgruvebakken (1972) mines. The Muggruva mine (1774) is located north of the Kongens Mine, draining to the Rugla/Gaula watercourses.

A) The Storwartz Mine area

The tailings represents a pollution threat because it is not secured against spreading and oxidation. The capacity of the dams is insufficient to ensure that the waste is covered with water.

Moreover there is a relatively large bank of tailings at the point where the Storwarts brook flows into Lake Djupsjøen. Due to the fact that the dam at the outlet of Lake Djupsjøen is poorly maintained, there is a danger that the bank will be exposed, representing a potential increase in pollution in the watercourse. In order to clarif the situation, a closer investigation is desirable. Pollution inputs from the Olavsgruva and Solskinnsgruva mines are of little significanc.

Infiltration water from the watercourse (Hittersjøen) is used as a water supply by the municipality of Røros.

B) The mine area of the Kongens, Sextus, and the Leirgruvebakken - Mines.

It is in this area that the chief sources of heavy metal inputs to the River Glåma are to be found. The area around Sextus drains to Lake Orvsjøen, where fish can no longer survive due to the concentrations of heavy metals. The Arvdalen and Kongens Mines are treated as one area.

Waste containing pyrite from the final period of operations at Leirgruvebakken Mine has been dumped in Lake Orvsjøen. An investigation of the present-day effects of these waste masses on Lake Orvsjøen is planned. Drainage conditions at the Kongens Mine are complicated, but the River Orva receives considerable quantities of heavy metals both from the mine and from the old tailings pond. It is not known whether or not there has been any negative development in the composition of the ground water after the abandonment of operations at the Leirgruvebakken Mine.

Analysis results of samples of mine water at the Leirgruvebakken Mine, 9/2-77.

	pH	Cond. mS/m	Turb. FTU	SO_4 mg/l	Ca mg/l	Mg mg/l	Fe mg/l	Cu mg/l	Zn mg/l
Unfiltered	8.61	41.3	220	71	44	10	29	2.95	6.8
Filtered	-	-	-	-	-	-	0.48	0.06	0.18

Although the River Orva is heavily polluted, the heavy metal load in the Glåma watercourse does not constitute a threat to fish in the river. However problems may arise in situations that affect the flow of water unfavourably, such as when there is a low water flow in the River Glåm as against a high flow in the River Orva.

Any measures taken in the area to improve the pollution situation will demand considerable financial investment.

C) The Muggruva Mine

The Muggruva Mine has only been inspected once on 3/9-79. The provisional conclusion was that there was no need for immediate investigation. Although samples take here were undoubtedly affected by heavy metal drainage, the pH values of the samples were surprisingly high.

Analysis results for samples taken on 3/9-79:

Component	Mine water	Mine water + discharge from tips	Stream below flowing east	Stream north of the area
pH	7.4	6.6	4.3	6.8
Cond. mS/m	12.7	16.1	16.4	6.16
SO_4 mg/l	28	60	60	16
Fe µg/l	130	50	250	60
Cu µg/l	657	1711	4100	265
Zn µg/l	310	570	512	128
Cd µg/l	1.1	1.3	1.0	0.32
Ca µg/l	18.7	19.8	10.4	7.5
Mg mg/l	1.9	3.3	3.3	1.1
Water flow l/s	<5	5-20	5-20	5-20

A number of the most significant material transport values revealed in the NIVA report on the Røros Copper Works (1980) are indicated below:

		Kongens	Sextus	Total for River Orva	Storwartz
Iron	tons p.a	47.5	8.7	-	12.4
Copper	tons p.a	1.8	1.4	4	1.6
Zinc	tons p.a	16.1	4.0	28	7.2
Cadmium	kg. p.a	16	8.7	-	12.7
Sulphate	tons p.a	237	51	-	155

D) <u>Hessdalen</u>

Map reference: 1620 I Haltdalen

1620 II Dalsbygda

<u>Description of the pollution situation.</u>

Several mines are to be found in this watercourse, and operations have taken place in two separate periods, firstly from 1670-1693, and secondly from 1830-1833. In addition to outflows from dumps and mine water, the watercourse also receives natural inputs of metals from exposed ores.

NIVA has not undertaken any systematic survey in the watercourse, but a number of samples were taken in connection with an inspection carried out in 1977.

Below are the results from samples taken on 22/6-77.

Grid ref	Name	pH	Cond. mS/m	SO_4 mg/l	Ca mg/l	Mg mg/l	Cu µg/l	Zn µg/l	Fe µg/l
1620 II 103531	Kjøla	6.67	5.12	3.0	5.0	0.50	6.5	<10	100
1620 I 111610	Storhesja	6.72	2.41	1.5	2.0	0.30	8.5	<10	40
1620 I 112642	Mine water	3.13	107.7	400	80	28	5000	7800	900
1620 I 118678	Hesja	6.30	2.96	1.7	2.1	0.35	13	10	60

The results do not indicate that drainage from the mining areas affects the main watercourse, Hesja, in any significant way. In the sample which is taken from the River Hesja downstream of the mine areas, the copper value is somewhat higher than natural background values.

E) <u>Other mines in the Røros field draining to Glåma</u>

Grid ref.	Mine	Draining to	Remarks
1720 III	Klinkenberg	Jamtbekken - Aursunden	
1720 III	Abrahams Mine	Aursunden	
1720 III	Klasberget	Aursunden	
1720 III	Lossius	Harsjøen-Hitterwatecourse	
1720 III	Rauhammer Mine	Harsjøen-Hitterwatercourse	Chromium Mine
1720 III	Fjellsjø Mine	Greater Fjellsjøen	
1720 III	Rødalen	Røa - Glomma	
1720 II	Feragen Chromium mining field	Røragen - Feragen - Håelva Geitsjøen-Geita-Håelva	Sample of stream flowing into Røragen Grid ref. 455408 collected 5/7-78 by NIVA Cu: 7.6 µg/l Cr: 2.0 µg/l Ni. 28 µg/l

F) Other mines in the Røros field draining to Gaula and Tya.

In the Røros mining field there are many mine areas that have not been checked. Pollution inputs from these are assumed to be tiny or diluted in larger water courses, so that pollution is confined to smaller brooks or watercourses.

Grid ref.	Mine	Draining to	Remarks
1720 IV 225814	Rauhammaren	Holta - Gaula	
1720 IV 287692 292698	Menna Mines	Stormeina-Gaula	No effects can be traced in River Meina
1720 IV 300705V	Guldals Mine	Lille Meina-Gaula	
1720 IV 195796	Kårslåtten	Lille Rena-Gaula	
1720 IV 362792 362796	Grøndalen	Grønsjøen - Tya	
1720 IV 348848	Allergot	Grønsjøen - Tya	
1720 IV 166648	Stor- høgd Mine	Rugla - Gaula	Belonged to Røros Copper Works
1720 IV 161661	From Mine	Benda-Gaula	- " -
1720 IV 143675	Rogn Mine	Benda-Gaula	- " -

2.3.2 The Kjøli Mines

Map reference: Alen 1720 IV

The mine is situated on the south flank of Mount Kjøli- fjellet, approximately 1050 metres above sea-level. The mine area drains to the Storbekken stream which comes from the northern stretch of Lake Kjøli-tjern. The stream flows into the upper reaches of the River Gaula.

In two periods from 1766-98, and 1857-68 copper was extracted, and a total of about 250 tons of metallic copper was dispatched from the mine. In the years from 1896-1907 and 1910-1920 pyrite was extracted. The total production amounted to some 201,000 tons of pyrites for export. The principal dumps were probably established in the period from 1896-1920, and have a total volume of approximately 80,000 m^3.

The area was surveyed by NIVA in 1977/78 and the findings were published in a report in 1979.

Annual mass transport from the area was calculated as follows:

	Copper tons	Zinc tons	Iron tons	Sulphate tons
Mine water	0.4	0.05	5.3	36
Seepage from tips	2.3	0.11	22	102
Total	2.7	0.16	27.3	138

Furthermore, it was discovered that drainage from the mining area contributed some 42% of the copper inflow to the River Gaula, upstream of Reitan Station. (6 kilometers downstream from the input from Killigdal Mine).

On the basis of the report's conclusions, the Department of Industry undertook measures to renovate and lime the dumps in July-Septemer 1981. The heaps were levelled out, and 100 tons of hydrated lime ($Ca(OH_2)$) added.

NIVA has followed up this scheme with a measurement programme. No reduction in the amount of metal inputs from the area had been registered by the end of 1983.

2.3.3 The Killingdal Mine

Map reference: 1720 IV, Ålen 262652.

The mine is still operative, but the old mining complex, located at a height of 900 metres, was abandoned in 1968. There are two ore deposits, one of which, the Nordre Mine, was found in 1674, while the other, the Søndre Mine, was found in 1793. Ore in the former has the following composition : 1.1 % Cu, 7.0 % Zn, and 27 % S; in the latter the ore's composition is : 1.7 % Cu, 3.5 % Zn and 42 % S. Operations were sporadic up to 1850. From 1953 onwards, the pyrite has been dressed at the company's flotation plant in Trondheim. So far a total of approximately 3 million tons of crude ore have been extracted.

The pollution situation

Drainage from the abandoned mine area runs into the Gruvebekken brook which flows into the River Gaula. In addition, mine water is pumped out into the stream.

An investigation was carried out by NIVA in 1977/78. The findings were that discharge from the mining area was responsible for 58 % of copper transport, 99 % of zinc transport, 73 % of iron transport, and 63 % of sulphate transport in the River Gaula upstream of Reitan Station.

The annual mass transport was calculated as:

Copper	:	37	tons
Zinc	:	25	"
Iron	:	79	"
Sulphate	:	238	"

2.3.4 The Nyberget Mine (The Indset Mine)

Map reference: 1520 II, Innset 560534.

The mine is situated on the River Orkla, upstream of Innset.

Pollution inputs from the mine area are judged to be limited, and are probably of significance only during periods of thaw and heavy precipitation.

The deposit consists of pyrite with a low copper content.

2.3.5 Undal Works

Map reference: 1520 I Rennebu 535661.

The mine lies at Berkåk on the River Skauma,a tributary of the River Orkla, at a height of 490 metres above sea-level. Between 1650 and 1971 there have been several phases of mining operations, with a peak of activity from 1952 till the abandonment of the mine in 1971. The total production of crude ore is estimated at 300,000 tons. There are no waste piles in the area, but ore-bearing gangue has been used as backfill in the mining area along the River Skauma.

NIVA carried out a brief investigation of the area in 1980-81.

Pollution

Although pollution inputs from the area are modest, the of concentrations heavy metals in the River Skauma are so high, that the river is affected to a considerable degree. The River Skauma flowser into the Riv Orkla downstream from the Brattset Power Station, so that an adequate supply of water to dilute heavy metal inflows is ensured for the future.

Material transport from the area is estimated as:

Copper kg/p.a	Zinc kg/p.a	Iron kg/p.a	Cadmium kg/p.a	Sulphate kg/p.a
176	536	6700	3	63.000

2.3.6 Løkken Works

The pollution situation at Løkken has many different aspects. Earlier operations (1654-1974) account for the major share of pollution. The mine is still operative, and is dealt with in a NIVA report on the pollution situation in the centre of Løkken (NIVA 1983).

The mine area drains to the Raubekken brook which is heavily polluted. The stream is presently diverted to the Svorkmo Power Station, and flows out into the River Orkla at Svorkmo.

2.3.7 Dragset Works

Map reference: 1521 III 273012.

Description

The mine is situated in the municipality of Meldal, and the mine area drains to Lakes Ringevatn and Hostonvatn, which have an outlet in the River Vorma, a tributary of the River Orkla.

Løkken Works ran the mine, with production starting up in 1867, and ending in 1909. The peak of activity occurred towards the end of the 1890's, and the total production of crude ore is estimated at 100,000 tons.NIVA carried out an inspection of the mine area in 1980-81, and of Lakes Ringevatn and Hostonvatn in 1975/76.

The pollution situation

NIVA's investigations concluded that, while pollution inputs from the mine area are considerable, they only affect local water-courses, and are of no consequence for the River Orkla downstream of its confluence with the River Vorma.

The concentrations of heavy metals in Lakes Ringevatn and Hostonvatn, where there is a good stock of trout, exceed the level where one can expect toxicity. The fact that there is a stock of trout in these lakes can probably be attributed to the speciation of the heavy metals. Investigations have shown that even minor changes in an unfavourable direction will lead to toxicity.

Pollution inputs have been localized to a definite area where measures can be taken to reduce the load on the lakes further down.

The annual mass transport from the area is calculated at:

Copper	Zinc tons/p.a	Iron tons/p.a	Cadmium kg/p.a	Sulphate tons/p.a
1,6	2,2	4,7	6,4	65

2.3.8 Høydalsgruva Mine

Description

The mine was operated periodically from 1659 to 1911 by Løkken Works. Drainage occurs via a network of streams to the River Svorka, a tributary of the Orkla river.

No systematic investigations have been conducted to determine input, but NIVA has sampled the stream from the area on two occasions.

Grid ref.	Date	Water flow l/s	pH	Cond. mS/m	SO_4 mg/l	Cu mg/l	Zn mg/l	Fe mg/l	Cd µg/l	Al mg/l	Ca mg/l	Mg mg/l
378989	820930	ca.10	2.88	161	765	3.36	21.3	115	70	24	503	17.4
398019	820924	-	-	-	-	0.018	0.13	0.46	0.44	-	-	-

The results show that although the stream is considerably polluted, the run-off has no real significance for conditions in the River Svorka.

2.3.9 Other mines belonging to Løkken Works

Aamodt Mines

Grid reference: 1521 II, Hølonda 418004.

The mine area drains to the River Svorka. No investigations have been made of the pollution situation, but inputs are assumed to be minimal, so that conditions in the River Svorka are unlikely to be affected.

Grefstadfjell Mines

Grid reference 1521 II, Hølonda 369927, 372921

Run-off from this area is received by a small brook which flows into the River Orkla at the centre of Meldal. The pollution situation has not been investigated, but it is believed that discharge is negligible, and there is no trace of it in the Orkla river downstream of Meldal (National Environtment Monitoring Programme for Orkla).

2.3.10 Lillefjell Mine

Map 1721 I, Meråker

Description

The mine was first opened in 1761, and was abandoned in approximately 1890. Mining activity was at its height in the years between 1876 and 1880. Altogether a total of some 100,000 tons of ore and shale have been extracted.

Water from the mine and the dumps drains to the Dalåen river, a tributary of the River Stjørdalselva, joining it at Meråker.

Assessment of results

Sampling of the stream below the dumps catches outflow from them as well as drainage water from the lowest adit. The results of sampling at Grid Ref. 390167 are :

Date	Water flow l/s	ph	Cond. mS/m	SO_4 mg/l	Cu µg/l	Zn µg/l	Fe µg/l	Cd µg/l
17/6-8	5 - 20	3.71	21.4	63	2290	5360	4380	9.0

These results show that discharge from the area is extensive and may well affect conditions in the Dalåen river. However, the water flow in the River Stjørdalselva is so great that it is unlikely to be affected by the smaller Dalåen watercourse.

2.3.11 Gaulstad I

Grid reference: 1722 I, Vuku 597965.

Description

The mine area is located south of Lake Snåsavatnet.

The mine was initially opened in 1764, and abandoned in 1980, with activity at its height in the years 1770-1786 and 1830-1840. Cupriferous pyrite and pyrite dominate. A total of 1624 tons of ore has been extracted. Drainage is to the River Mokkaelva, a tributary of the Ogna watercourse.

Assessment of analysis results

Analysis of samples from the stream that receives half of the run-off from the mine area (Grid ref.: 598967), produced the following results:

Date	Water flow l/s	ph	Cond. mS/m	Ca mg/l	Mg mg/l	Cu µg/l	Zn µg/l	Fe µg/l	SO_4 mg/l	Pb µg/l	Cd µg/l
18/6-81	1 - 5	4.35	5.48	1.83	.78	420	60	68	9.0	0.6	0.4

It is evident that oxidation of cupriferous pyrite is occurring in the catchment area. Even so, the main watercourse is unlikely to be affected by the outflow due to the minimal water flow in the stream. A low calcium value suggests that water quality in the catchment area can only tolerate relatively small inputs of heavy metals before toxicity develops.

2.3.12 Tjerngruben Mine

Grid reference: 1722 I, Vuku 597965

Description

The mine, which is located in the vicinity of Gaulstad, was originally opened in 1764, and was operated jointly with the Gaulstad I mine. Exploratory operations have taken place on one occasion, with two small shafts connected by an adit in production. Mine water drains to a lake which has an outlet to the River Mokkaelva via a stream.

Assessment of results

Sampling of the lake's outlet gave the following analysis results:

Date	Water flow l/s	ph	Cond. mS/m	Ca mg/l	Mg mg/l	SO_4 mg/l	Cu µg/l	Zn µg/l	Fe µg/l	Pb µg/l	Cd µg/l
18/6-81	< 1	4.82	3.21	1.48	0.50	4.7	150	20	56	0.95	0.30

Although the outlet of the lake is clearly affected by the weatering of cupriferous pyrite it seems that the discharge is not of such a scale as would affect water quality in the watercourse below.

2.3.13 Other mines in the Trondheim District

Quite a number of smaller mines in the Røros district are mentioned in Sections 2.3.1 E and F, Røros Copper Works. In addition the following may be mentioned:

Area:	Draining to:
Selbu Copper Works	Tya
Fonnfjell	River Meråkerelva
Mannfjell	" "
Malså copper Works	Skjærdal/Verdalswatercourse
Gjersvika (Grong Mines)	At Limingen
Svanø Mine	At Florø

On later inspection in the autumn of 1984, there was no excessively acid run-off in brooks that receive drainage from the Mannfjell area. Nor does the River Meråkerelva appear to be affected by mine water pollution. Otherwise there are no data on the pollution situation in the area.

A small brook containing effluent from the deposit at Gjersvika flows towards Limingen, but it is unlikely that conditions in the river are affected.

At Svanø, 12 kilometres south of Florø, there has been extensive mining activity in the period from 1909-1919. The mining area consists of three deposits close to each other. The mines are situated two metres above sea level.

2.4 The Northern Norway Mines District

2.4.1 Bossmo Mines

Grid reference: 1927 I (595 576).

Description

The mines lie at the end of the Ranafjord, at Mo i Rana.

There have been continuous operations at the mine in the period from 1894-1921, and a total of approximately 526,000 tons of ore for export has been produced. Estimates put the total of crude ore extracted at 1.5 million tons.

The main components of the pyrite are given as:

48.3 - 49.9 % S
42.9 - 44.1 % Fe
0.39 - 0.47 % Cu
0.31 - 0.50 % Zn

Although there has been no survey of the pollution situation, an analysis of samples from the stream receiving effluent from the mining area gave the following results:

Date	pH	Cond. mS/m	SO_4 mS/l	Cu mg/l	Zn mg/l	Fe mg/l	Pb µg/l	Cd µg/l
830928	2.90	102.5	412	2.87	2.67	79	2.5	8.3

The stream flows through a residential district to its outlet in the Ranafjord. The Ranafjord may be affected locally.

2.4.2 Other mines in the Rana area

In the neighbourhood of Rana there are several mines in operation. No investigations of the pollution situation at other abandoned mine areas have been conducted, but the following two locations should be inspected:

Malmhaug Mine (Grid reference 2027 IV).

Pollution discharges are believed to be modest.

Rødfjeld Mine (Grid reference 2027 IV).

The mine was opened in 1911, and abandoned in 1970. Totally, production amounted to 52,000 tons of pyrite for export. Drainage conditions are not known, but input is estimated to be negligible.

2.4.3 The Sulitjelma region

In the Sulitjelma region a number of small deposits have been worked. Abandoned mining areas such as Jakobsbakken and Ny-Sulitjelma are the source of metalliferous, acid drainage, which runs off to Lake Langvatn. A closer inspection of the water in the Lake Langvatn region reveals that only a few lakes are affected by heavy metal pollution (NIVA 1980). At present, mining is still continuing at Sulitjelma, and the tailings are dumped in Lake Langvatn. Heavy metal concentrations in the Lang watercourse are so high that no fish can survive (NIVA 1979). This is chiefly caused by current mining operations, therefore the area will not be presented in more detail here.

2.4.4 Bjørkåsen Mines

Grid reference: 1331 I

The mine is located 50 metres above sea level close to Balangen in Balangen municipality.

The mine was opened in 1915, and abandoned in 1965. Effluent reaches the sea via a brook. Despite the fact that heavy metal concentrations in the stream can be considerable, run-off from the area is estimated as being minimal. It is not known whether drainage affects conditions in the sea.

Results for samples taken from the stream:

Date	pH	Cond. mS/m	SO_4 mg/l	Fe mg/l	Cu mg/l	Zn mg/l
6/10-75	6.10	155	1000	43.8	0.02	1.12

2.4.5 <u>Tårstad Pyrite Mines (Tårrestad Copper Works)</u>

Map: 1331 IV Evenes.

<u>Description</u>

The mine was initially opened in 1636, and abandoned in 1939-40. Activity reached a peak in the years 1906-07. Drainage in the area runs off to the River Tårstadelva/Lavangseidet. Test samples from the mine area do not indicate any outflow of heavy metals that need cause concern.

<u>Results</u>:

Date	Sample	pH	Cond. mS/m	Fe µg/l	Cu µg/l	Zn µg/l	SO_4 mg/l	Water flow l/s
790704	Drainage from shaft (main shaft)	7.77	43.1	160	5.0	290	63	< 1
"	Draiage from shaft Jacob-sensshaft)	7.33	111	330	3.5	19	596	< 1

2.4.6 <u>Repparfjord</u>

Grid reference: 1935 I Repparfjord.

Although the deposit was discovered at the turn of the century, the mine was first worked in 1972 by Folldal Works. Operations were abandoned in 1978.

The ore was retrieved by open-pit mining. Tailings from the dressing plant were discharged into the Repparfjord, it is not known how this has affected conditions in the fjord.

2.4.7 Bidjovagge

Map reference: 1833 III, IV.

The Bidjovagge mines are located in the Caskias Massif, and drainage is to the Alta/Kautokeino watercourse. Operations commenced in 1968, while the dressing plant started up in 1970. The mine was abandoned in 1975. Control tests carried out in the watercourse do not currently indicate any significant discharge of heavy metals. The initial investigation of the Alta watercourse (NIVA 1981) reveals that the River Stuorajavre, for example, is not noticeably affected by mine pollution.

Results:

Date	Sample	pH	Cond. mS/m	SO_4 mg/l	Fe µg/l	Cu µg/l	Zn µg/l	Pb µg/l	Cd µg/l
830912	Mine Water	8.05	59.7	230	30	2.6	30	1.3	<0.1
"	Final holdin pond(?)	7.86	39.9	140	60	3.8	<10	0.7	<0.1

2.4.8 Birtavarre

Grid reference: 1634 II Kåfjord and 1633 I Manndalen.

Birtavarre Copper Works were operative in the period from 1889- 1919. Measured by contemporary standards, production was sizeable. Starting in 1910, 2500 tons of copper were smelted in the smelting works.

The pollution situation in the watercourse which flows into Kåfjord at Lyngen, is not recorded.

2.4.9 Other mines in the Northern Norway Mines District

Grid references:

Vaddas mines	1734 IV	Nordreisa.
Middavarre mines:	1734 I	Kvænangen.
Alta Copper mines:	1834 I	Alta.

Since these mines are situated close to the sea, any water pollution effects will presumably be restricted to a confined area round the mines. The pollution situation is not more precisely known.

3. THE SIGNIFICANCE OF SEEPAGE FROM ABANDONED MINE AREAS FOR SOME LARGER WATERCOURSES

3.1 Pollution inflows to Glåma from abandoned mines

At Røros three rivers meet: the River Glåma from Aursunden, the River Orva and the River Håelva. The River Orva comes from Lake Orvsjøen, which receives drainage from the Christianus Sextus Mine, the Kongens Mine, and the Orvdalens Mine (Fig.2).

In 1978-79 samples of water were collected and flow readings recorded in areas considered to be the principal transport routes for metalliferous outflow in the Røros district. Following a preliminary inspection, four measuring sites in the Orva catchment area were selected.

Estimated inflows to Lake Orvsjøen from the Sextus Mine area are tabulated below. The recorded inflows to the lake from the mine only constitute part of the total inflow of pollutants. Transport values out of Lake Orvsjøen indicate that precipitation of copper has taken place, whereas zinc transport out of the lake exceeds recorded inflows. Drainage conditions at the Kongens Mine/ Orvdalens Mine are rather complex. Heavy metal transport is computed at the outlet of the lower sludge dam, but, in addition, metalliferous mine water drains directly to the River Orva. Following an evaluation of various inputs in the river in 1978-79, metal transport for the river's lower stretch was determined to be 4 tons Cu and 28 tons Zn annually.

	Cu tons p.a.	Zn tons p.a.	Cd kg p.a.	Fe tons p.a.	SO_4 tons p.a
To Lake Orvsjøen from Sextus	1.4	4.0	8.7	1.6	51
Out of Lake Orvsjøen	1.2	8.2	(0.2)		140
Lower shidge pond					
Kongens Mine	1.8	16.1	16	47	237
Storwartz Lower pond	1.6	7.2	12.7	12.4	155
Olavsmine Mine water	0.2	0.3	0.5	4	9
Solskinnsmine					

Water quality in the Orva river was recorded in connection with the 1966-1980 survey of the Glåma. At a mean water flow of 0,8 l/s, transport can be roughly estimated at 6 tons Cu and 40 tons Zn on a yearly basis. Even though the available data are sparse, the two methods of calculation give transport values of similar magnitude. This implies elevated metal concentrations in the River Orva, where there is no fish life.

Drainage from the sludge ponds in the Storwarts mine area results in discharges of heavy metals in Lake Djupsjøen. and subsequently to Lake Hittersjøen. The concentrations are lower than those recorded in drainage from the dams at the Kongens mine, but transport is considerable, due to the volume of water. The watercourse flows into the Håelva river just above the latter's confluence with the River Glåma. Transport from the Storwartz area far exceeds that found in mine water from the Olavsgruva and Solskinnsgruva mines. However, these inflows are diluted and neutralized to some extent prior to their reaching the River Glåma. In the case of the River Håelva, it does not appear that the cobalt mine areas at Feragen contribute elevated metal concentrations to the river. In contrast, inputs from the Storwartz area appear to cause significant increases in the Cu- and Zn-concentrations in the Håelva river.

The impact of inflows from both the River Orva and the River Håelva can be observed in the Glåma river at Røstefossen, where metal concentrations are approximately twice as high as those found in the river at Glåmos according to a survey carried out in 1979-81 (NIVA 1982). Glåmos may be regarded as a reference site since the abandoned mines in the Aursunden catchment area are most probably of little significance. The River Orva, however, shows higher metal concentrations than the River Håelva.

Further down the watercourse the largest heavy metal concentrations are in the River Folla. In 1982, the mean annual concentrations of copper and iron in the river prior to its confluence with the Glåma river exceed those recorded in 1979/80 for the Glåma at Tellneset. However, the data analysed are insufficient for the conclusion to be drawn that this is an overall trend.

No systematic analyses of metal ions have been carried out further down the watercourse, but we assume that concentrations are low. In such conditions moss can be utilized to detect metal, and moss surveys of this nature were performed in 1980 and 1981 in Glåma (NIVA 1984 in prep.). Moss was placed in the watercourse and collected 3-4 months later. Presumably concentrations of metal in the moss will vary in accordance with the mean concentration of metals in the water over the same period. Moss downstream of the Glåma's confluence with Orva showed far higher metal concentrations than moss positioned at a weference site upstream Orva. In the River Håelva moderate heavy metal concentrations were measured the first year, while in the second year much higher concentrations were read. The three sites located on the stretch from Røstefossen, below the confluence of Håelva and Glåma, down to Stai, gave elevated metal concentrations although values decreased down the watercourse. In the Folla River, concentrations of metals in the moss were somewhat higher than were found in Glåma, downstream of their confluence. The surveys of moss indicate that, even though metal concentrations in water from the Glåma river show low values for the stretch below Røstefossen, a gradient of decreasing heavy metal concentrations can be observed down the watercourse. This is to be expected since heavy metal inflows to the watercourse are presumably more extensive from the abandoned mining areas at Røros than further down the watercourse. Nevertheless, inflows from the River Folla and other tributaries that are less seriously affected by mine drainage may be a contributory factor to heavy metal concentrations in the moss in excess of the background level at Stai.

Annual median concentrations of heavy metals at stations in the Glåmos's northerly catchment area. The number of observations is given in brackets. Sampling in the River Håelva has taken place upstream and downstream, respectively, of the seepage from the Stortwartz mine area via Lake Djupsjøen (NIVA, in publication).

Year	Parameter	Copper µg Cu/1	Zinc µg Zn/1	Cadmium µg Cd/1	Iron µg Fe/
Glåmos					
1978		-	-	-	40.00 (3)
1979		4.15 (2)	<10.00 (2)	0.20 (2)	15.00 (7)
1980		5.30 (3)	10.00 (3)	0.64 (3)	30.00 (4)
Orva					
1978		131.00 (1)	1100.00 (1)	1.60 (1)	-
1979		217.50 (2)	959.00 (2)	1.75 (2)	245.00 (2)
1980		280.00 (3)	1960.00 (2)	2.55 (3)	1650.00 (4)
Håelva upstream					
1979		4.40 (2)	<10.00 (2)	0.20 (2)	140.00 (2)
1980		2.50 (3)	<10.00 (3)	0.90 (3)	95.00 (4)
Håelva downstream					
1978		25.00 (1)	70.00 (1)	0.45 (1)	140.00 (3)
1979		26.50 (2)	104.00 (2)	0.38 (2)	160.00 (7)
1980		18.00 (3)	60.00 (3)	2.30 (3)	175.00 (4)
Røstefossen					
1978		14.00 (1)	20.00 (1)	<0.10 (1)	120.00 (3)
1979		9.90 (2)	29.50 (2)	0.25 (2)	80.00 (7)
1980		9.70 (3)	50.00 (3)	0.48 (3)	105.00 (4)
Tellneset					
1978		-	-	-	95.00 (3)
1979		11.50 (2)	29.50 (2)	0.25 (2)	90.00 (7)
1980		10.00 (3)	50.00 (3)	1.80 (3)	125.00 (4)
Folla/Gjelten Bridge (before Sølna)					
1982		26.5	50.0	0.17	480

3.2 The Gaula

Figure 2 also shows that several abandoned mines drain to the River Gaula. The more inportant of these are Kjøli and Killingdal (the old mine), and, further down the watercourse, the mines of Stornøgd, Rogn and From, as well as the Hesjedal mines. At Reitan Station the metal concentrations in the Gaula exceed EIFAC's norms for satisfactory water quality. An investigation by NIVA in 1979 concluded that the two mines, Killingdal and Kjøli are the main sources of heavy metal pollution in the upper stretches of the Gaula. Annual transport of copper from Killingdal was calculated at 3.7 tons ,a figure that is 1.4 times greater than the input from Kjøli in 1977/78. Zinc input from Kjøli is negligible in comparison with the zinc input from Killingdal.

The significance of inputs from Stornøgdhøgda,and Rogn and From, for water quality in the Gaula is not known. The impact of the Hesjedal mines on the River Hesja is probably minimal because the river has an extensive catchment area.

As a consequence of discharge from mine areas no fish life is to be found in a long stretch of the River Gaula. In a letter of 9 August 1977, the Fisheries Research Station at Ås reports heavy metal analyses from the Gaula at Haltdalen and Ålen. Metal concentrations at Ålen were clearly elevated. In the period from 1965-77 metal concentrations varied from 60-900 µg Zn/l and 10- 250 µg Cu/l. At Haltedalen concentrations were considerably lower.

The water quality and the effect on biological conditions, however, has not been investigated in detail. Most probably inputs from both operative and abandoned mines are a significant factor. Presumably, the Gaula is mainly affected when the flow of water is low, but variations in the water quality are not known more precisely. Furthermore, there has been no evaluation of the impact of abandoned mines downstream of Reitan.

At Kjøli, wide-ranging measures have been undertaken, partly to level out the area, and partly to reduce pollution levels in the outflow. In consequence, water quality in the Kjøli river is being recorded with the aim of evaluating the effectiveness of the measures. Moreover SFT receives frequent control analyses from Killingdal. However, it is not known how water quality in the River Gaula is affected by the various sources.

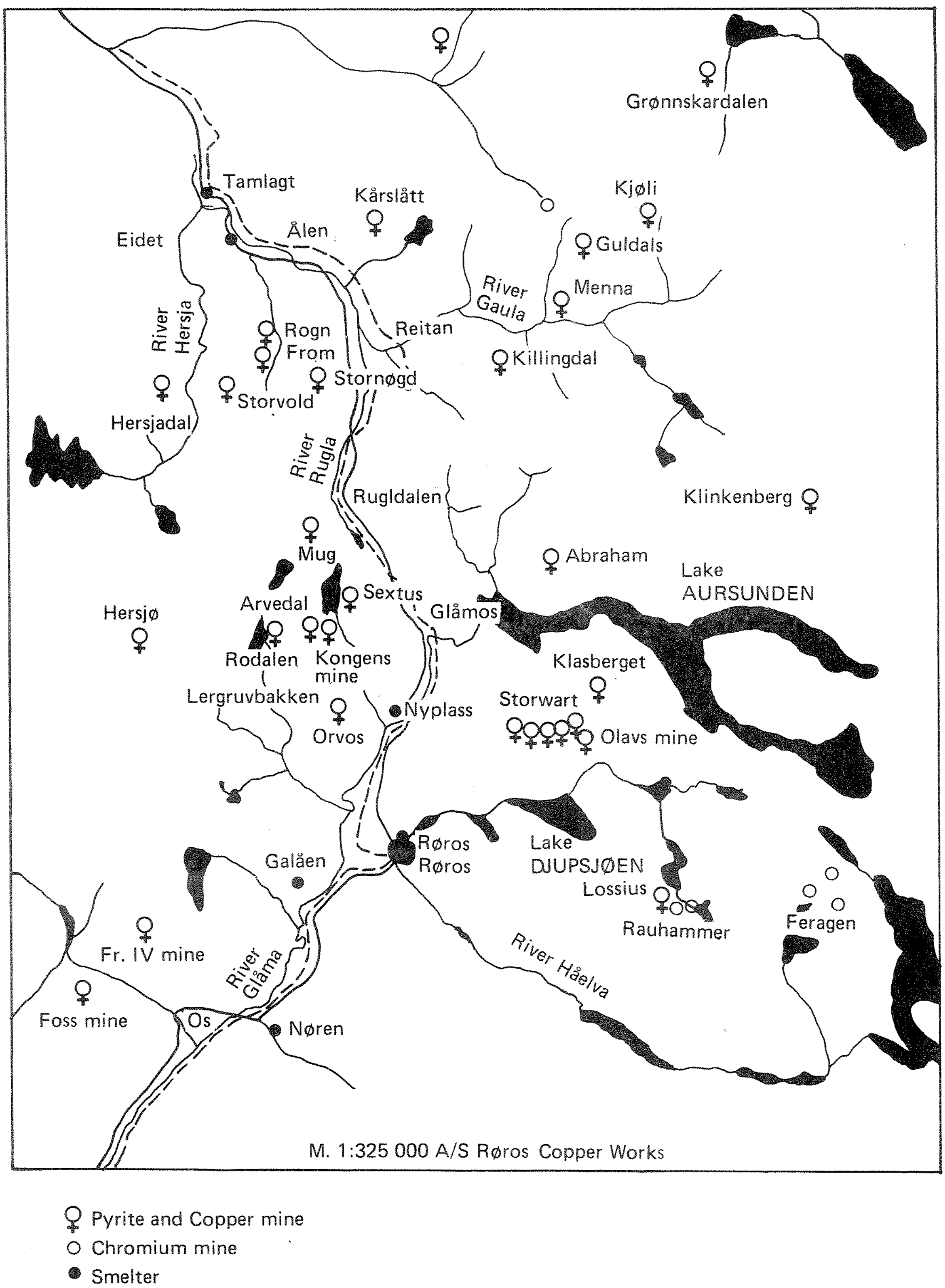

Fig. 2. Abandoned mines in the Røros area. Some of them are not mentioned in the text.

Mines and smelting Works in the Røros area.

Copper and pyrite mines
Chromium mine
Smelting works

3.3 The Orkla and its tributaries

The length of the River Orkla from its source in Lake Orkelsjøen in the valley of Oppdal to its outlet in the Orkdalsfjord is 170 kilometres. The catchment is extends to approximately 2,700m^2.

In Fig.3, the mine areas of greatest significance for water quality in both main and subsidiary watercourses are indicated on a sketch-map of the watercourse.

At the present time, a hydro-electric power development is underway in the Orkla watercourse, and power-stations as well as regulated flows are also given in Fig.1.

The following large mining areas drain to the watercourse:

Area	Draining to
Kvikne Copper Works	Ya
Nyberget (Indset)	Orkla at Innset
Undal Works	Skauma
Grefstadfjellet mines	Orkla at Meldal
Dragset Works	Vormawatercourse
Løkken Works	Raubekken
Høydalsmines	Svorka
Aamodtmines	Svorka

Individual areas are described earlier (2.2.15, 2.3.4, 2.3.10). Water quality and hydrobiological conditions have been verified in investigations carried out by NIVA and in connection with the National Environment Manitoring Programme which is in progress in the watercourse.

The results of these investigations verify that only the discharges from the Løkken mine area are of such magnetude as to clearly affect the main watercourse. Concentrations of heavy metals in the Orkla river downstream of the mouth of the Raubekken stream have reached concentrations critical for the survival of salmon in the river.

The Raubekken stream was diverted to the River Svorka in the autumn of 1983, and is now channelled to the River Orkla via the Svorkmo power station. At the present time the data available are inadequate for any conclusion to be drawn regarding the effect of this regulation.

The remaining mine areas are of little significance for conditions in the Orkla itself, but from time to time slightly elevated copper values can be detected in the entire watercourse upstream of the mouth of the Raubekken brook. However, there have been no indications of any effects in the main watercourse as a result of heavy metal inputs from the remaining areas.

In the case of the subsidiary watercourses, Ya is affected by drainage from Kvikne Copper Works. There will be a deterioration in conditions here when the regulation of Lake Falningssjøen is completed. It is uncertain whether conditions in the River Orkla in the vicinity of Kvikne will be affected by elevated heavy metal concentrations brought about by a reduction in water flow.

Outflow from the Nyberget area is estimated as negligible, nor does it pollute any local watercourse.

The River Skauma is severely affected by metal discharge from Undal Works, but because the Skauma flows into the Orkla downstream of the Brattset Power Station, it is unlikely that the inflows have any significance for the Orkla.

Drainage from Dragset Works reaches the Vorma watercourse via two lakes, Lake Ringevatn and Hostonvatn. Heavy metal concentrations in the watercourse upstream of Lake Ringevatn are too high for salmonid. However in Lake Ringevatn itself, and also in Lake Hostonvatn, there is a stock of trout, despite the fact that the concentrations of heavy metals would lead one to expect toxicity.The speciation of the heavy metals is presumed to play a major role in determining biological conditions in the watercourse.

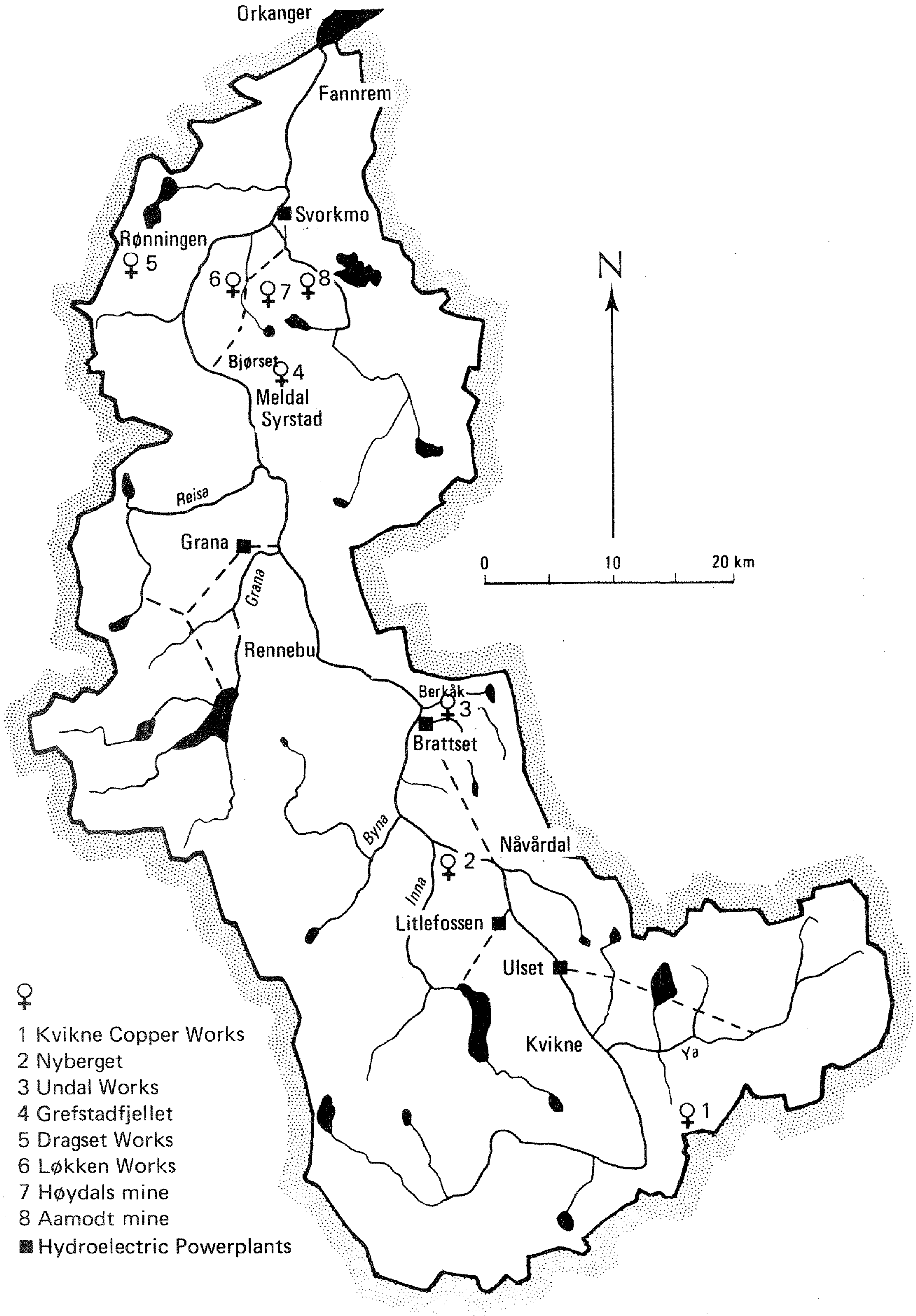

Fig. 3. Mines in the river Orkla basin.

Although it is assumed that drainage from the Høydalsgruva Mine has a noticeable local effect on the stream system leading to the Svorka river, conditions in the Svorka itself do not show evidence of this. The Aamodtgruva Mine possibly causes pollution locally, but the area has not been investigated.

4. SUMMARY AND RECOMMENDATIONS

This compilation of the pollution situation in areas where there are abandoned mines is based on reported investigations, inspections, and various analyses. When pyrite decomposes due to the weathering action of oxygen and water, sulphuric acid is formed causing a metalliferous, acid run-off. Furthermore, finely ground waste may give rise to undesired particle transport in the watercourse. Experience shows that the extent of such pollution can be roughly estimated from an inspection combined with water chemical analyses. The conditions that in fact determine the pollution situation are primarily the prevailing hydrological conditions in the area, in addition to such factors as the size and positioning of the refuse piles, the construction of the mine itself, the dressing technique employed, and finally the rock's neutralization potential. Nevertheless it is desirable that we increase our knowledge of the correlation of cause and effect in the composition of mine drainage through closer chemical and biological investigations in selected areas.

The existing body of data for the evaluation of the pollution situation at the different mines varies tremendously. The table on the following page reports the situation at mines where we have sufficient data to give a more detailed analysis. In addition to mines listed in this table, a number of mines about which we have inadequate background information are mentioned in the text. There is no evidence, however, that these are the source of any significant pollution.

The table below gives a reading from each mine area of the extent of pollution (inputs), and the apparent effect of inputs on the adjacent recipient (effects).

The table indicates the apparent magnitude of pollution from various mine areas (inputs), and how these inputs seem to affect the adjacent recipient (effects).

In the table O and X denote the following:

Effects		Inputs	
O	Unknown, negligible	O	Unknown, negligible
(O)	Unknown (possible effects)	X	Moderate
X	Minor effects	XX	Substantial
XX	Significant effects	XXX	Large
XXX	Severe effects		

Sect.	Name	Municipolitz	Draining to	Inputs	Effects	Further measures, investigations
2.1.1	Vigsnes Copper Works	Karmøy	Lake Vigsnesvatn	XX	X	Inspection + controll programme
2.2.1	Evje Nickel Works	Evje and Hornnes	Otra	O	O	Inspection
2.2.3	Ertelien Nickel Works	Modum	Henoa/Tyrifj.	XX	X	Inspection + controll investigation
2.2.4	Langdalen	Romerike/ Modum	Skjærdalswater-course/Tyrifj.	X	X	Lower stretch of Skjærdalswatercourse should be investgated
2.2.5	Eiker Copper Works	Øvre Eiker	Drammenswater-course	X	X	
2.2.6	Modum Cobalt Works	Modum	Snarumselva-Simoa Drammensw.course	X	O	Inspection
2.2.7	Konnerud	Drammen	Drammenselva-Sandew.course	X	O	Affects ground water in the area
2.2.8	Grua	Gran	Viggaw.course	X	O	
2.2.9	Espedalen	Sør-Fron/ Gausdal	Gausa	O	O	
2.2.10	Fossgruva	Tolga-Os	Vangrøfta-Glåma	X	X	
2.2.11	Oscar II	Tolga-Os	Vangrøfta-Glåma	X	X	
2.2.12	Folldal	Folldal Alvdal	Folla-Glåma	XXX	XX	Detailed investiga-tined ... carried out 1984/85. Measures are under concerderation
2.2.14	Røstvangen etc.	Tynset	Gløta-Tunna Glåma	X	X	Effect of measures is being monitored
2.2.15	Kvikne Copper Works	Tynset	Ya-Orkla	XX	X	To be monitored of after the regulations of the Orkla w.course

In the table O and X denote the following:

Effects		Inputs	
O	Unknown, negligible	O	Unknown, negligible
(O)	Unknown (possible effects)	X	Moderate
X	Minor effects	XX	Substantial
XX	Significant effects	XXX	Large
XXX	Severe effects		

Sect.	Name	Municipolitz	Draining to	Inputs	Effects	Further measures, investigations
2.3.1A	Røros Copper W. Stortvartz	Røros	Glåma	XX	X	Measures in Lake Djupsjøen
2.3.1B	Røros Copper W. Kongens	Røros	Glåma	XXX	XX	Lake Orvsjøen is has been monitored
2.3.1C	Røros Copper W. Muggruva	Røros	Gaula	X	O	
2.3.1D	Røros Copper W. Hessdalen	Holtålen	Hesja-Gaula	X	X	
2.3.2.	Kjøli	Holtålen	Gaula	XX	XXX	Furhter liming etc. in 1985?
2.3.3	Killingdal	Holtålen	Gaula	XXX	XXX	Measures in draft
2.3.5	Undal Works	Rennebu	Skauma-Orkla	X	X	
2.3.6	Løkken Works	Meldal	Raubekken-Orkla	XXX	XXX	Further measures should be drafted. The situation is being closely monitored
2.3.7	Dragset Works	Meldal	Vorma-Orkla	XX	X	The situation should be monitored by means of a con-troll programme
2.3.8	Høydalsgruva	Meldal	Svorka	X	O	
2.3.10	Lillefjell	Meråker	Stjørdals-watercourse	X	(X)	The Meråker area should be inspected
2.3.11/12	Gaulstad-Mokk			O	O	
2.4.1	Bossmo	Mo i Rana	Ranafjorden	X	(X)	
2.4.3	Sulitjelma	Fauske	Sulitjelma watercourse	XXX	XX	
2.4.4	Bjørkåsen	Balangen		X	O	
2.4.5	Tårstad	Evenes	Lavangseidet	O	O	
2.4.7	Bidjovagge	Kautokeino	Altawatercourse	O	O	

The main conclusions that can be drawn from the investigations are:

1. Fairly comprehensive documentation exists of the pollution situation in cases where drainage from the mine area affects parts of larger courses to a noticeable extent. This applies both to the upper stretch of the Glåma and subsidiary watercourses, and to the Orkla with its subsidiary watercourses. In the case of the River Gaula (North Trøndelag) the pollution situation is known in broad outline, but a more detailed survey of the significance of the various mine areas for water quality and biological conditions in the upper reach of the Gaula is necessary.

   (The Sulitjelma watercourse and the Namsen receive run-off from mine areas where ore is currently being extracted, and therefore they are not included in this compilation.)

2. It is quite clear, however, that some areas where mining activities have been on a small scale are known to be a source of pollution in the local environment. The old mine areas at Ertelien,the old Folldal Works, Storwatz and Vigsnes all give rise to considerable effects in the area round the mines. On the other hand, pollution problems at large mines can be small, as is the case at the Muggruva Mine, for example.

3. There are still a number of isolated areas where mining operations have been fairly extensive but where there are no data on the pollution situation. This applies, for instance, to abandoned mines in Troms and Finmark, to mining areas on the island of Stord, and in the Hardanger and Bamble regions. We suggest that inspections should be made in these areas in connection with other activities in the region.

4. The extent to which the present pollution situation is considered to cause problems, depends on local user interests. For instance, the mines at Konnerud pollute the ground water in the area. Furthermore, though the pollution situation at Dragset Works is described as moderate, it conflicts with fish interests there. Another example is found at the Bossmo Mines, where a small stream containing polluted water flows through a new residential area. These examples demonstrate that, when evaluating possible measures, local interests can also be taken into account, as well as general interests in the larger watercourses. Moreover, an evaluation should also be made of what measures are technically and economically feasible in the various areas.

5. Finally the data base which forms the present basis of evaluation, should be expanded. Fields that should be further researched are, for example:

    - How is the environment affected after the termination of mining activities by the finely ground flotation refuse which has been dumped.

      Investigations in Lake Orvsjøen and Lake Djupsjøen would throw light on the problem.

    - What is the composition of mine water in flooded mines, and to what extent is the release of metal reduced by flooding. (For example, Undal Works and Løkken Works.)

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