

A Study of Some Trace Metals in Surface and
Ground Waters at Bridgewater, Nova Scotia

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Abstract

Much controversy has arisen concerning the water quality in an area northwest of Bridgewater, Nova Scotia.

To resolve the problem, water samples were taken and analyzed for trace metals, from the area which was also mapped. This showed the area to be forested with the preferred drainage direction to be towards the La Have River. Two dumps were discovered which could affect the area. In order to construct highway 103, two road metal pits were opened. In these pits there is exposure of Halifax slates which have been metamorphosed and folded. Interbedded in the slates are iron sulfides. The analysis of the water disclosed patterns of ion distribution radiating from the pits down slope. This is due to acid leaching of the newly exposed beds of iron sulfides in the slates. These mobilized ions are then precipitated down slope with a change in pH and other chemical properties.

Introduction

For the last two years, the residents of Northwest Bridgewater, Nova Scotia have reported a deterioration in the quality of their ground water. The reports began shortly after several pits were developed for road metal to construct a road bed for Highway 103. This study is an attempt to evaluate the current water quality by analyzing the trace metal content of surface and ground waters in this area.

The field work was carried out in November 1977 over a period of 7 days.

I would like to acknowledge help extended to me in this study by members of the department. In particular I would like to thank Professors D.J.W. Piper, D.B. Clarke, H.B.S. Cooke, T.W. Hennigar, W.B. Ervine, P.E. Schenk, Mr. S. Parikh, Mr. P.D. Bourque and Ms. D.E. Webb.

General Setting

The study area is 3 km. west of the town of Bridgewater, Nova Scotia and 100 km. southwest of Halifax. The 8 square kilometer area, measuring approximately 2 km. by 4 km. is on the south slope of the valley of the La Have River (Figure 1). It is forested, predominantly by white pine and spruce, and drained by streams and ditches flowing north-easterly to the La Have River. (Plate 1)

The natural ground surface has been disturbed in several places. Highway 103, consisting of two lanes, was constructed in 1975-76 (Plate 1). Road metal for this highway was removed from a large area just north of the tire factory (Figure 1 and Plate 2). This factory, about 4000 square meters in area, was built in 1970 and is owned and operated by the Michelin Tire Co. of Canada, Ltd.

There are also two dumps in the area. One is the town dump 0.5 km. south of the study area. The other is a small dump located in the west pit (Figure 1), consisting of tires, rubber and plastics. This dump appears to be fairly recent (3 months).

General Geology

The following summary of the geology is based on reports by Taylor (1964), by Schenk (1978), and on my

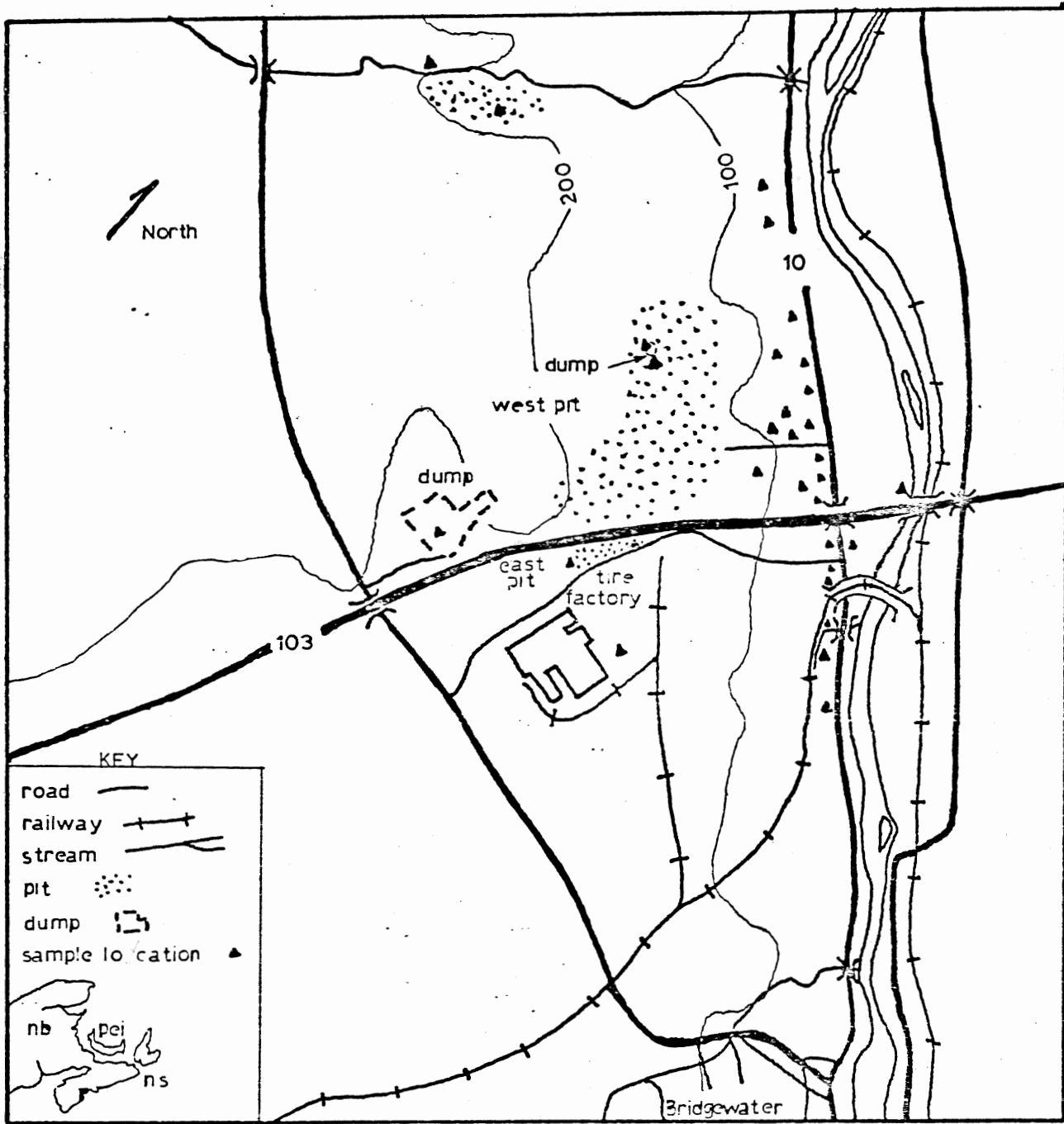


FIG 1 GENERAL TOPOGRAPHY

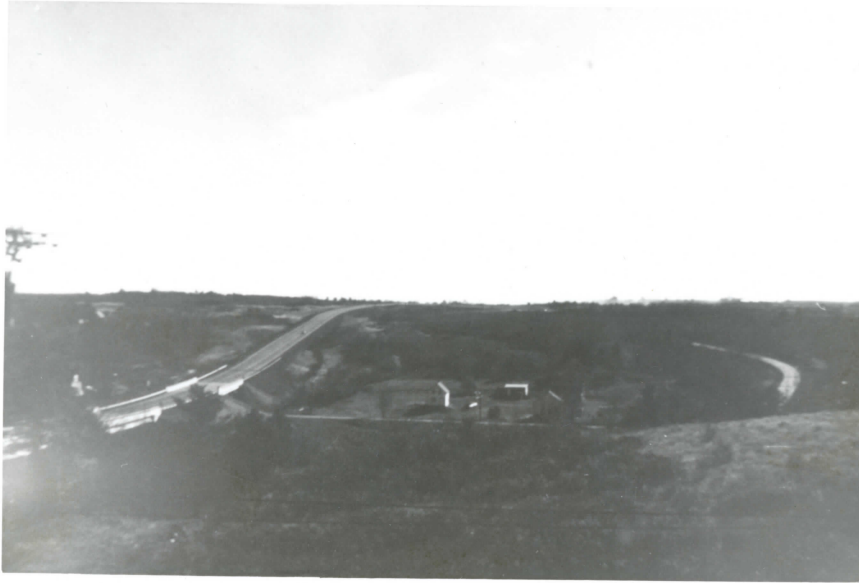


Plate 1: Photograph of general topography, taken from north slope of La Have River, looking south.



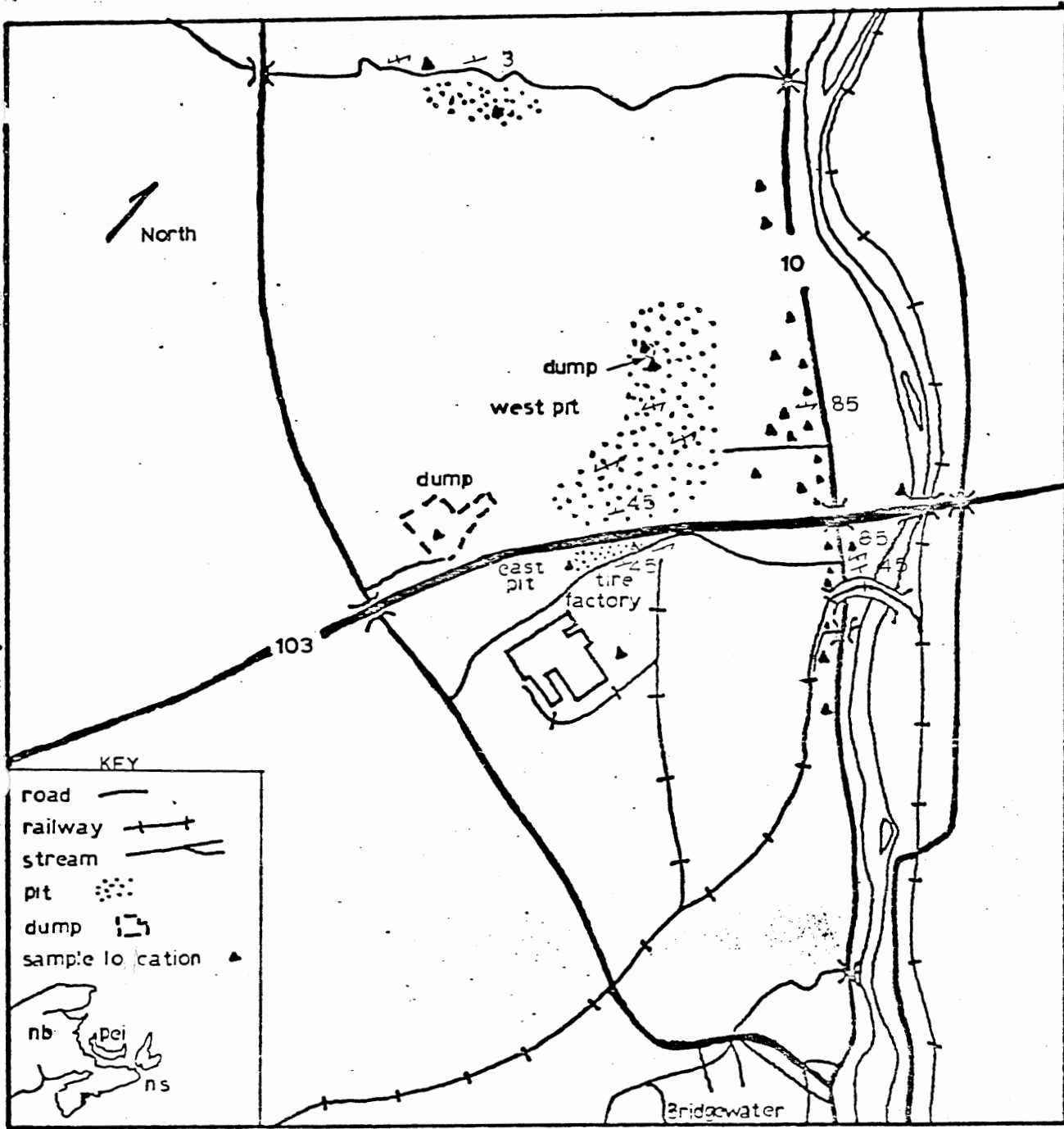
Plate 2: Taken in East Pit looking north.

observations in the immediate area.

Bedrock exposures are generally small and of poor quality due to activity in these pits. However, a few well-exposed outcrops in the west pit, in a stream 2 km. to the west, and in the west pit were examined in detail. The geology is shown in Figure 1a .

The area is underlain by slates and very few thin beds of quartzite of the Halifax Formation. These rocks strike northeasterly and dip moderately northwest. The rock in the Bridgewater area has been metamorphosed to the greenschist facies. There appear to be two folding episodes, East-West and North-South. The latter event has given rise to the anticline-syncline nature of the area and the Meguma in this area as a whole. Taylor (1969) describes the axis of a syncline north of the study area.

The area has also been glaciated. Smooth rock surfaces or roches moutonnées can be found, these exhibit southeast-northeast oriented striations. The thickness of glacial drift varies generally from a few meters to nil, as can be seen in areas of the West Pit and in road cuts of Highway 103. Some wells intersect bedrock at depths of 0.5 to 3 meters (Appendix A). Pebbles in drift material have been identified as Triassic sandstones and basalts, and as Devonian granites in addition to Meguma slates.






STRIKE/DIP 
CLEAVAGE/DIP 
CLEAVAGE/VERTICAL 

FIG 1a
GENERAL GEOLOGY

The soil, known locally as the Bridgewater sandy loam, consists of light-brown sandy loam overlying a yellowish brown or olive-brown loam. These soil horizons vary in thickness.

The slates in the road-metal pits have interbedded layers of iron sulfides. These beds are up to 5 cm. wide and continue along strike for several tens of meters. The iron pyrite varies from blebs to a highly disseminated form. Where these slates contain numerous interlayers of these sulphides they are overlain by a conglomerate of probable Pleistocene age, called the Bridgewater Conglomerate by Cann and Hilchey (1958). Limonite appears to cement the overlying boulders and pebbles of slate, sandstone, and granite. Cann and Hilchey (1958) believe it formed when iron is dissolved during the soil-forming process and is reprecipitated as cement between the fragments.

Field Procedure

Thirty-three samples of water from wells, ditches and streams were collected in one liter polyurathane bottles. These were first cleaned with a very weak solution of HCl and then rinsed three times with distilled water.

Since, by November 19, 1977, the open wells had already been covered with plastic sheeting, brush and even sawdust to protect them from freezing winter temperatures, the samples of well waters had to be taken from the taps at the surface. These and other conduits were composed of brass, copper, and stainless steel.

In each case the water was allowed to flow for about 3 minutes to remove as much contamination from the pumping system as possible. Before the bottles were filled they were rinsed twice with the water. The pH of each sample was measured at this time.

An attempt was made to record the depth of the wells (dug and drilled) but this information was not available in most cases. In general, however, drilled wells are deeper than dug wells.

Samples of surface waters (i.e. ponds, puddles, ditches, streams, and rivers) were obtained by simply dipping the water from the pools, etc.. Care was taken not to disturb the sediments on the bottom as these were rusty in some cases. All sample sites were examined carefully and are described in Appendix A.

Laboratory Procedure

In the laboratory, small (60 ml.) polyurathane bottles

were cleaned, rinsed, and then filled with water from each of the 33 samples taken in the field. Standards were made by taking appropriate aliquots of commercially prepared solutions and diluting to the working range for each element (Table I).

The waters were analyzed at the Department of Geology, Dalhousie University, on a Model 503 Perkin-Elmer Atomic Absorption Spectrophotometer equipped with printed read-out. Standards were used to bracket each analysis. Indicated concentrations beyond the working range of the instrument for a given element were reanalyzed using a more dilute sample. Similarly, concentrations below the minimum detection level of the instrument for a given element were gently evaporated to concentrate them by a factor of exactly 10. These were also re-analyzed.

Table I

Range of Concentrations Used For Standards

<u>Element</u>	<u>Range of Standards</u>
Ca	1 - 5 ppm
Fe	1 - 5 ppm
Mn	0.5 - 2.5 ppm
K	0.4 - 2.0 ppm
Na	0.2 - 1.0 ppm
Mg	0.1 - 0.5 ppm
V	0.2 - 4.0 ppm
Zn	0.2 - 4.0 ppm
Ba	0.2 - 4.0 ppm
Cu	0.2 - 0.4 ppm

Data from Perkin-Elmer "Bluebook" (1974)

Results

The analytical results are shown in Table II. Each value listed is an average from 3 determinations on the same sample. Because vanadium analyses tended to be variable (noisy), the values listed in Table II have been calculated from a computer program developed by S. Parikh.

Graphic Analysis

The results of the analysis have been plotted on separate maps. Each map is coloured in a manner to show high and lows for each of the 10 elements and for free hydrogen (pH). The locations of the sample sites are shown on Figure 2.

High acidity (pH 3) occurs mainly in the road-metal pits and decreases towards the La Have River (Figure 3). The disturbed areas have pH values of 4 or 5. The town dump shows the least measured acidity (pH 6). Surface waters have lower acidity than the wells as a whole, and dug wells have a lower acidity than drilled wells.

Barium concentrations, ranging from 0.22 ppm to below detection levels, are highest in the road-metal pit and diminish somewhat towards the La Have River (Figure 4). Values along Highway 10 generally decrease northward from

Analyses of Waters from NW Bridgewater, N.S.

Sample		pH	Ca*	K	Na*	Mn	Mg	Fe*	Ba*	V*	Cu*	Zn*
1	Dug	5	5.2	0.64	6.0	.08	36	.25	.08	.006	.12	.85
2	Dug	4	3.05	0.42	11.6	0.09	30	2.2	ND	ND	.21	.085
3	Surface	4	1.2	0.60	6.8	.56	20	0.5	.06	.003	.01	.10
4	Drilled	4	ND	.04	19.0	.04	0.25	0.1	.14	ND	.015	.005
5	Spring	4	1.15	.70	8.0	.62	.24	.5	.22	ND	.015	.095
6	Surface	5	2.4	1.46	6.0	.22	36	.1	.22	.01	.01	.115
7	Surface	3	3.05	1.46	8.5	.92	32	3.6	.22	.006	.005	.065
8	Surface	3	0.30	.70	10.6	1.10	56	3.7	.04	ND	.25	.45
9	Dug	4	22.5	.72	8.6	.42	60	2.9	.10	.008	.015	.5
10	Dug	4	2.8	.68	6.0	.07	24	.1	.10	.009	ND	.005
11	Dug	4	2.95	2.4	3.0	.04	10	.1	ND	.004	3.1	.045
12	Drilled	4	.10	.04	20.0	.02	.01	.2	.22	ND	.005	.005
13	Drilled	4	ND	ND	14.0	.02	.01	.2	ND	ND	.01	.006
14	Surface	4	2.00	1.32	2.5	2.46	24	2.5	.22	ND	.01	.6
15	Surface	3	1.45	1.0	2.0	.36	12	3.0	.10	.003	.005	.045
16	Dug	4	3.0	1.16	3.2	.09	24	.2	.10	.01	.01	.1
17	Dug	4	2.75	1.96	6.0	.52	24	.1	.06	.004	.15	.16
18	Drilled	5	21.0	.7	2.8	.14	54	8.2	.04	.005	.005	.175
19	Drilled	4	2.7	1.92	4.8	.52	24	.2	.06	.008	.00	.13
20	Drilled	4	0.25	0.02	19.6	.02	.06	.1	ND	.004	.005	.005
21	Town	4	3.2	.24	2.8	.02	5	.25	.14	ND	.025	.03
22	Surface	6	31.0	4.32	20	.02	18	1.5	.18	.01	.01	.12
23	Surface	3	2.1	.88	3.8	.45	15	.25	.14	.005	.005	.37
24	Drilled	5	7.75	.68	2	.50	25	.7	.31	ND	.03	.02
25	Drilled	5	.15	.10	19.6	.02	.03	.3	.14	.004	.045	.06
26	Drilled	4	16.5	.96	3.8	.14	40	.5	.04	.004	.01	.02
27	Dug	5	.10	.10	20	.02	.02	.1	.04	.008	.01	.03
28	Dug	5	1.25	.52	.3	.04	.03	.1	.125	ND	.125	.38
29	Dug	4	1.80	.54	.2	.05	.6	.1	.125	ND	.125	.2
30	Surface	3	1.15	.58	.3	.02	.6	.5	.13	.001	ND	.02
31-33	Surface	4	2.75	.80	.2	.42	29	1.75	ND	ND	.13	.8

. indicates samples have been diluted

* indicates samples have been concentrated

ND not detected

values are in ppm

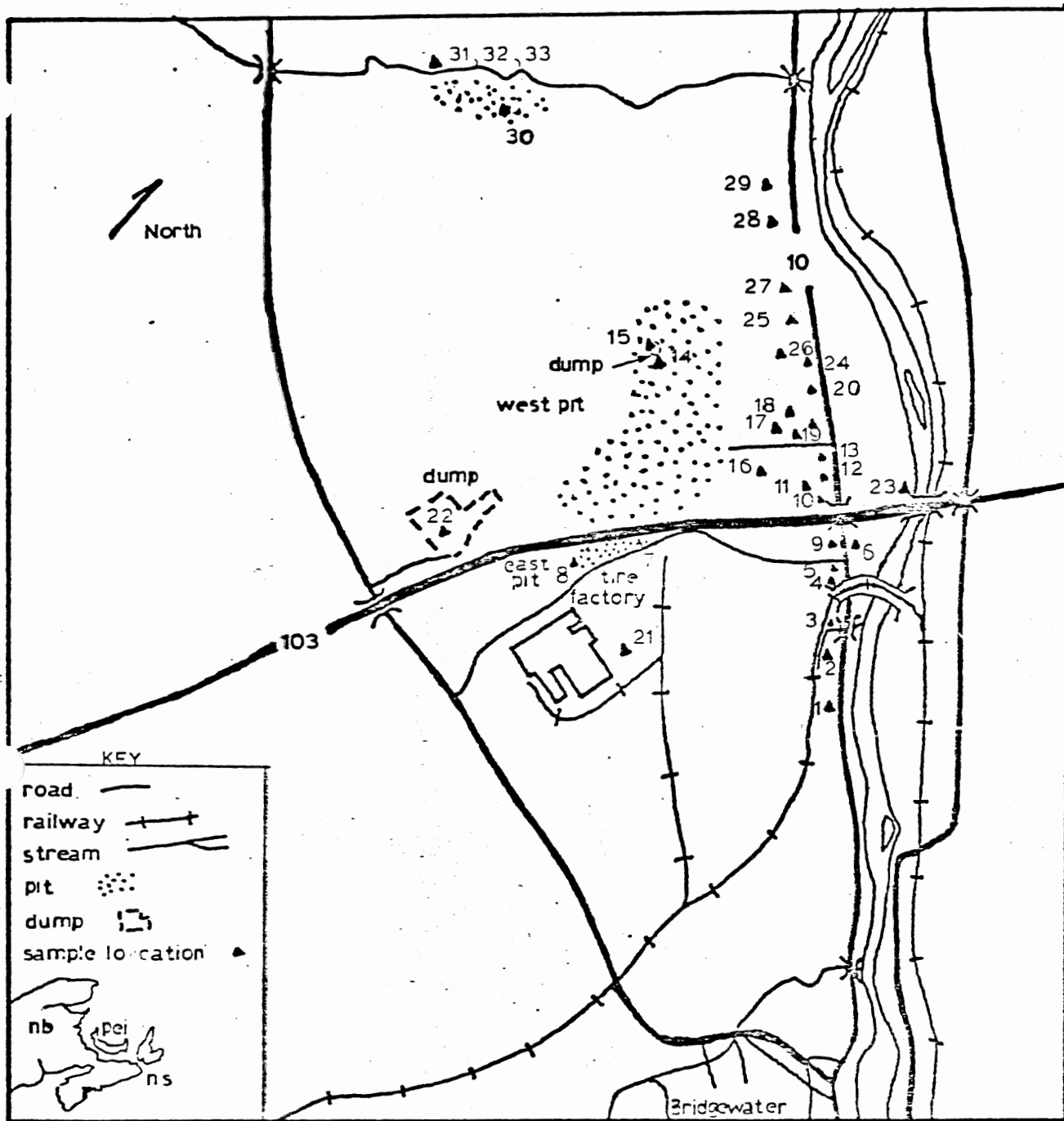
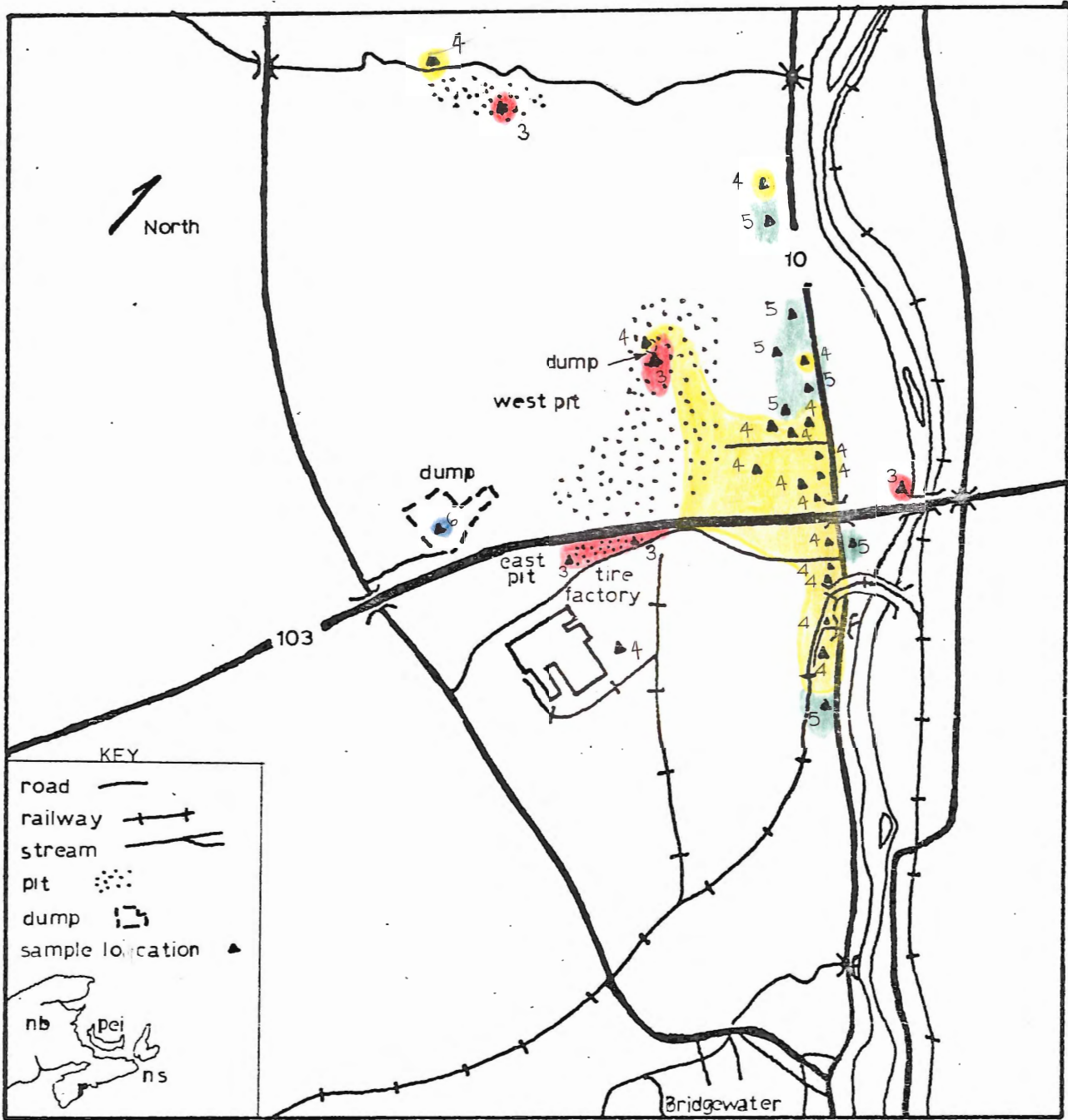


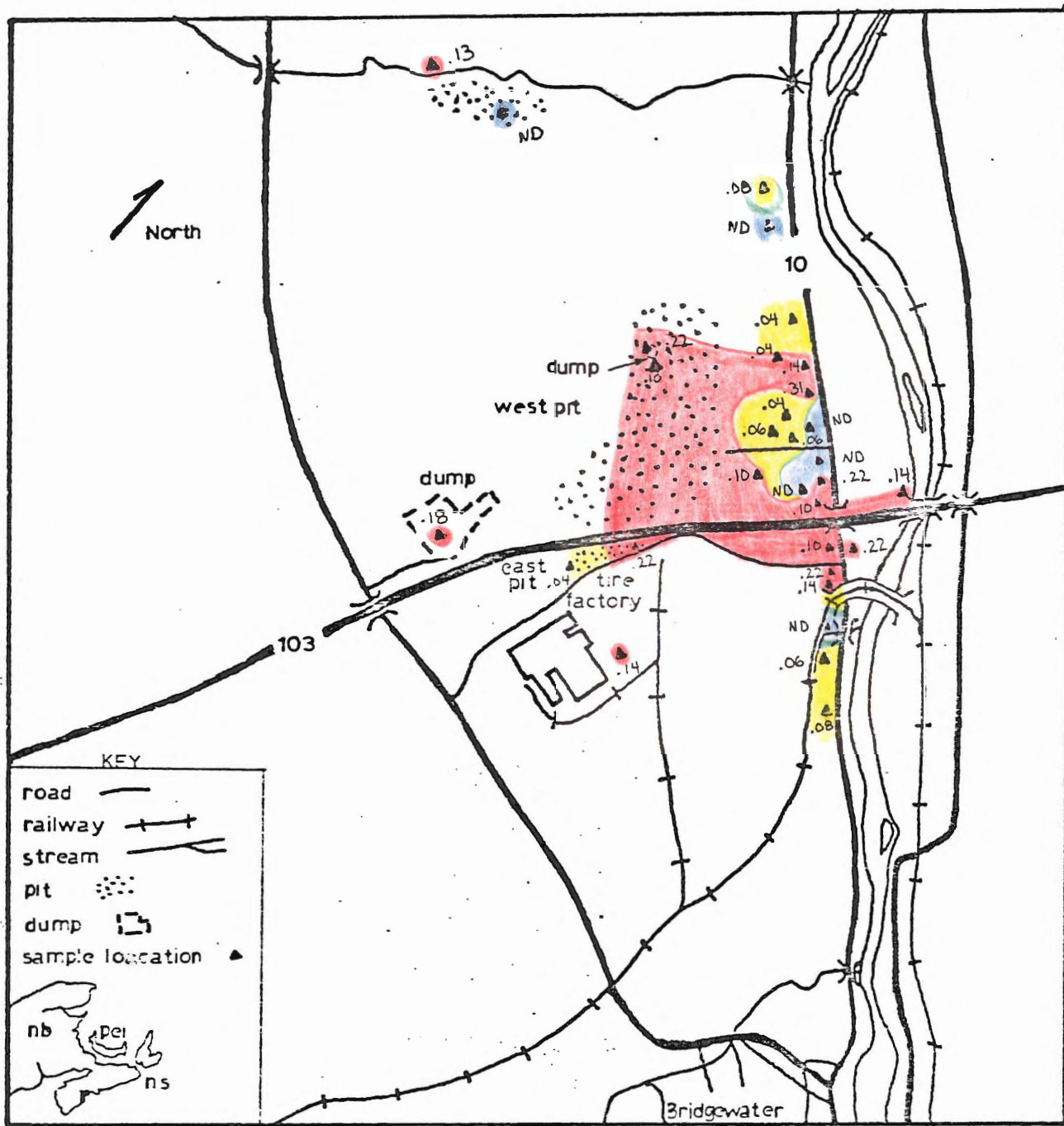
FIG 2
WATER SAMPLE
LOCATIONS



0 1000 METERS

FIG 3
pH OF WATER

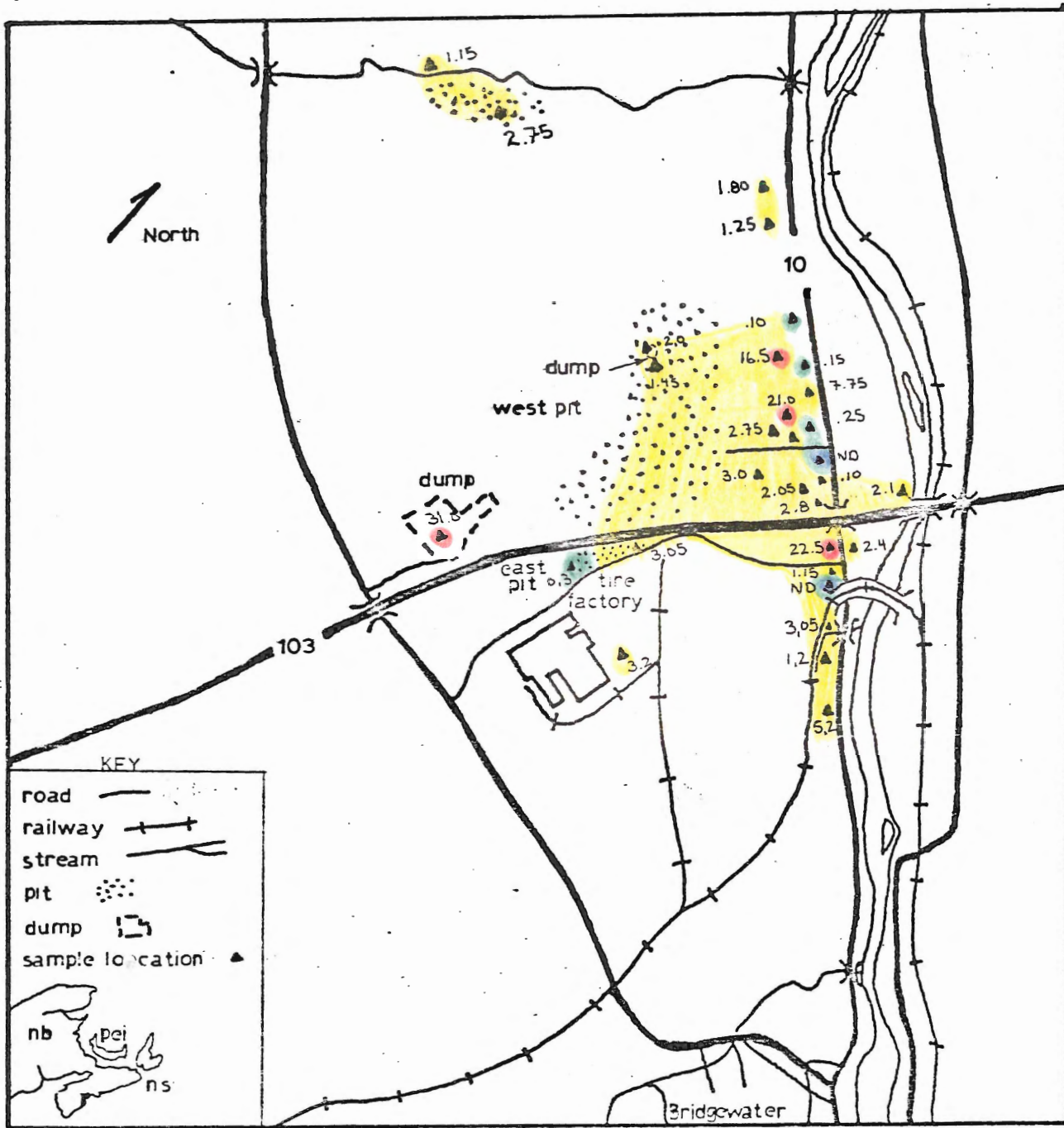
- 3
- 4
- 5
- 6



0 1000 METERS

FIG 4 Ba ppm

- >.1
- .1-.01
- .01-.001
- <.001



- > 10
- 10 - 1
- 1 - .1
- < .1

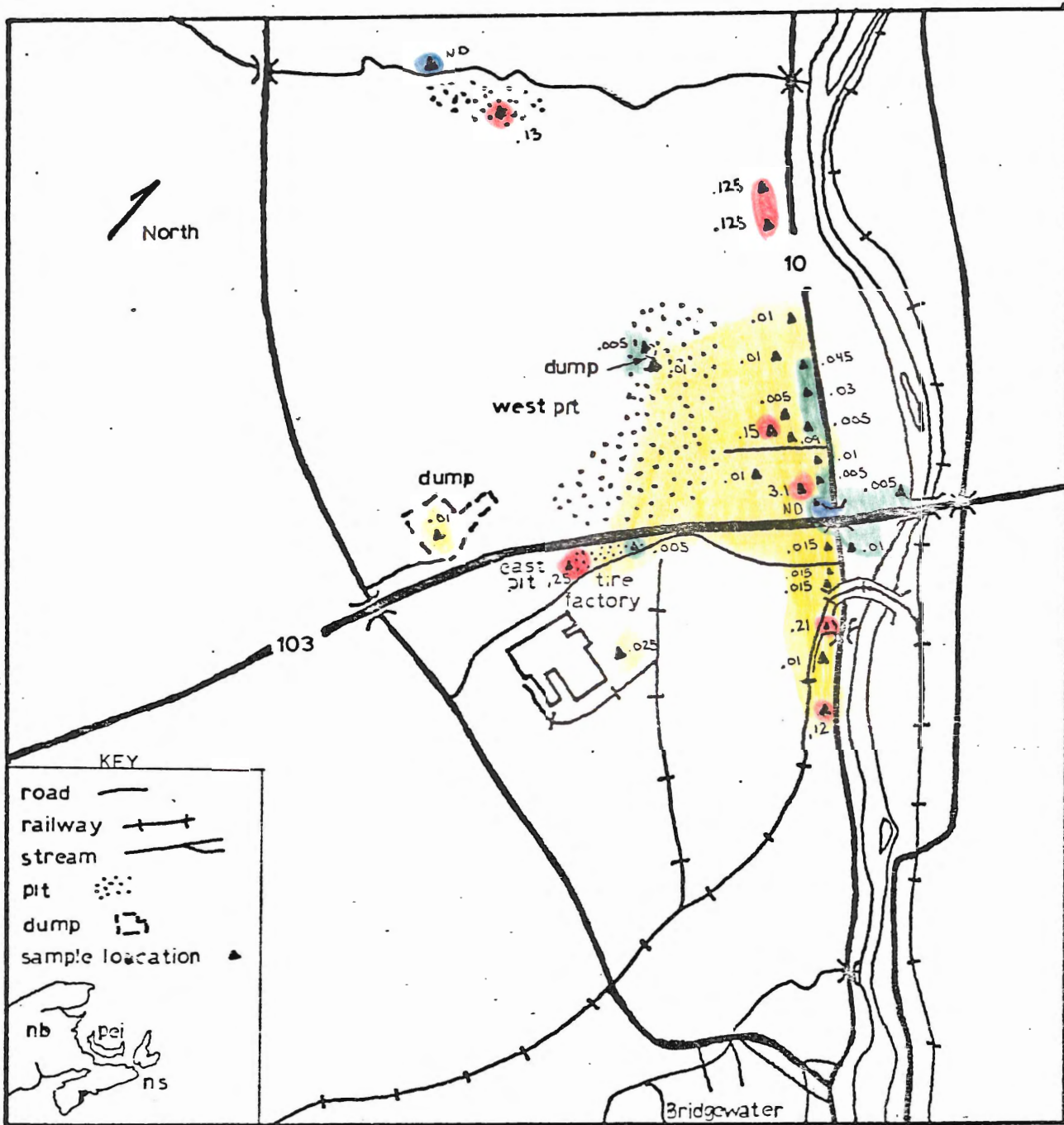
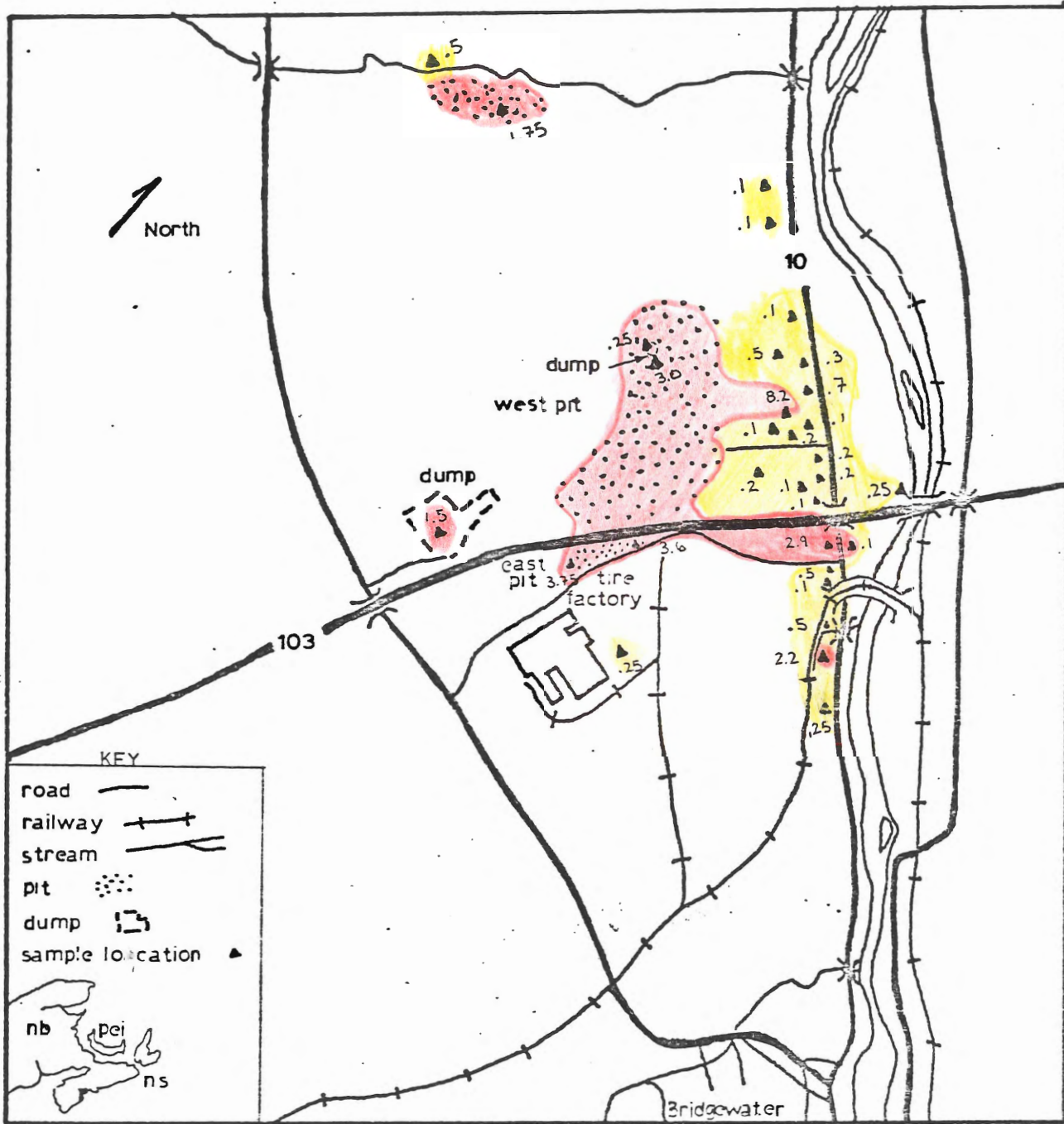


FIG 6 Cu ppm

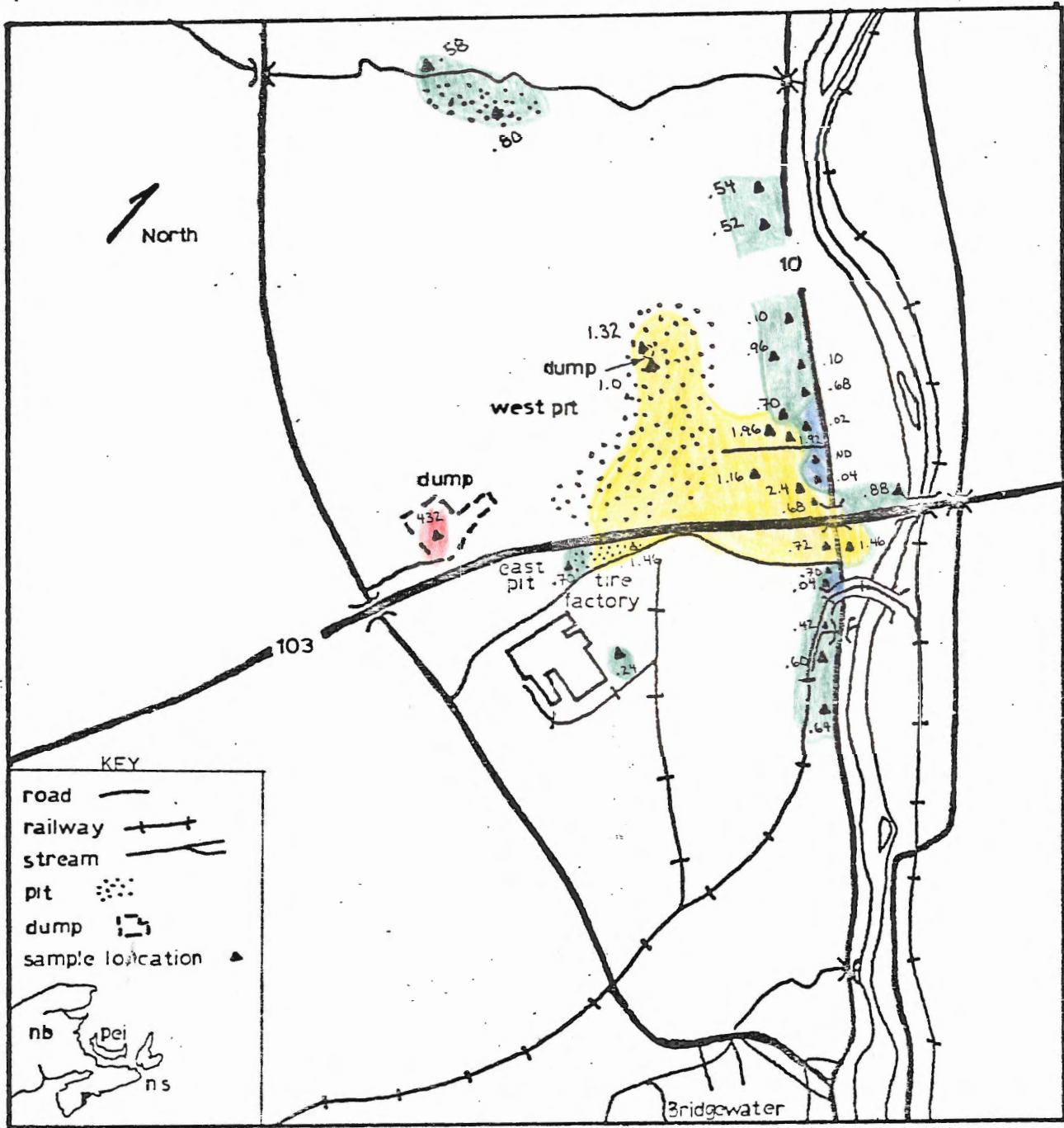
- > .1
- .1 - .01
- .01 - .001
- < .001



0 1000 METERS

FIG 7 Fe ppm

- > 1
- 1-.1
- .1-.01
- < .01



0 1000 METERS

FIG 8 K ppm

- > 10
- 1-10
- .1-.1
- < .1

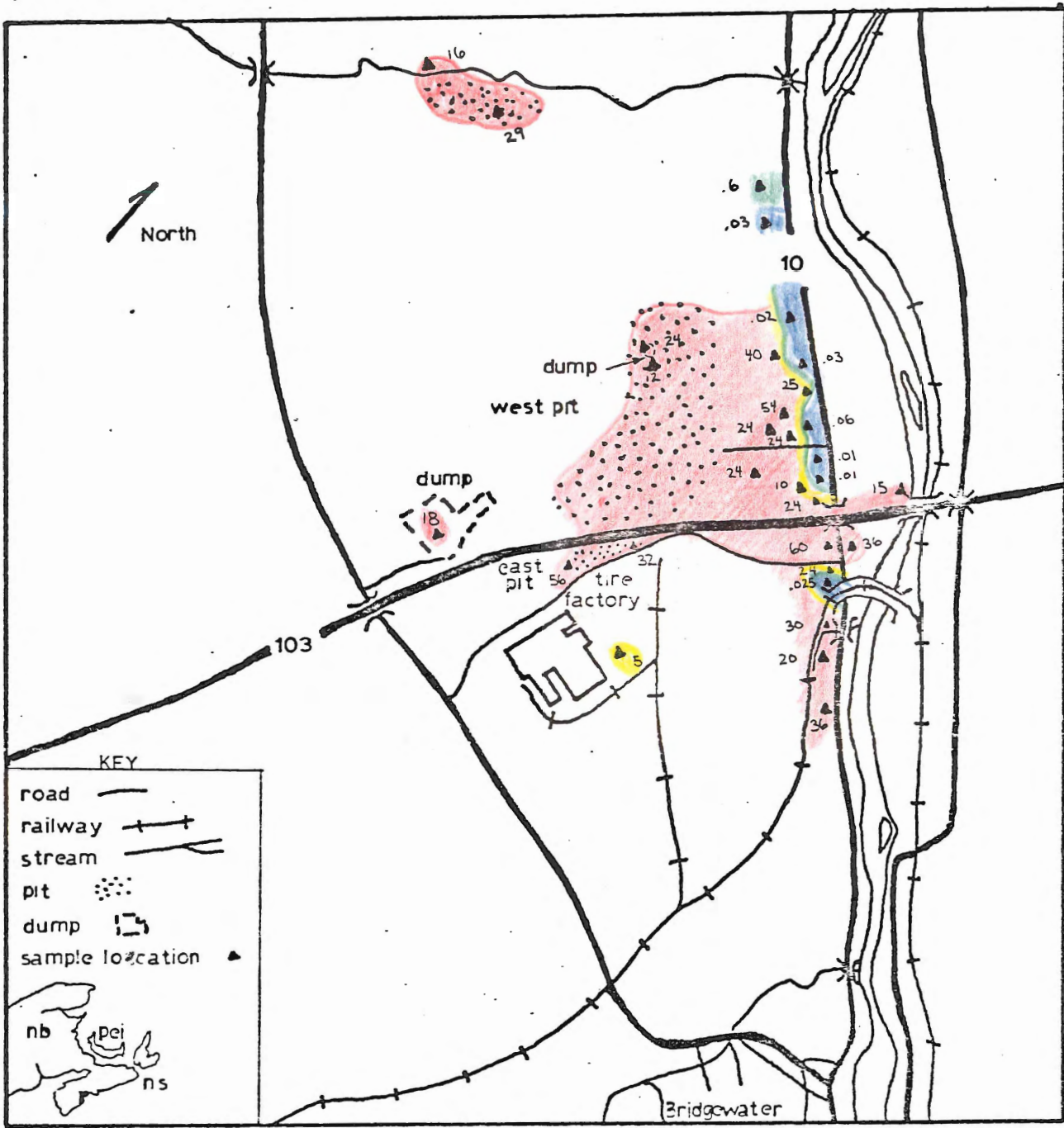
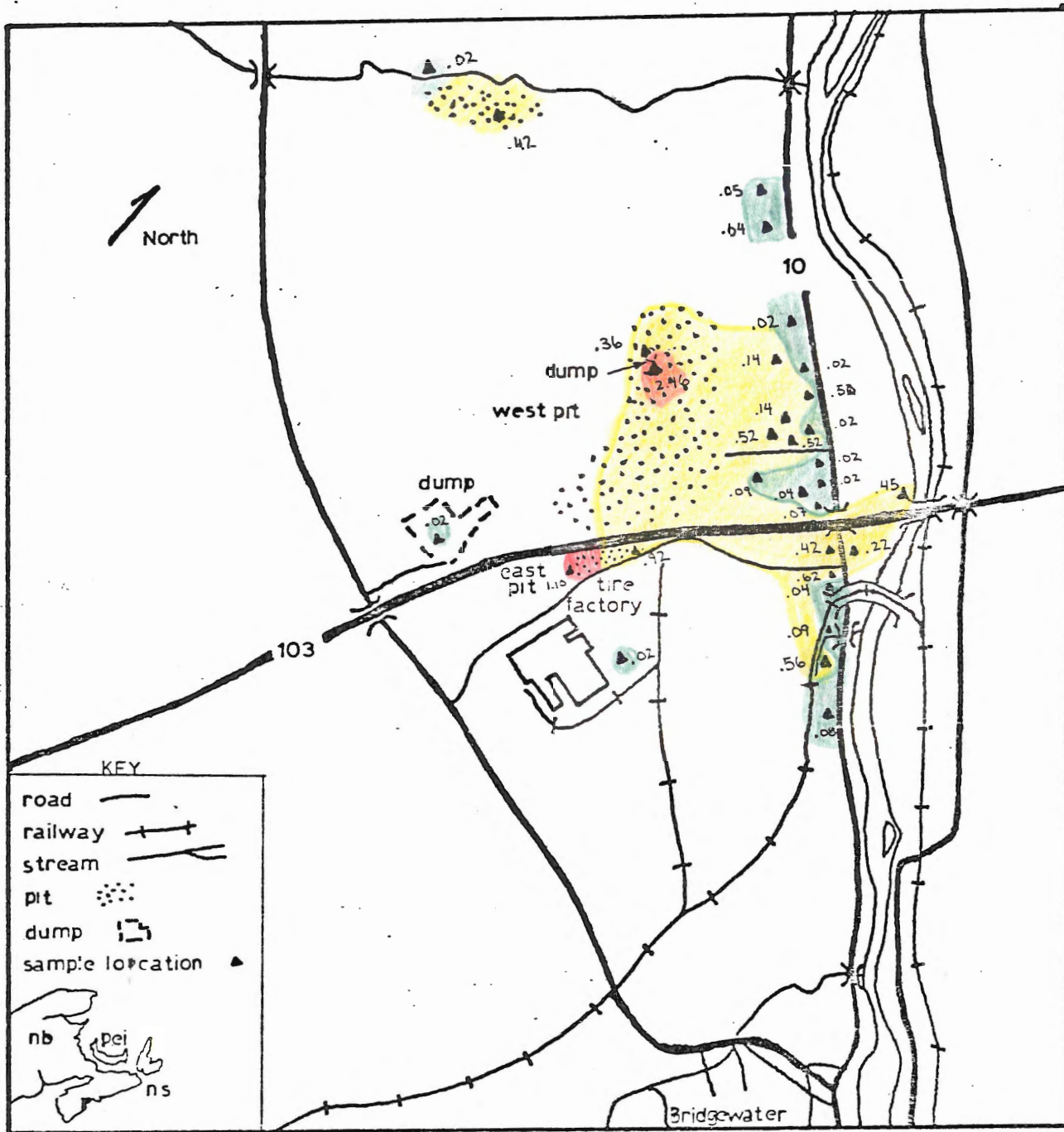
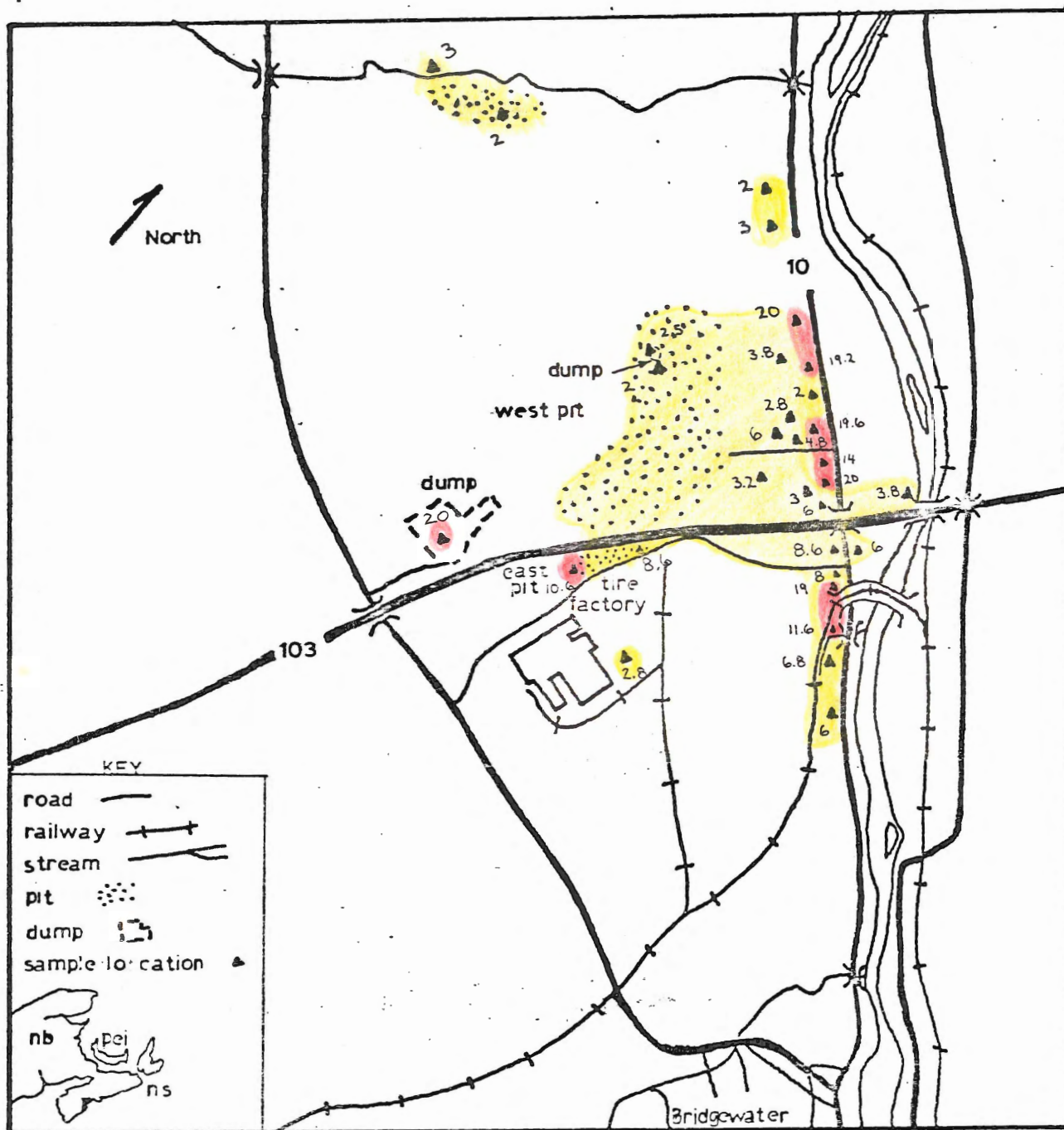


FIG 9 Mg ppm

- > 10
- 1 - 10
- 1 - .1
- < .1

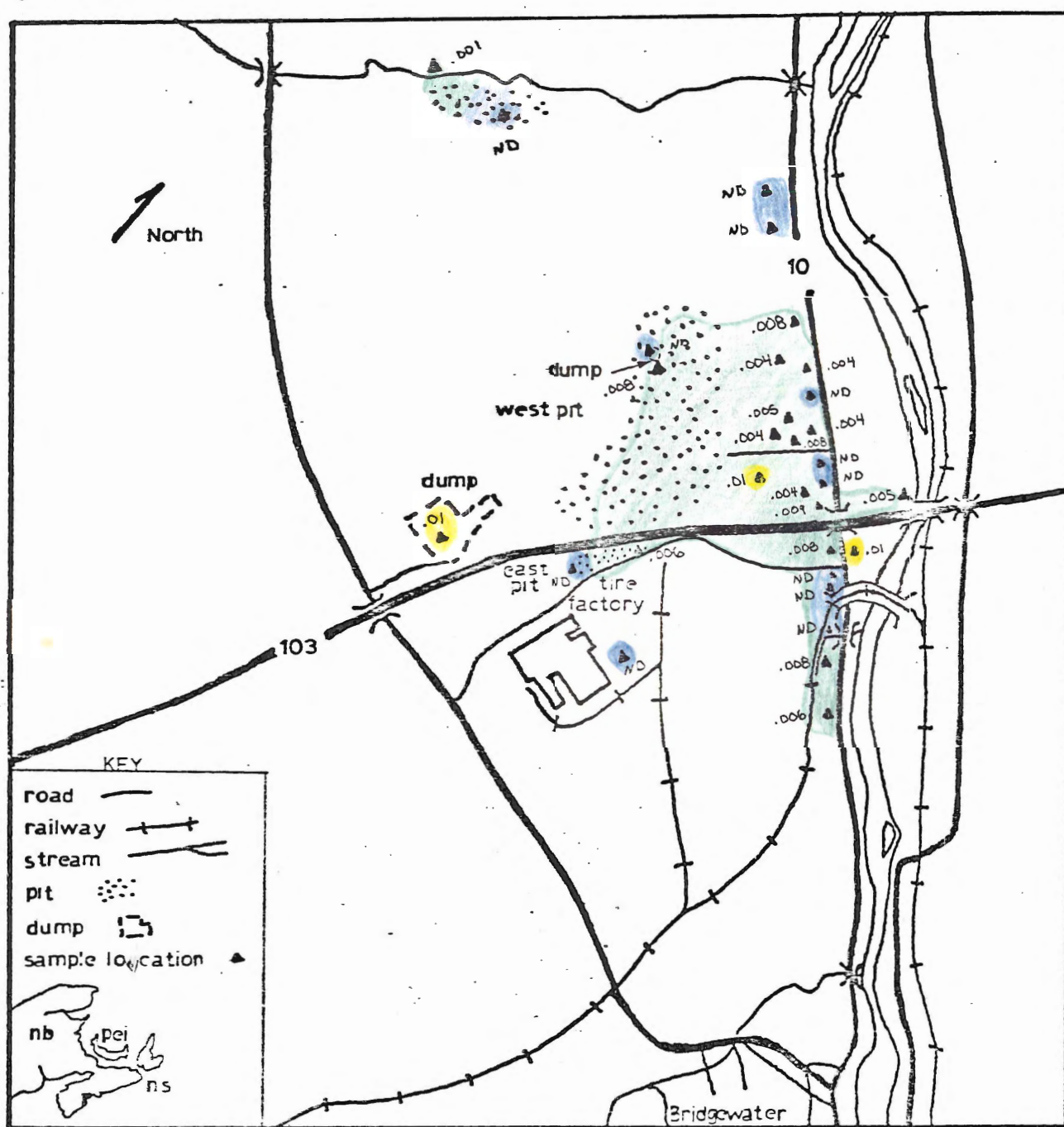




0 1000 METERS

FIG 11 Na ppm

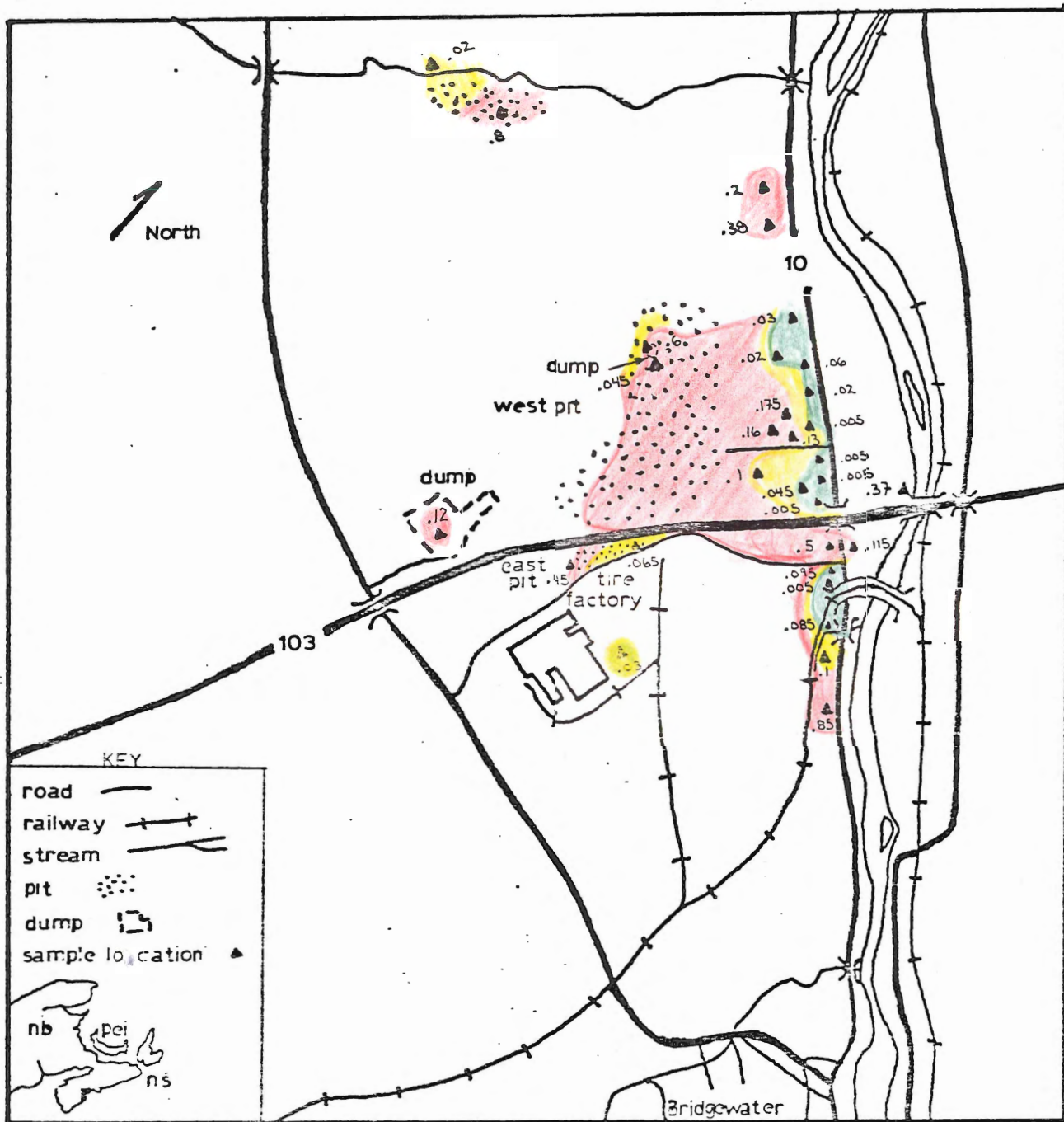
- > 10
- 1 - 10
- 1 - .1
- < .1



0 1000 METERS

FIG 12 V ppm

- > .1
- .1 - .01
- .01 - .001
- < .001



0 1000 METERS

FIG 13 Zn ppm

- Red circle: > .1
- Yellow circle: .1 - .01
- Green circle: .01 - .001
- Blue circle: < .001

the intersection with Highway 103. The surface waters tend to have higher values than the wells and the drilled wells tend to have lower values than dug wells. Barium concentrations seem, therefore, to decrease with depth.

Calcium concentrations range from 31 ppm to below detection levels. The highest values found in this study were at the town dump and in 3 wells along Highway 10 (Figure 5). The rest of the area shows moderate values of 1 to 10 ppm. Surface waters tend to have lower values than well water and those for drilled wells are lower in value than for dug wells. Calcium, then, seems to be variable with depth.

Copper values range from 3.1 ppm to values below detection. There appears to be little correlation of copper values with location within the study area (Figure 6). That is, isolated high values occur at intervals scattered throughout the area. Low values are also scattered. Copper concentrations in surface water are generally higher than the wells and dug wells have values higher than drilled wells. Copper concentrations therefore appear to decrease with depth.

Iron concentrations range from 8.2 ppm to values below detection. The highest values are in the pits and diminish

generally towards the La Have River (Figure 7). Values from waters tend to be higher than well waters, and those from dug wells are higher than for drilled wells. Iron concentrations, therefore, decrease with depth.

Potassium concentrations range from 1.92 ppm to values below detection. The highest values (432 ppm) occur in the dump (Figure 8). The lowest values occur along Highway 10 and near the river. Surface water values are higher than well water, and drilled values have lower values than dug wells. Potassium then, decreases with depth.

Magnesium values range from 60 to 0.01 ppm, the highest values are in the pits and diminish towards the La Have River. Surface water values are higher than well waters and dug wells have higher values than drilled wells. Magnesium, then, decreases with depth.

Manganese values range from 2.46 to 0.02 ppm, the highest values are in the pit and diminish towards the La Have River. Surface water values are higher than well waters and dug wells have higher values than drilled wells.

Sodium values range from 20 to 2.0 ppm. The study areas as a whole has higher values with localized highs in

wells along highway 10 which are greater than 10 ppm.

Vanadium values in the study area range from 0.01 to values below detection. The area as a whole is low with respect to vanadium.

Zinc values range from 0.85 to 0.005 ppm. The values are high in the pits and diminish gradually towards the La Have River, less so elsewhere. Surface water values generally are higher than well waters, dug well waters have higher values than drilled waters. Therefore zinc values decrease with depth.

In summary, then, concentrations of Zn, Fe, Ba, Mn, Mg, and K are relatively high in and around the pits and dump. These values generally decrease downslope toward the river, except near Highway 103 where they remain fairly high. High and low concentrations of the other trace metals (Ca, Na, Cu, V) seem to have an uneven, or at least trendless, distribution. However, in almost every case, the trace-metal concentrations, including the hydrogen ion concentrations, decrease with depth.

A Comparison With Other Waters

The trace-metal concentrations in these waters can be

compared to those in nearby Hebb Lake (Kelley 1975) and to drinking water standards prepared by the Department of Health and Welfare of Canada. Table III and Table IV which present the range of the samples in this study and how these can be compared to some known values. This shows calcium, copper, iron, potassium, magnesium, manganese, sodium and zinc to be above other known values, where barium is below known values.

Discussion

The source of most of the trace metals appears to be from the pit area. Since the metal concentrations are highest in the pits which are topographically higher and due to the chemical process at work here. It appears that surface and ground waters have migrated downslope along drainage ditches and cleavage planes (Plate 3 & 4 and Figure 14) to the river. Possibly the water from the pit has mixed with water from other areas and has become diluted.

In the pit area the main process involves the oxidation of sulfur by oxygen which is reduced. The redox reaction (Levinson, 1974, P. 77).

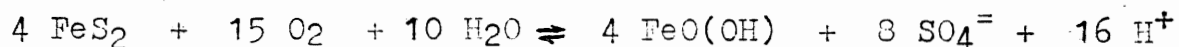


Table III

Drinking Water Standards

Calcium	200.0 ppm [#]	1.0 ppm [*]	15.0 ppm ⁺
Copper	1.0	0.05	1.0
Iron	0.3		0.3
Manganese	0.05		0.05
Magnesium	150.0		0.4
Sodium	200.0	3.2	6.0
Zinc	0.5	0.009	0.05

Department of Health and Welfare (1975)

* Hebb Lake, Kelley (1975)

+ Average River Water, Hem (1970)

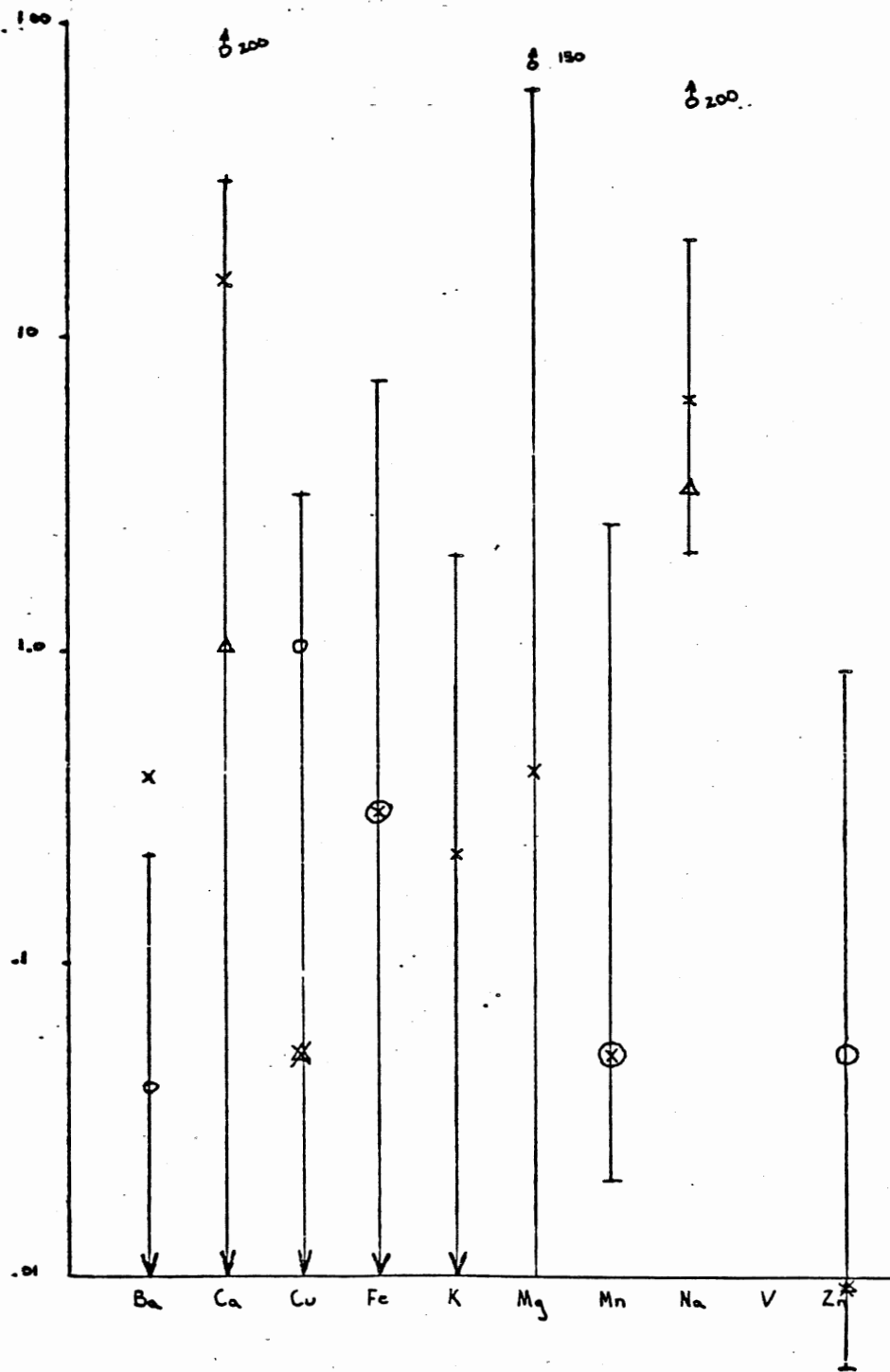


Table iv A comparison of trace metal concentrations with other water values

- I range in this study
- x average river water (Hen 1970)
- △ Hebb Lake (Kelley 1975)
- drinking water standards (Dept health & welfare)

When freshly exposed pyrite comes in contact with the oxidizing atmosphere, the water is only slightly acid, so any iron dissolved by surface water will tend to precipitate as ferric hydroxide (Goethite) because of the insolubility of this compound in other than very acidic waters. The goethite may tend to cement loose particles and make an indurated conglomerate. However, with time, the H^+ concentration should increase as described in the reaction above so that the ferric iron (Fe^{+++}) remains in solution. Also the acid waters have a far greater leaching effect on other materials composed of a variety of metals. In an acidic environment the metal Zn, Cu, Mn could easily be dissolved from sulfides, silicates or any material such as those common to dumps. Other metal such as Ca, Mg, K, Na, Ba were most likely leached in a similar manner from the slates. The high acidity near the pits would ensure that these metals remain in solution, even in an oxidizing environment.

As the acid metal bearing waters migrate away from the pits they would tend to lose their acidity through reactions with rocks and/or soils and being diluted by less acidic waters. This would again cause ferric iron to precipitate and to a lesser extent Mn. Since Fe and Mn hydroxides adsorb metal ions when formed, it is possible

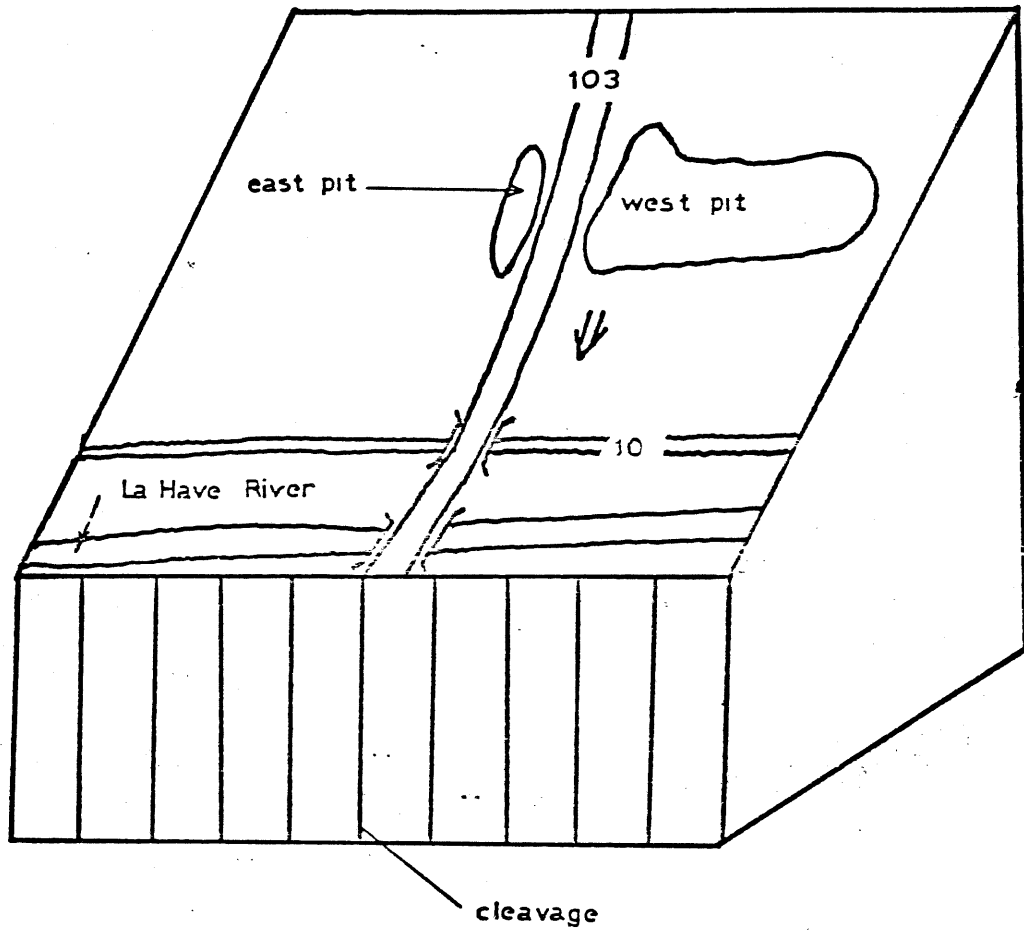


FIG 14 Model for groundwater flow
Arrow indicates flow direction

that when the hydroxides precipitate they would also remove the other metals.

Some local concentration such as those seen in the Na, V, Cu and Zn graphs could be due to other means than the pits. The localized higher sodium values appear along Highway 10 and thus they may be the result of road salt. The high vanadium values could be the result of the oil used to surface the dirt roads to the town dump, to the west pit, and to the east pit. The copper highs are also localized in some wells and may be the reflection of copper in the pumping fixtures. Similarly, some dug wells are often lined with galvanized (zinc plated) sheet metal; this could possibly explain some zinc anomalies.

Some wells show high values while nearby wells show lower values. The wells with the high concentrations tend to be dug wells while the lower values tend to be in deep drilled wells. The drilled wells appear to have been scrubbed of metal due to adsorption process of hydroxides. A correlation of estimated Eh and measured pH in the area shows how acidity and oxidation had decreased together. (Figure 15).

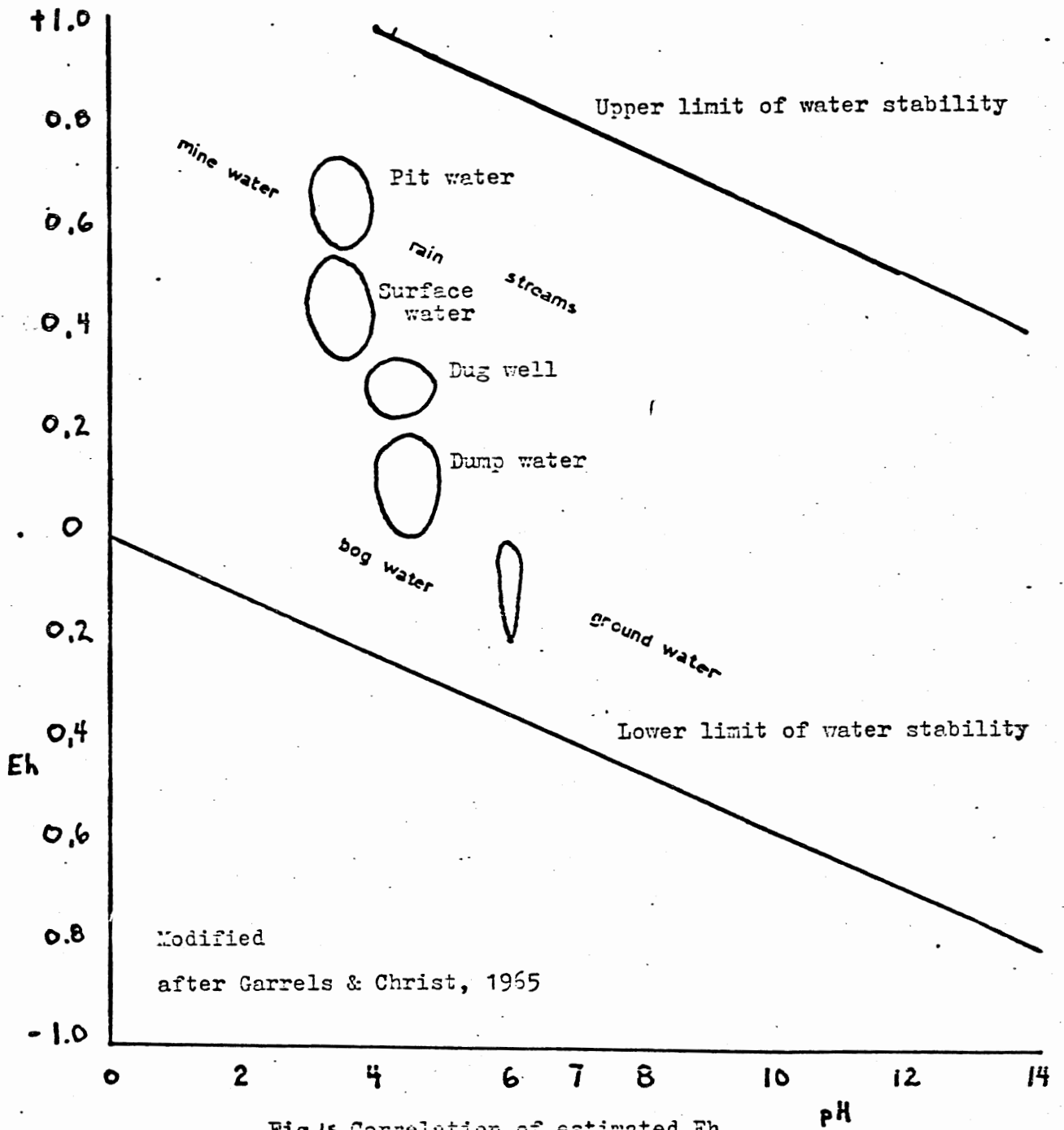


Fig 15 Correlation of estimated Eh values and measured pH values

Conclusion

It has been shown that a spatial distribution of metals does exist in the study area. Metals from the pits have been leached from the sulfides which are interbedded with the slates. These were exposed when the pits were opened for road construction. These metal ions in solution migrate down slope along drainage ditches in the surface environment and along cleavage planes of the slates in the ground water system, and are adsorbed on hydroxides and precipitated.

These waters interact with well systems causing the deterioration in the quality of the drinking water, as some well waters are in excess of the drinking water standards and known averages of the area.

If this project was to be followed up, it may be interesting to test these results by taking two samples directly from the well and to acidify one of these two, to keep iron from precipitating out. It would be of interest to expand the analytical technique to include Pb, As, chlorides, anions and a measure of the oxidation potential (Eh).

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APPENDIX A

<u>Sample</u>	<u>Description</u>
1	Hand dug well 15-18' depth pH 5 possible contamination: railway
2	Hand dug well 6' depth pH 4 possible contamination: railway
3	Running stream - moderate rate pH 4 possible contamination: railway
4	Drilled well 150' depth, cased 20' pH 4, possible contamination: railway
5	Spring pH4, possible contamination: railway
6	Construction pit for sewage, being built pH 5, possible contamination: highway
7	Stream in ditch by South Pit moderate rate pH 5
8	Pool in South Pit, slow drainage, pH 3
9	Dug well, pH 4
10	Dug well, pH 4
11	Dug well, pH 4
12	Drilled well 130' depth cased to 90' pH 4
13	Drilled well 140' depth cased 20' pH 4
14	Pool in dump in North pit, moderate drainage, pH 4, possible contamination: plastic, tires
15	Stream in North Pit, pH 3, moderate- slow flow

<u>Sample</u>	<u>Description</u>
16	Dug well 6.5' pH 4
17	Dug well, pH 4
18	Drilled well 104' depth, cased 20' pH 5
19	Dug well 6', pH 4
20	Drilled well, pH 4, 120' depth cased 60', possible contamination: sewage up slope
21	Town water, pH 4
22	Dump - general garbage slow drainage, pH 6
23	La Have River, moderate flow
24	Drilled well 75' depth, cased 20' pH 5
25	Drilled well 100' depth, cased 20' pH 5
26	Drilled well 160' depth, cased 20' pH 4
27	Dug well, pH 5, possible contamination: blasting at new school
28	Dug well, pH 5, possible contamination: blasting at new school
29	Dug well, pH 4, possible contamination: blasting at new school
30,31,32	Stream, fast flow, very high, possible: contamination swamp
33	Pool in stream in pit, pH 3