INVESTIGATION OF SEPTIC LEACHATE DISCHARGES INTO BIG PLATTE LAKE, BENZIE COUNTY, MICHIGAN

AUGUST 18-20, 1981

FOR
THE MICHIGAN DEPARTMENT OF NATURAL RESOURCES
AND
THE PLATTE LAKE IMPROVEMENT ASSOCIATION

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INTRODUCTION

Swanson Environmental, Inc. (SEI) has been retained by the Michigan Department of Natural Resources (MDNR) to conduct a septic leachate detection survey on Big Platte Lake in Benzie County, Michigan. The location of Big Platte Lake and the study area are illustrated in Figure 1. The shoreline scanning for septic system discharge was conducted from August 18 through 20, 1981, in cooperation with the MDNR. Objectives of the study were to locate and sample septic leachate plumes entering Big Platte Lake, and to study groundwater flow patterns in the immediate vicinity of the lake.

PROCEDURES

One of the causes of accelerated lake eutrophication is domestic septic systems located on lake shores which malfunction and release nutrients and bacteria into lake water through the bottom sediments. Septic seepage into lakes can result from several conditions including; (1) shallow groundwater, encouraging soil water saturation and anaerobic conditions; (2) location too near the water's edge to allow complete bacterial degradation and soil absorption of potential contaminants; and (3) hydraulic overloading of good systems and poorly designed or poorly installed systems due to excessive use during peak recreation periods (Kerfoot and Brainard, 1979).

When any of the above conditions exist, septic leachate can be carried with the groundwater through porous soils, erupting as an active plume along the lake bottom. Figure 2 illustrates how a typical septic system might fail and discharge pollutants into a lake. The discharge tends to travel horizontally with the groundwater flow, entering the lake in shallow shoreline areas.

Septic leachate contains both UV fluorescent organics and conductive inorganics. Whiteners, surfactants, and natural degradation

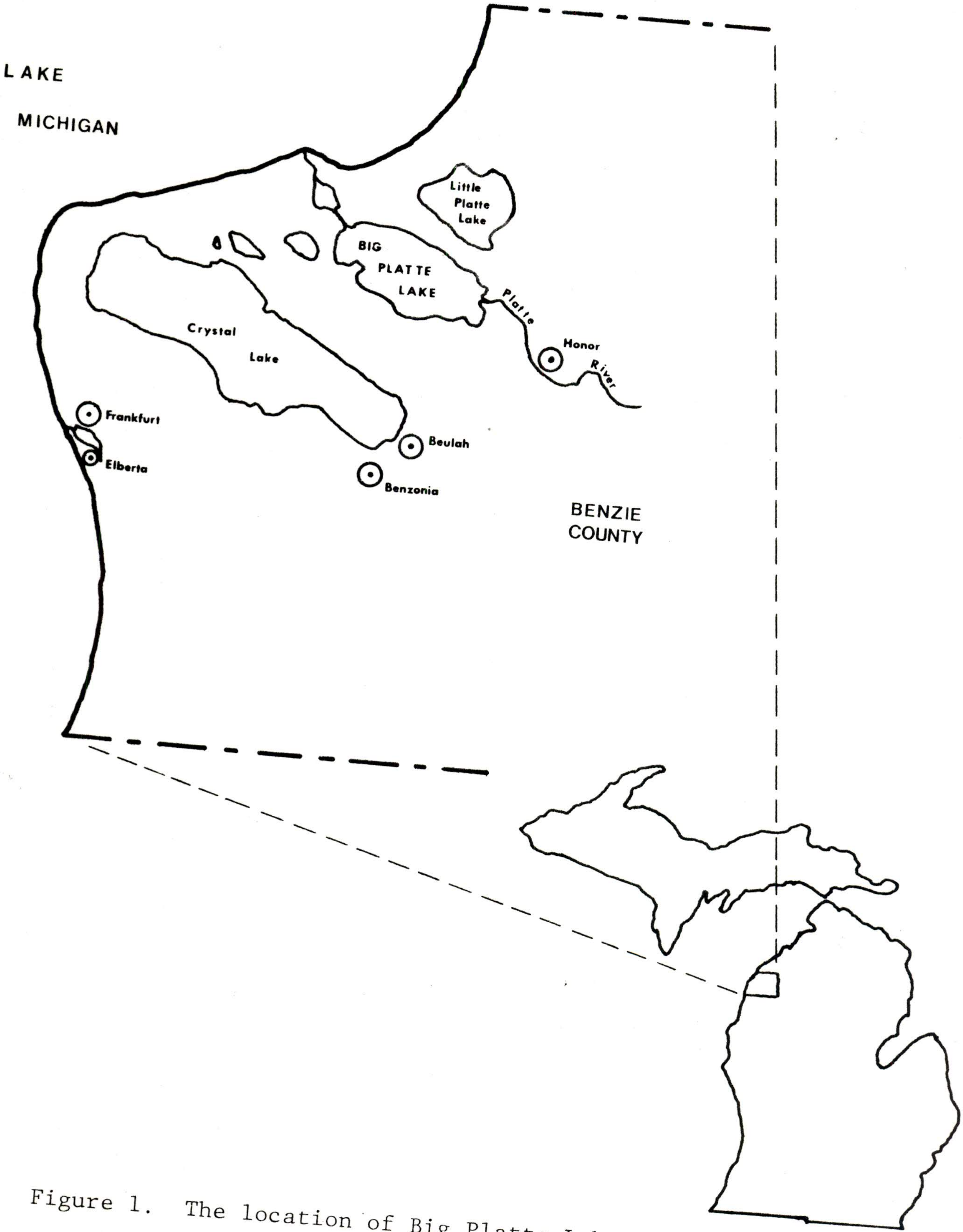


Figure 1. The location of Big Platte Lake, Benzie County, Michigan.

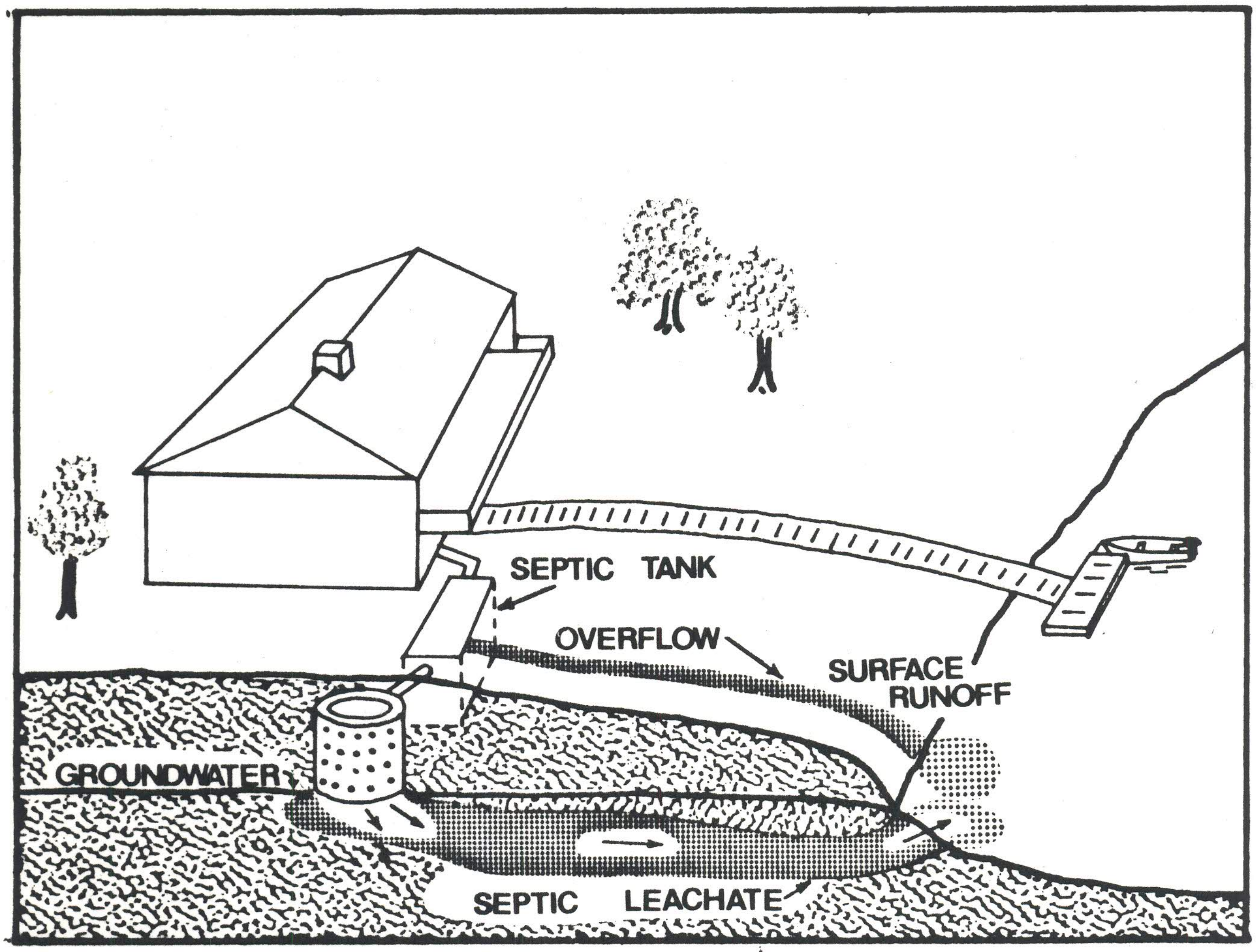


Figure 2. Types of septic system failures likely to cause contamination of groundwater and surface waters

products fluoresce in the UV range, while inorganics such as chlorides are highly conductive. A stable ratio exists between fluorescence and conductivity which permits the detection of active septic leachate plumes (Kerfoot and Brainard, 1979).

In addition to actively erupting plumes, passive plumes may also be encountered. This usually occurs where septic systems have been in disuse such as during winter months or when groundwater levels fluctuate causing intermittent septic discharge. Passive plumes are indicated by high fluorescence and normal levels of organic materials which continue to be released from the sediments for up to six months after active discharge. Inorganics are highly mobile and quickly dissipate once the source is removed.

The septic leachate detection survey was conducted using an ENDECO Model 2100 Septic Snooper TM to identify leachate plumes entering the lake. The detector is a portable unit which continuously measures fluorescence and conductivity of water passing through the instrument. Sample water is continuously drawn from the lake through an attached submersible pump, scanned, and discharged back into the lake. The pump is mounted on a long handled probe to facilitate sampling near the bottom where plumes are most likely to occur.

Immediately preceding the survey, the leachate detector was calibrated to local conditions using secondary effluent from a local treatment facility diluted with lake water taken from an offshore sample. Such calibration is required to account for local effluent characteristics and background water quality, specifically natural fluorescence and conductivity.

The survey was executed using a fourteen-foot jon boat to transport survey personnel and equipment slowly along the shoreline. During the survey, the boat was pulled or rowed within 15 feet of the actual shoreline to effectively sample likely plume areas. In some instances, particularly along the northwest shore, scanning the nearshore area was inhibited by wide shallow bars. In those areas scanning was conducted as near to shore as possible. Normally, the sample probe was positioned in 1 - 2 feet of water, continuously drawing water from within one foot of the lake bottom. As sample water was scanned, a continuous graphic output was recorded and septic leachate plumes were noted on large scale shoreline maps. When significant increases in fluorescence and conductivity were observed, the vicinity was scanned in detail to determine the point of maximum concentration. At this point, surface water samples were collected from the discharge hose of the leachate detector and location of the plume recorded.

At the same time, interstitial groundwater samples were collected at the point of eruption as detected by the leachate detector. Samples were collected by driving a shallow well point to a depth of 12-18" beneath the lake bottom. Water was drawn from the well by a battery operated, peristaltic pump. The pump was purged by pumping approximately one liter of groundwater prior to sample collection, and was purged after sample collection by pumping a small quantity of ambient lake water.

All samples were placed in polyethylene containers and immediately placed on ice. At the conclusion of each day, samples were turned over to MDNR personnel for transport to laboratory facilities in Lansing, Michigan, for analysis.

Groundwater flow velocities and direction were determined at fourteen locations around the lake. Groundwater flows were measured with a Model 10 Dowser Electronic Flow Meter developed by K-V Associates, Inc. The flow meter consists of a central heat source surrounded by 10 sensory heat probes. When inserted into the soil at groundwater level, the meter measures thermal change as heat is conducted along a transient established by groundwater movement. Rate and direction of flow are determined by measuring the relative direction and magnitude of heat change (K-V Associates, Inc. 1980). Results are calculated as movement in feet per day in a predominant direction.

RESULTS

A summary of the survey area, septic leachate plume locations and groundwater flow monitoring results are presented in Figure 3. Strip chart recordings of background water quality and leachate plumes encountered are included in Appendix A.

Locations of Septic Leachate Plumes

A total of 40 septic leachate plumes were identified along the shores of Big Platte Lake (Table 1). These included 17 active plumes, 13 passive plumes, and 10 surface plumes. In addition, several questionable locations showed signs of contributing septic leachate, however, disturbed or suspended bottom materials prevented positive identification. Table 2 categorizes and lists the anticipated source of each plume. The lots listed are the closest to the plume site and in several cases, neighboring lots could be the source or additional contributors to the leachate plume.

Of the septic leachate plumes detected on Platte Lake, 30 were located on the south shore (Figure 3). Twenty of these plumes emanated from subsurface discharge while ten were related to surface streams or runoff. Due to variable shoreline conditions along the southern shore, emergence of septic leachate was noted to occur by several mechanisms. Along the southeast shore, (P 1-11) low, restricted lot conditions resulted in fairly typical subsurface plumes. Emergence usually was observed in the near-shore region, breaking out through cracks in concrete breakwalls or the lake bottom in shallow water. In a few instances, a single plume was observed to erupt at several points through very shallow water on sand bars extending from the shoreline. Limited patches of algal growth were commonly associated with plume eruption points at these sites.

The south central shoreline (P 12-25) was dominated by surface discharge. Again, lots were generally low and dwellings close to

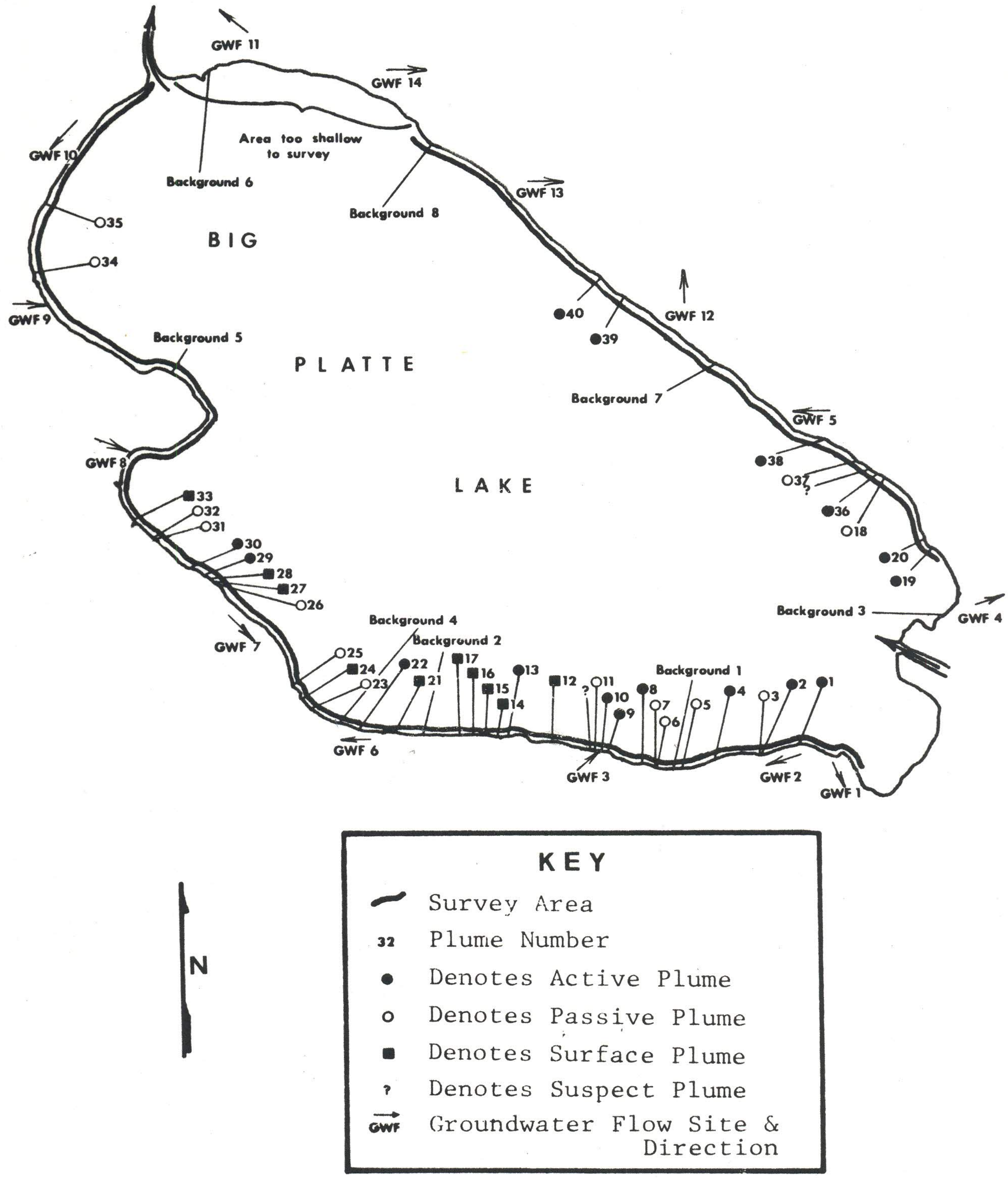


Figure 3. Location of the septic leachate survey area, plume sites, and groundwater flow monitoring results on Big Platte Lake, Benzie County, Michigan.

TABLE 1. CORRELATION OF SAMPLE NUMBERS, PLUME AND BACKGROUND SITES. PLATTE LAKE 8/18-20/81.

Sample Number	Samples * Taken	Site
1	All	Plume 1
2	All	Plume 2
3	All	Plume 3
4	All	Plume 4
5	All	Plume 5
6	All	Background #1
7	All	Plume 6 & Replicate
8	All	Plume 7
9	All	Plume 8
10	All	Plume 9
11	All	Plume 12
12	All	Plume 13
13	All	Background #2
14	All	Clear stream background
15	All	Plume 18
16	SW, GW	Plume 19
17	SW, GW	Plume 20
18	All	Background #3
19	SW, FC	Plume 21 (Stream)
20	SW, FC	Plume 22
21	All	Background #4
22	All	Plume 23
23	SW, FC	Plume 24 (Stream)
24	All	Plume 25
25	All	Plume 26
26	All	Plume 28
27	All	Plume 30
28	SW	Plume 33
29	All	Plume 31 & 32
30	All	Background #5
31	All	Plume 34
32	All	Plume 35
33	SW, FC	Platte River Exit
34	All	Background #6
35	All	Plume 36
36	All	Plume 37
37	All	Plume 38
38	All	Background #7
39	SW, GW	Plume 39
40	All	Plume 40
41	All	Background #8

* SW = Surface Water; FC = Fecal Coliform; GW = Groundwater.

TABLE 2. SOURCE AND DESCRIPTION OF SEPTIC LEACHATE PLUMES DETECTED ON BIG PLATTE LAKE, BENZIE COUNTY, MICHIGAN.

PLUME NUMBER	ACTIVITY	PROPERTY IDENTIFICATION
1	Active	Chester
2	Active	Hastings
3	Active	Hastings
4	Active	D. Loewen 8120 Yukon
5	Passive	8038 Yukon
6	Passive	8018 Yukon
7	Passive	8018 Yukon
8	Active	Rettig
9	Active	
10	Active	
11	Passive	
12	Surface (Stream)	Winton
13	Active	S. Schenk 7734
14	Surface (Stream)	
15	Surface (Stream)	
16	Surface (Stream)	
17	Surface (Stream)	
18	Passive	8491
19	Active	Ereeman 8915
20	Active	8855
21	Surface (Stream)	
22	Active	
23	Passive	6786
24	Surface (Stream)	
25	Passive	E. Reynolds
26	Passive	Priest
27	Surface	
28	Surface	N. Schutes
29	Active	
30	Active	E. D. Amstutz
31	Passive	Delaney
32	Passive	Delaney
33	Surface (Stream)	
34	Passive	Hawkins
35	Passive	Hultgren 4415 Arbor Vitae
36	Active	Van Hammens Resort
37	Passive	8355
38	Active	Scharmen
39	Active	Wanner
40	Active	Bitzan 7765

the lake. A large number of artesian wells were discharging into the lake along this stretch, some of which may have been transporting septic system waste. The channels transporting spring overflow tended to form drainage paths for shallow groundwater suspected of containing septic leachate from adjacent lots. A large amount of surface water seepage from springs or shallow groundwater was observed along much of the shoreline. Leachate from plumes located in these areas were frequently disperse as it emerged over a broad area with the seepage water.

A concentrated area of plumes was observed along the southwest shore of Platte Lake (P 26-33). Lot elevations were higher in this area and in several cases (P 26-30) leachate appeared to be flushing down the steeply sloped shore during intermittent storm events. Commonly, plumes appeared as unusually sporadic organic fluctuations dispersed across one or more lots. Because of the slope, and appearance of plumes, it is believed that additional sources such as fertilizer, street runoff and lawn debris may be contributing to the organic loading. Lower lots and an increased abundance of algae and weeds were observed in the area of plumes 31-33. Plume 33 was a surface stream which residents claimed was draining an inland dump site.

A series of six septic leachate plumes were detected along a short stretch of shore at the northeast corner of the lake (Figure 3). Lots in this area were low with intense cottage development. Much of the development appeared to be small rental units. In contrast to other areas of the lake, weed growth was considerably more abundant in the vicinity of plumes on the northeast shore. Conditions suggest that a substantial influx of nutrients is occurring.

Four additional septic leachate plumes were detected along the north and western shores of Platte Lake (Figure 3). While extremely shallow nearshore conditions inhibited scanning along these shores, septic leachate is not believed to be a major problem. In most cases dwellings were set well back from the shoreline on large elevated lots. These conditions would limit septic system failure and discharge into the lake.

Water Chemistry

Analysis of the chemical composition of water samples collected in the surface and groundwaters at septic leachate plumes provide information to verify the source and magnitude of the problem. Samples were analyzed for: nitrogen, phosphorus, chlorides and fecal coliforms. Nitrogen and phosphorus are commonly associated with plant growth and increased rates of eutrophication. Chloride is a very mobile ion which is found in elevated concentrations in septic leachate. Fecal coliforms are normally abundant in human waste and provide an indication of health hazards resulting from contamination by septic waste.

Results of surface water and groundwater chemical analysis are presented in Tables 3 and 4 respectively. Comparison of background surface water samples to the values presented in Table 5 indicate that Platte Lake can presently be classified as mesotrophic with low to moderate productivity.

Nitrogenous compounds normally occur in elevated concentrations in human wastes and provide a good indicator of seepage from shoreline septic systems. Because various forms of nitrogen are interchangeable, depending on the availability of oxygen, organic nitrogen, nitrate+nitrite-nitrogen and ammonia nitrogen have been used as indicators in this study. Nitrogen can be toxic to humans when occurring in large concentrations. An upper limit of 10 mg/l of nitrate in drinking water is recommended by the U.S. Department of Health for prevention of methemoglobinemia in infants.

Nitrogen concentrations observed in septic leachate plumes on Platte Lake are reported in Table 3. The data indicate that levels of nitrogen are elevated to some degree at most plume sites. Nitrate+nitrite-nitrogen was elevated in 19 plumes with an average

TABLE 3. CHEMICAL COMPOSITION OF SURFACE WATER SAMPLES COLLECTED IN BACKGROUND AND LEACHATE PLUME SITES. PLATTE LAKE, MICHIGAN.

SURFACE WATER SAMPLES

Plume No.	Sample No.	NO_2+NO_3-N (mg/l)	NH_3-N (mg/l)	Org N (mg/l)	TKN (mg/l)	Ortho P (mg/l)	Total P (mg/l)	Chloride (mg/l)	Conductivity (μmhos)	Fecal Coliforms (Col/100 mls)
1	S1	0.006	0.012	0.28	0.29	<0.001	0.013	3.9	280	1
2	S2	0.006	0.010	0.28	0.29	<0.001	0.011	4.2	285	0
3	S3	0.052	0.020	0.30	0.32	<0.001	0.013	4.5	285	1
4	S4	0.006	0.007	0.26	0.27	<0.001	0.011	4.1	280	0
5	S5	0.007	0.013	0.28	0.29	<0.001	0.018	4.0	280	0
BG #1	S6	0.007	0.010	0.26	0.27	<0.001	0.010	4.0	280	1
6	S7	0.003	0.013	0.34	0.35	<0.001	0.018	4.1	280	4
Dup.	S7	0.007	0.011	0.31	0.32	<0.001	0.013	4.0	285	11
7	S8	0.006	0.011	0.33	0.34	<0.001	0.013	4.0	285	4
8	S9	0.021	0.012	0.29	0.30	<0.001	0.011	4.6	290	33
9	S10	0.036	0.009	0.34	0.35	<0.001	0.012	4.4	290	5
12	S11	0.28	0.010	0.33	0.34	<0.001	0.016	3.6	310	97
13	S12	0.32	0.012	0.65	0.66	0.001	0.036	4.0	305	104
BG #2	S13	0.009	0.013	0.31	0.32	<0.001	0.013	3.9	280	26
BG Stream	S14	0.008	0.012	0.38	0.39	0.001	0.017	4.1	285	89
18	S15	0.007	0.016	0.60	0.62	0.001	0.022	4.2	275	35
19	S16	0.007	0.006	0.57	0.58	0.001	0.036	4.7	275	
20	S17	0.007	0.010	0.49	0.50	0.001	0.034	4.4	275	
BG #3	S18	0.007	0.014	0.38	0.39	0.001	0.017	4.3	275	
21	S19	0.031	0.006	0.22	0.23	0.001	0.010	3.8	295	28
22	S20	0.006	0.008	0.29	0.30	0.001	0.020	4.0	290	4
BG #4	S21	0.006	0.005	0.22	0.22	<0.001	0.008	3.9	280	2
23	S22	0.006	0.006	0.25	0.26	<0.001	0.010	3.9	285	4
24	S23	0.064	0.032	0.20	0.23	0.001	0.016	7.6	405	29
25	S24	0.008	0.005	0.26	0.26	0.001	0.012	4.4	285	3
26	S25	0.012	0.005	0.34	0.35	0.001	0.026	4.1	270	16
28	S26	0.029	0.009	0.38	0.39	0.001	0.021	4.5	255	4
30	S27	0.005	0.006	0.30	0.31	<0.001	0.001	4.0	265	3
33	S28	0.76	0.017	0.33	0.35	<0.001	0.019	3.9	290	5
31	S29	0.007	0.017	0.69	0.71	0.001	0.036	4.3	380	1
BG #5	S30	0.005	0.021	0.27	0.29	<0.001	0.013	4.2	280	9

TABLE 3. (Cont) CHEMICAL COMPOSITION OF SURFACE WATER SAMPLES COLLECTED IN BACKGROUND AND LEACHATE PLUME SITES. PLATTE LAKE, MICHIGAN.

SURFACE WATER SAMPLES

Plume No.	Sample No.	NO_2+NO_3-N (mg/l)	NH_3-N (mg/l)	Org N (mg/l)	TKN (mg/l)	Ortho P (mg/l)	Total P (mg/l)	Chloride (mg/l)	Conductivity (µmhos)	Fecal Coliforms (Col/100 mls)
34	S31	0.006	0.009	0.32	0.33	<0.001	0.012	4.2	280	96
35	S32	0.004	0.008	0.47	0.48	<0.001	0.016	4.6	290	19
Platte River	S33	0.005	0.006	0.27	0.28	0.001	0.009	4.0	280	1
BG #6	S34	0.006	0.007	0.29	0.30	0.001	0.011	4.0	270	11
36	S35	0.006	0.009	0.26	0.27	0.001	0.011	4.2	290	
37	S36	0.005	0.016	0.29	0.31	0.001	0.010	4.2	290	
Dup.	S36	0.002	0.006	0.29	0.30	0.001	0.009	4.2	290	
38	S37	0.007	0.011	0.70	0.71	0.001	0.036	4.7	300	
BG #7	S38	0.005	0.011	0.27	0.28	0.001	0.008	4.2	280	
39	S39	0.005	0.005	0.34	0.35	<0.001	0.011	5.1	295	
40	S40	0.014	0.006	0.31	0.32	<0.001	0.025	4.9	300	
BG #8	S41	0.006	0.026	0.26	0.29	<0.001	0.010	4.8	290	
Stream	S42	1.1	0.013	0.40	0.41	0.012	0.034	7.1	440	

TABLE 4. CHEMICAL COMPOSITION OF GROUNDWATER SAMPLES COLLECTED IN BACKGROUND AND LEACHATE PLUME SITES. PLATTE LAKE, MICHIGAN.

GROUNDWATER SAMPLES

Plume No.	Sample No.	NO_2+NO_3-N (mg/l)	NH_3-N (mg/l)	Org N (mg/l)	TKN (mg/l)	Ortho P (mg/l)	Total P (mg/l)	Chloride (mg/l)
1	GW 1	0.007	1.1	1.1	2.2	0.130	0.167	21.0
2	GW 2	0.007	0.26	0.36	0.62	0.054	0.062	11.3
3	GW 3	0.004	0.31	0.42	0.73	0.113	0.125	11.9
4	GW 4	0.004	0.35	0.59	0.94	0.066	0.27	6.3
5	GW 5	0.005	3.0	0.55	3.5	0.194	0.70	5.5
BG #1	GW 6	0.004	0.049	0.30	0.35	0.018	0.075	5.7
6	GW 7	0.005	0.157	0.35	0.51	0.034	0.076	6.6
Dup.	GW 7	0.005	0.159	0.34	0.50	0.031	0.060	6.6
7	GW 8	0.005	0.31	0.44	0.75	0.043	0.081	18.4
8	GW 9	0.006	1.0	0.22	1.3	0.190	0.25	12.3
9	GW 10	1.06	0.010	0.19	0.20	0.013	0.023	9.8
12	GW 11	1.00	0.011	0.08	0.09	0.009	0.025	3.4
13	GW 12	0.60	2.0	0.09	2.1	0.106	0.137	10.0
BG #2	GW 13	0.007	0.110	0.23	0.34	0.013	0.051	18.7
18	GW 15	0.006	0.83	0.20	1.0	0.021	0.042	15.1
	BG 1	0.006	1.0	0.33	1.3	0.152	0.20	5.0
19	GW 16	0.011	1.0	0.84	1.9	0.124	0.28	8.0
20	GW 17	0.010	1.3	1.2	2.5	0.32	0.42	45.0
BG #3	GW 18	0.008	4.2	0.23	4.4	0.073	0.099	3.7
BG #4	GW 21	0.008	0.97	0.17	1.1	0.005	0.162	4.5
23	GW 22	0.008	0.62	0.29	0.91	0.023	0.057	6.8
25	GW 24	0.008	0.27	0.36	0.63	0.039	0.077	22.0
26	GW 25	0.008	0.014	0.55	0.56	2.0	2.1	4.5
28	GW 26	0.139	0.004	0.14	0.14	0.058	0.085	16.3
30	GW 27	0.006	0.55	0.36	0.91	0.057	0.138	5.0
31	GW 29	0.006	0.28	0.39	0.67	0.032	0.057	2.2
BG #5	GW 30	0.006	0.074	0.34	0.41	0.007	0.014	2.2
34	GW 31	0.012	0.88	0.79	1.7	0.038	0.123	8.8
35	GW 32	0.006	0.42	0.58	1.0	0.21	0.30	12.2
36	GW 35	0.006	3.3	0.39	3.7	0.52	0.60	15.9
37	GW 36	0.006	0.16	0.39	0.55	0.040	0.063	7.4
Dup.	GW 36	0.007	0.18	0.35	0.53	0.039	0.053	6.9
38	GW 37	0.22	2.6	0.7	3.3	0.90	1.0	21.0
BG #7	GW 38	0.007	0.32	0.18	0.50	0.066	0.108	11.6
39	GW 39	4.7	0.015	0.30	0.32	0.22	0.68	15.6
40	GW 40	19	1.4	0.65	2.0	0.24	0.27	39.0
BG #8	GW 41	0.005	0.080	0.13	0.21	0.018	0.028	5.9
BG #6	GW 34	0.008	0.24	0.63	0.87	0.047	0.181	2.5

TABLE 4. (Cont) CHEMICAL COMPOSITION OF GROUNDWATER SAMPLES COLLECTED IN BACKGROUND AND LEACHATE PLUME SITES. PLATTE LAKE, MICHIGAN.

GROUNDWATER SAMPLES

Plume No.	Sample No.	Conductivity (μmhos)	ΔC_i	Ratio ΔTN_i	ΔTP_i	% Breakthrough N	% Breakthrough P
1	GW 1	670	205	1.651	0.092	16.91	2.35
2	GW 2	505	40	0.071	-	3.72	
3	GW 3	500	35	0.178	0.05	10.68	7.5
4	GW 4	595	130	0.388	0.195	6.26	7.875
5	GW 5	585	120	2.949	0.625	51.60	27.34
BG #1	GW 6	505					
6	GW 7	515	50	-	0.001		0.105
Dup.	GW 7	515					
7	GW 8	660	195	0.199	0.006	2.143	0.16
8	GW 9	530	65	0.75	0.175	24.23	14.13
9	GW 10	475	10	0.65	-	136.5	
12	GW 11	395	-	0.534	-		
13	GW 12	550	85	2.144	0.062	52.9	3.83
BG #2	GW 13	575					
18	GW 15	510	114	0.48	-	8.84	
	BG 1	505					
19	GW 16	440	44	1.385	0.174	66.10	20.76
20	GW 17	645	249	1.984	0.208	16.73	4.38
BG #3	GW 18	600					
BG #4	GW 21	420					
23	GW 22	535	70	0.362	-	10.86	
25	GW 24	860	395	0.82	0.002	4.36	0.026
26	GW 25	285	-	0.012	2.025		
28	GW 26	440	-	-	0.01		
30	GW 27	425	-	0.36	0.63		
31	GW 29	415	-	0.12	-		
BG #5	GW 30	360	-	-	-		
34	GW 31	385	-	1.156	0.048		
35	GW 32	505	40	0.45	0.225	23.62	29.53
36	GW 35	535	139	3.18	-	48.04	
37	GW 36	455	59	0.03	-	1.06	
Dup.	GW 36	455					
38	GW 37	565	169	2.994	0.89	37.2	27.64
BG #7	GW 38	515	119	-	0.002		0.088
39	GW 39	545	149	4.494	0.574	63.33	20.22
40	GW 40	935	539	20.474	0.164	79.76	1.597
BG #8	GW 41	385					
BG #6	GW 34	290					
			Mean Breakthrough			33.24%	10.47%

TABLE 5: GENERAL RELATIONSHIPS OF LAKE PRODUCTIVITY TO AVERAGE CONCENTRATIONS OF EPILIMNETIC NITROGEN AND TOTAL PHOSPHORUS

General level of lake productivity	Total Phosphorus (mg/l)	Inorganic N (mg/l)	Organic N (mg/l)
Ultra-Oligotrophic	<0.005	<0.2	<0.2
Oligo-Mesotrophic	0.005 - 0.01	0.2 - 0.4	0.2 - 0.4
Meso-Eutrophic	0.01 - 0.03	0.3 - 0.65	0.3 - 0.65
Eutrophic	0.03 - 0.10	0.5 - 1.5	0.5 - 1.5
Hyper-Eutrophic	>0.1	>1.5	>1.5

Modified from Wetzel, 1975, pp. 196 and 217.

elevation of 0.079 mg/l. Notable increases were observed at plumes 12, 13 and 33. Ammonia (NH_3-N), which is usually associated with a reducing environment, showed little variation from background concentrations. Organic and total kjeldahl nitrogen were elevated in most plumes but not at alarming levels. Maximum elevations were seen in plumes 13, 18, 19, 20, 31 and 38. Average elevation of total kjeldahl nitrogen was 0.287 mg/l in surface water samples reflecting a substantial discharge of nitrogen.

Concentration of nitrogen in groundwater samples collected at septic leachate plume sites are presented in Table 4. The tendency for nutrients to accumulate in the sediments is apparent from these results, with all forms of nitrogen considerably higher in the interstitial sediment samples than in surface waters. Notable elevations in nitrates were observed at site 40 where 19 mg/l of nitrate-nitrite-nitrogen were detected.

Concentrations of ammonia nitrogen (NH_3-N) were distinctly elevated in most groundwater samples indicating that reducing conditions exist in the soils around much of the lake. This is particularly evident at plume sites 1, 5, 8, 13, 16, 17, 36, 38 and 40. The high levels of ammonia detected at these locations suggest that overloading of the soil by **waterlogging** or excessive organic loading has occurred. The resulting anaerobic conditions prevent nitrification of ammonia to nitrate and strongly suggests that discharge from malfunctioning septic systems is occurring at these sites.

Organic and total kjeldahl nitrogen were similarly elevated in a majority of the groundwater plumes. These data support the assertion that transport of nutrients from septic waste is occurring through the shallow groundwater.

Phosphorus occurs primarily as phosphates in the form of inorganic orthophosphate and organically bound phosphates in natural waters.

This is a bit high!

Total phosphorus concentrations in unpolluted lakes commonly range from 0.01 - 0.05 mg/l. Highly labile orthophosphates are predominant in commerical fertilizers, while organic phosphates are formed by biological processes. Often greater than 90 percent of the phosphorus in lakes is in the organic form which is associated with living or dead organisms. Typically, phosphorus compounds which enter the water are rapidly assimilated by aquatic plants and are rapidly recycled until they eventually settle into deep unproductive areas and are buried in sediments (American Public Health Association, 1976; Wetzel, 1975).

Phosphorus concentrations detected in surface water plume samples reflected small but consistent elevations of total phosphorus. The very low levels of orthophosphate detected in all samples is not unusual. Orthophosphate is rapidly assimilated by aquatic plants and is seldom abundant in surface water. Groundwater samples showed more substantial elevations of both total and ortho-phosphorus. Mean elevation of total phosphorus was 0.33 mg/l compared to a background of 0.088 mg/l. Maximum elevations occurred in plumes 4, 5, 8, 19, 26, 35, 36, 38, 39 and 40.

Chloride is one of the major inorganic anions found in water and wastewater. Chloride concentrations are high in septic tank effluents since sodium chloride is common in the human diet and passes unchanged through the digestive tract (American Public Health Association, 1976). The average concentration of chloride commonly occurring in fresh water is approximately 8.3 mg/l (Wetzel, 1975).

Chloride concentrations were extremely low in both background and septic leachate plume samples collected on Platte Lake (Table 3). Groundwater samples were also generally low in chloride and quite variable. Notable elevations of chloride were detected in the groundwater in plumes 1, 18, 20, 25, 36, 38, 39 and 40. The greater elevation of chlorides in groundwater samples reflects a slow rate of breakthrough and rapid dispersion once the contaminants reach the lake water.

Fecal coliforms are commonly associated with human and animal waste. The existence of coliform bacteria occurs naturally, but concentrations are frequently elevated in waste discharge areas. Their presence does not necessarily mean pathogenic organisms are also present but does indicate the existance of a potential health hazard.

Fecal coliforms were generally low in surface water samples collected on Platte Lake (Table 3). Most samples contained less than 10 colonies/100 mls. Only two septic leachate plumes (P 12 & 13) had substantial elevations with 97 and 104 colonies /100 mls respectively. In addition, high numbers of fecal coliforms were detected in one surface stream, BG sample number 14. In no case did coliform levels indicate a health hazard. U.S. drinking water standards recommend a maximum of 4 colonies /100 mls, while the federal standard for bathing is an average of 200 fecal colonies/100 mls at any time.

better read your standards

a geometric mean of 5 or more samples collected within a 30 day period

Nutrient Analysis

The contribution of shoreline septic systems to the nutrient budget of Big Platte Lake can be estimated from the chemical composition of surface and groundwater samples collected during the survey. The method involved was developed by K-V and Associates, Inc. to predict sediment breakthrough of phosphates and nitrogen associated with septic leachate.

Predicted Nutrient Breakthrough

Prediction of nutrient breakthrough is calculated according to K-V Associates (1978; 1979). The technique uses the difference between specific conductance and nutrient concentrations in interstital water samples collected from septic leachate plume sites, versus background samples, to estimate breakthrough and nutrient loading rates. The calculations correct for dilution and error in sample collection by adjusting the nutrient levels above background to concentrations anticipated in typical sand filtered effluent. The process is best described by the following equations reported by K-V Associates (1979).

$$100 \times \frac{\Delta C_{ef}}{\Delta C_i} \quad \frac{\Delta TP_i}{\Delta TP_{ef}} = \% \text{ breakthrough of phosphorus}$$

$$100 \times \frac{\Delta C_{ef}}{\Delta C_i} \quad \frac{\Delta TN_i}{\Delta TN_{ef}} = \% \text{ breakthrough of nitrogen}$$

Where: $TP_i - TP_o = \Delta TP_i$ Total phosphorus

$TN_i - TN_o = \Delta TN_i$ Total nitrogen (sum of NO_2+NO_3-N and total kjeldahl nitrogen)

$C_i - C_o = \Delta C_i$ Conductance

C_o = conductance of background groundwater (μmhos/cm)

C_i = conductance of observed plume groundwater (μmhos/cm)

ΔC_{ef} = conductance of sand-filtered effluent minus the background conductance of municipal source water (μmhos/cm) (Assumes 100% of conductance in wastewater passes through)

TP_o = total phosphorus in background groundwater (mg/l)

TP_i = total phosphorus of observed plume groundwater (mg/l)

TP_{ef} = total phosphorus content of standard effluent (mg/l)

TN_o = total nitrogen content of background groundwater, here calculated as NO_2+NO_3-N and Total Kjeldahl Nitrogen (mg/l)

TN_i = total nitrogen content of observed plume groundwater, here calculated as NO_2+NO_3-N and Total Kjeldahl Nitrogen (mg/l)

TN_{ef} = total nitrogen content of local standard effluent (mg/l)

Nutrient breakthrough was calculated using the values for interstitial groundwater samples reported in Table 4. A summary of background groundwater characteristics is included in Table 6.

TABLE 6. SUMMARY OF CHEMICAL COMPOSITION OF BACKGROUND GROUNDWATER SAMPLES COLLECTED ON BIG PLATTE LAKE.

	Nitrogen (mg/l)				Phosphorus (mg/l)		(mg/l)	(μmhos/cm)
	NO_2+NO_3	NH_3	Org. N	TKN	Ortho P	Total P	Chloride	Conductivity
All Backgrounds	0.006	0.755	0.27	1.02	0.030	0.089	6.85	456
South Shore	0.006	0.30	0.26	0.55	0.010	0.075	7.7	465
North Shore [a)]	0.006	0.213	0.313	0.52	0.043	0.105	6.6	396

a) Excludes high nitrogen and conductance concentrations in Background sample 3.

Since background samples varied somewhat around the lake, values determined from north shore and south shore samples were segregated for the analysis. Due to unusually high levels of nitrogen and conductance in background 3, that sample was deleted from the analysis. Background 3 was collected near a marsh area on the east shore of the lake which is believed to have biased the results.

K-V Associates (1978) reported a conductance:total phosphorus: total nitrogen ratio of 700:8:20 in typical wastewater from Benzonia County and Emmet County sewage treatment facilities. It is assumed that effluent from on-site disposal systems around Platte Lake would have similar characteristics. Background surface water samples collected during the survey exihibited a conductance:total phosphorus:total nitrogen ratio of 280:0.287: 0.013. Subtracting background surface water samples from the assumed wastewater characteristics indicates a change in the concentration of wastewater to lake water with a $\Delta C_{ef}:\Delta TP_{ef}:\Delta TN_{ef}$ ratio of 420:8:20.

Breakthrough of septic leachate on Platte Lake was calculated for nitrogen at 20 plume sites and for phosphorus at 16 sites (Table 4). The analyses could not be executed at a number of plumes for which conductivity or one of the nutrient parameters did not exceed background levels. On several occasions (ex: P 26, P 30) leaching into surface waters is indicated by elevated nutrient levels despite low conductivities. In other cases it is probable that the center of the plume was not sampled resulting in greater dilution of leachate and lower observed nutrient levels.

Percent breakthrough of septic leachate on Platte Lake was extremely variable between plume sites (Table 4). Predicted breakthrough values for nitrogen ranged from one percent to greater than 100 percent, with breakthrough in excess of 50 percent common. The average percent breakthrough for nitrogen was 33.24 percent.

Percent breakthrough of phosphorus ranged from less than one percent to 29 percent. Average breakthrough of phosphorus was 10.47 percent for the plumes analyzed. The lower breakthrough ratio for phosphorus reflects the tendency for phosphorus compounds to adsorb to soil particles while nitrogen is more readily transported to the lake.

3.6
x 10.47

Nutrient Loading

An estimate of nutrient loading to Platte Lake from shoreline septic systems can be calculated by multiplying the occurrence of septic leachate plumes by a calculated average loading per plume. A per dwelling loading of 9.1 kg/year for nitrogen and 3.6 kg/year for phosphorus is assumed (K-V Associates, 1978). Multiplying by average percent breakthrough (Table 4) results in a loading rate of 0.7369 kg/year/dwelling for phosphorus, and 3.02 kg/year/dwelling for nitrogen. Multiplying times the number of plumes detected reflects an estimated loading rate of 15.0 kg/year (32.6 lbs/year) of phosphorus and 120.7 kg/year (266.3 lbs/year) of nitrogen.

.37692

=20 lbs

Table 1 provides a breakdown of nutrient loading along major shoreline segments. As expected, maximum nutrient loading is occurring in areas with the greatest plume density. These shorelines include much of the southern shore of Platte Lake and a short stretch at the northeast end of the lake. The results are somewhat biased away from the region along the northwest shore where shallow sandy flats inhibited optimal scanning of the nearshore waters. In general however, that region is less developed than the southern and eastern shore with less septic seepage anticipated.

The nutrient discharge from septic systems indicated in Table 7 is surprisingly high considering the pristine appearance along much of the shoreline. While septic leachate plumes were commonly associated with patches of algae and occasionally rooted submergent vegetation, the nutrient load indicated could support a much

TABLE 7. PREDICTED NUTRIENT LOADING FROM SHORELINE SEPTIC SYSTEMS ON BIG PLATTE LAKE, BENZIE COUNTY, MICHIGAN.

Shoreline Section	Plume Nos.	Nutrient Load P kg/yr	Nutrient Load P lbs/yr	Nutrient Load N kg/yr	Nutrient Load N lbs/yr
SE Shore	1-17 (17)	6.4	14.1	51.3	113.2
SW Shore	21-33 (13)	4.9	10.8	39.3	86.6
W Shore	34-35 (2)	0.7	1.7	6.0	13.3
NE Shore	18-20, 36-38 (6)	2.3	4.9	18.1	39.9
N Shore	39-40 (2)	0.7	1.1	6.0	13.3
TOTAL	(40)	15.0	32.6	120.7	266.3

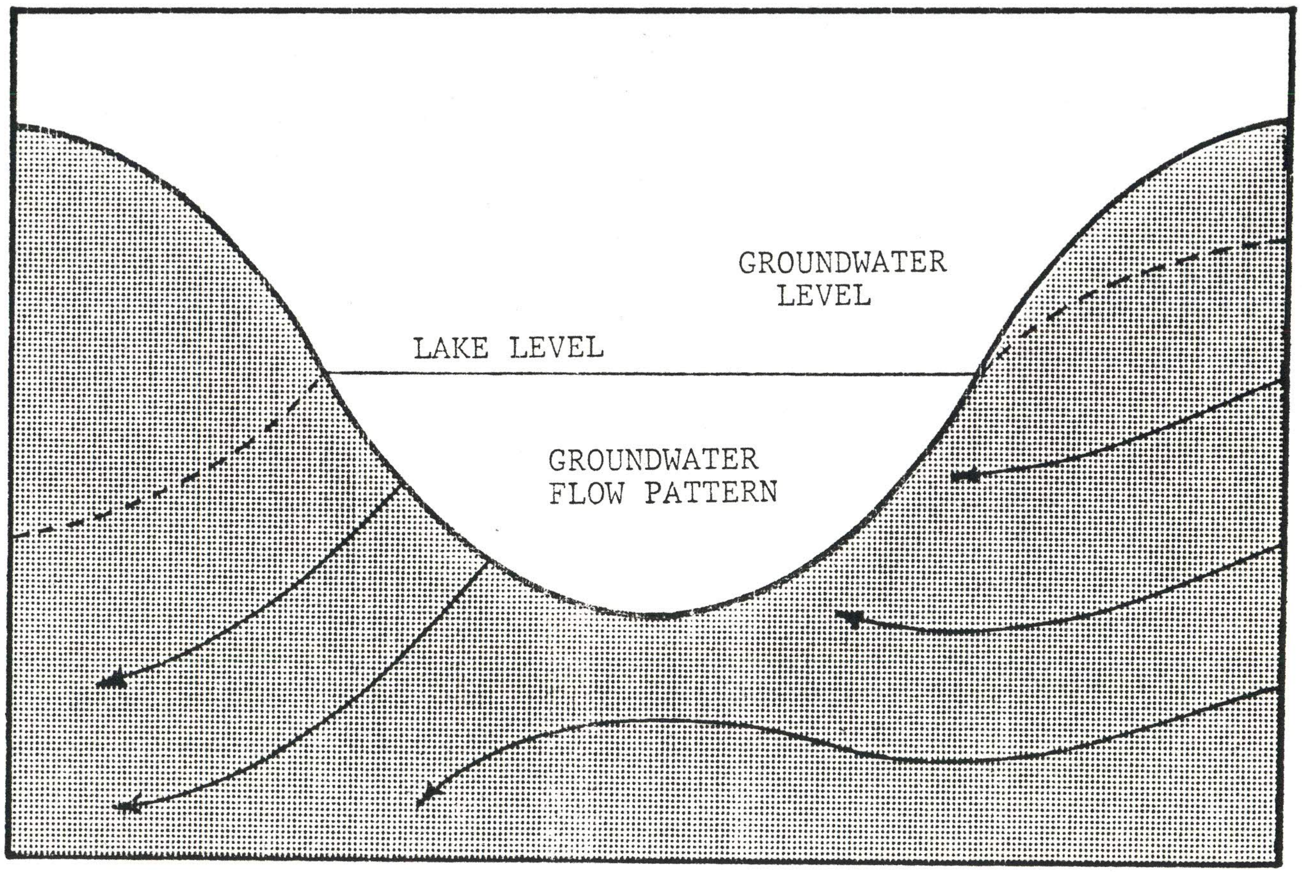
greater biomass of plant material than was observed.

It is believed that the apparent low primary productivity in the nearshore areas relates to marl deposition which was quite heavy at some locations. The formation of calcium carbonate (marl) is known to co-precipitate with phosphates, making them unavailable for utilization by plants. As a result, marl lakes are typically unproductive (Wetzel, 1975). A similar condition existed on the Stueben Lakes, Indiana, which prevented calculation of nutrient loadings. In that instance, it was speculated that nutrients which were mobile in subsurface plumes, would precipitate with the calcium carbonate as they emerged into the lake. The results were lower nutrient concentrations in the surface waters than normally anticipated (K-V Associates, 1978 b). The extent to which this phenomenon is occurring on Platte Lake has not been determined but is probably retarding the growth of obnoxious algae and weeds which could result from the predicted nutrient loading.

Groundwater Flow

Generally, lakes can be classified as either seepage lakes whose water budget is primarily from groundwater recharge, or drainage lakes which are dominated by surface water. Seepage into lakes may occur in a variety of patterns as described by Born et.al., 1974. Commonly, however, seepage lakes form a part of a regional system in which groundwater flows into a lake along one shore and out along the opposite (Figure 4) corresponding to the dominant regional flow direction. Localized variations in this pattern may occur as a result of precipitation, topography and soil characteristics which are often related to land use (Born, et.al., 1974). These flow patterns tend to encourage infiltration of septic seepage on the recharge side of the lake and limit it on the discharge side.

The rate and direction of groundwater flow was measured at fourteen locations as illustrated in Figure 4. Table 8 describes groundwater



From Born et.al. 1974.

Figure 4. Illustration of flow patterns around a typical flow-through seepage lake.

TABLE 8. GROUNDWATER FLOW RATES AND DIRECTION AT SELECT LOCATIONS AROUND PLATTE LAKE, BENZIE COUNTY, MICHIGAN. AUGUST 18-20, 1981.

Site	Flow Direction	Flow Rate (ft/day)
1	SSE	2.5
2	WSW	29.0
3	NE	17.0
4	ENE	5.5
5	W	15.5
6	W	3.0
7	SE	8.0
8	ESE	14.0
9	E	9.5
10	SW	8.0
11	NW	7.5
12	N	3.5
13	E	9.0
14	E	6.0

flows at each site. The data generated by this sampling is quite variable, with four sites exhibiting flow into the lake, four sites showed flow parallel to shore and six sites yielded groundwater flows away from the lake, The flow rates observed ranged from 2.5 to 29.0 feet per day. The high reading of 29.0 feet per day is an exceptional value obtained from a site where groundwater flow may have been channelized. The sampling point was a sand substrate boat slip with extensive sections of flow impeding concrete breakwall on both sides. The breakwall would direct shallow groundwater toward this opening.

Observations of the local topography suggested that groundwater flows would be into the lake, with discharge occurring along the northwest shore. Disregarding the one exceptionally high flow, the four sites with groundwater flow into the lake (GWF 3, 5, 8, 9) had the highest flow rates (9.5-17.0 ft/day). Additionally, GWF site 11 indicated flow in an expected direction. Groundwater flow at this site was away from the lake, toward the outlet (Platte River) at 7.5 ft/day. It was anticipated that flow directions at sites 10, 13, and 14 would also be along a northwesterly vector.

In several instances, groundwater flow directions were unexpectedly parrallel to shore or away from the lake. Since there doesn't appear to be a general trend among these flow directions, it is anticipated that the results represent local variations in groundwater flow. Substantial amounts of clay were observed at several sites and may have altered local drainage patterns by diverting groundwater to more permeable soils. Flow directions at both GWF 1 and 4 are difficult to explain. These sites were located near the inlet to the lake adjacent to a tag alder swamp. This situation may have influenced groundwater flows in that vicinity. The numerous streams along the south shore may have been a factor influencing the direction of shallow groundwater flow in that area.

The groundwater flow data supports septic leachate scanning information. Along the north and western shores of Platte Lake, flows were away from the lake. Only two plume sites were found in this area. Flows along the southern and northeastern shores were primarily into the lake at notably high rates. This factor enhances the opportunity for discharge of septic leachate. Maximum concentrations of septic leachate plumes were found in these areas.

CONCLUSIONS

A septic leachate detection survey was conducted on Big Platte Lake to locate and assess the impact of failing septic systems on lake water quality. The survey located 40 septic leachate plumes which were concentrated along the southern and northeastern shorelines. Most plumes were associated with low crowded lots and rapid groundwater flow rates into the lake.

Analyses of surface water and groundwater samples reflected a consistent elevation of nutrients in the vicinity of plume sites. The data indicate an influx of phosphorus and nitrogen from shoreline septic systems is occurring. Chlorides were not substantially elevated in surface samples collected at septic leachate plumes, and most elevations in conductivity were small. Chlorides were notably elevated in several groundwater samples. Fecal coliforms were somewhat elevated at only two sites and a health hazard is not anticipated from septic system discharge.

Evaluation of nutrient loading from failing shoreline septic systems predicts an annual discharge of 32.6 lbs/year of phosphorus, and 266.3 lbs/year of nitrogen. This discharge is concentrated along the south and northeast shores of Platte Lake where septic leachate plumes were most abundant. While the water appeared somewhat degraded in these areas, precipitation of phosphorus out of the water with calcium carbonate is believed to have minimized plant growth which could result from these levels of nutrient discharge.

In summary, conclusions of the septic leachate survey on Big Platte Lake indicate substantial nutrient loading from shoreline septic systems is occurring. While apparent effects have been minimal, a growing problem can be anticipated. Septic system discharge did not comprise an important hazard to human health at the time of the survey.

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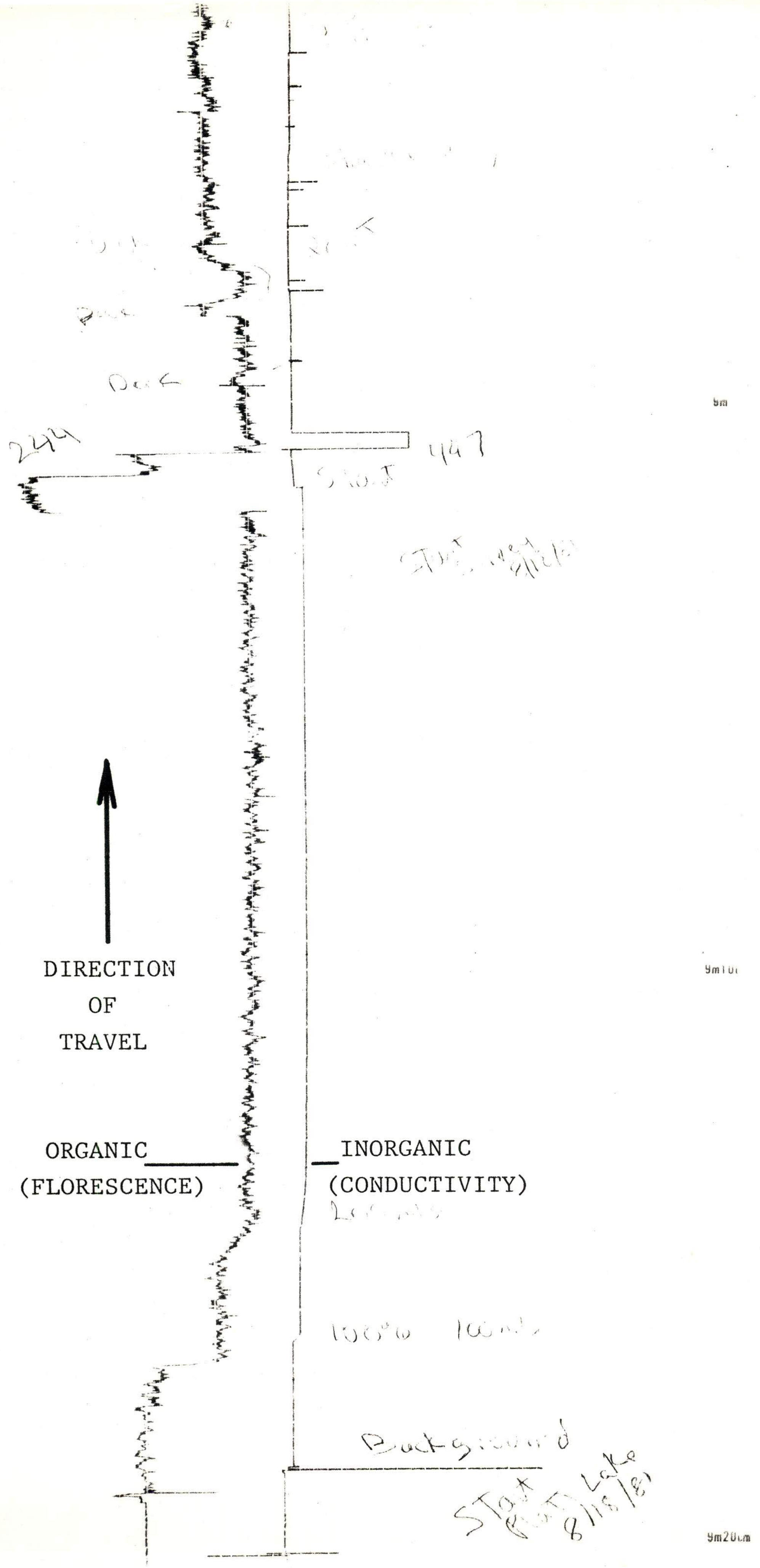
BIG PLATTE LAKE

APPENDIX A



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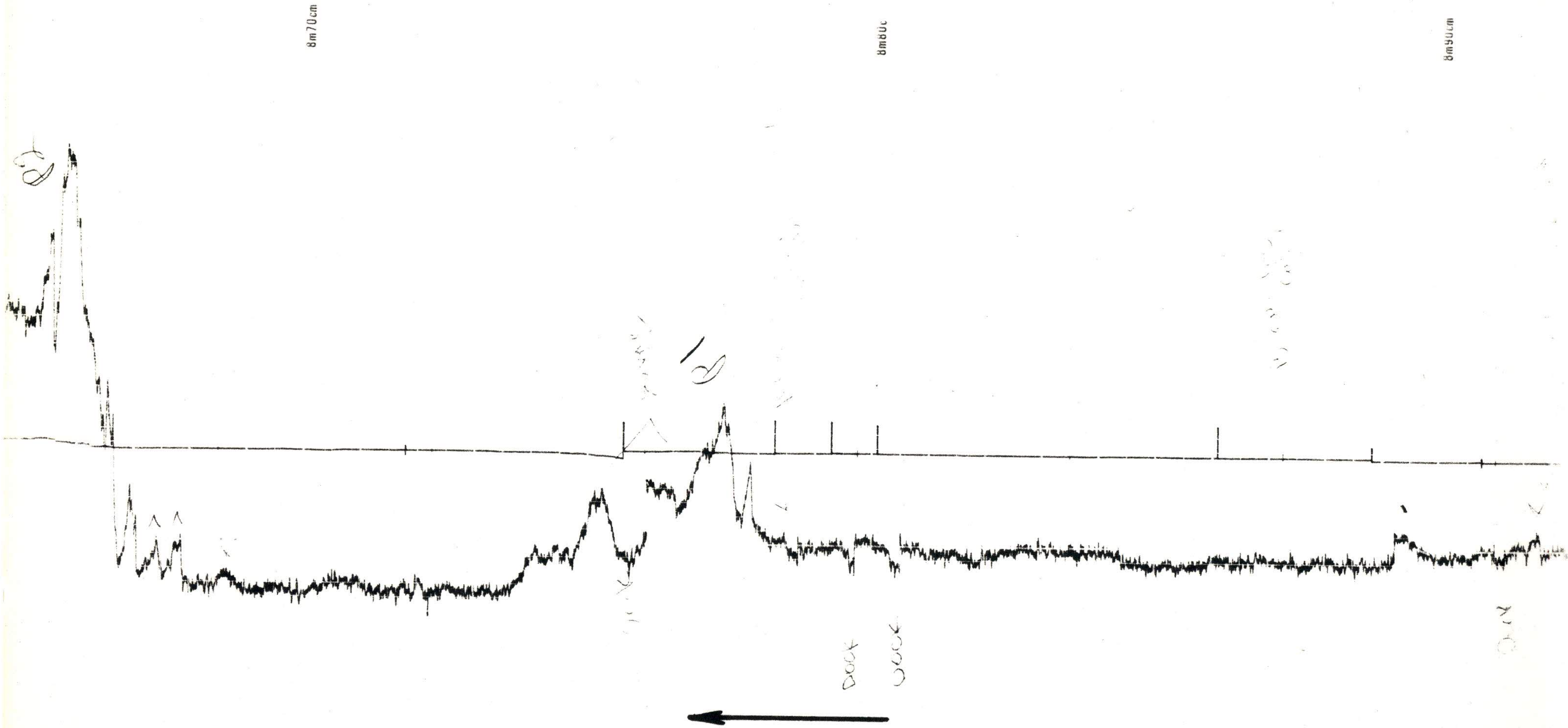

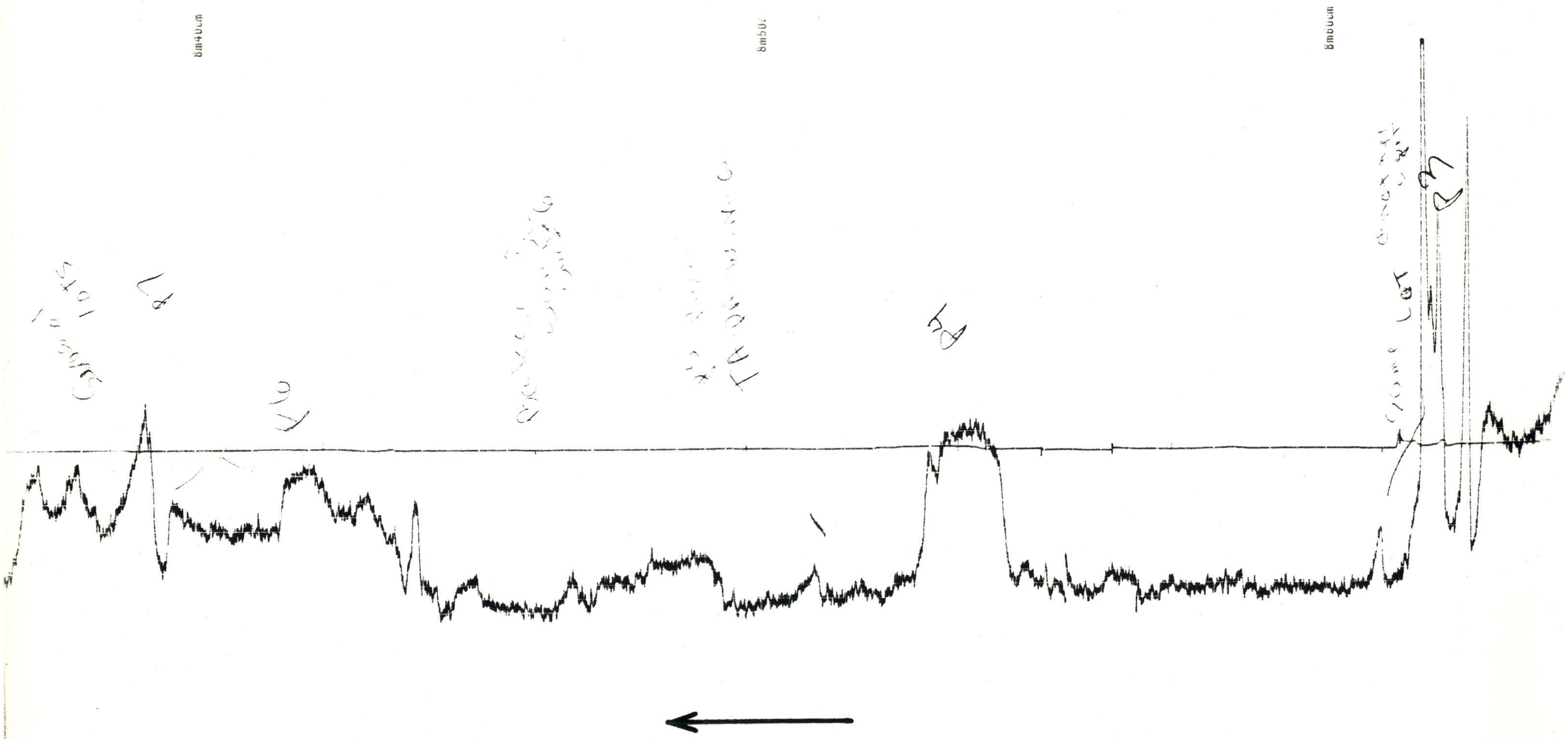
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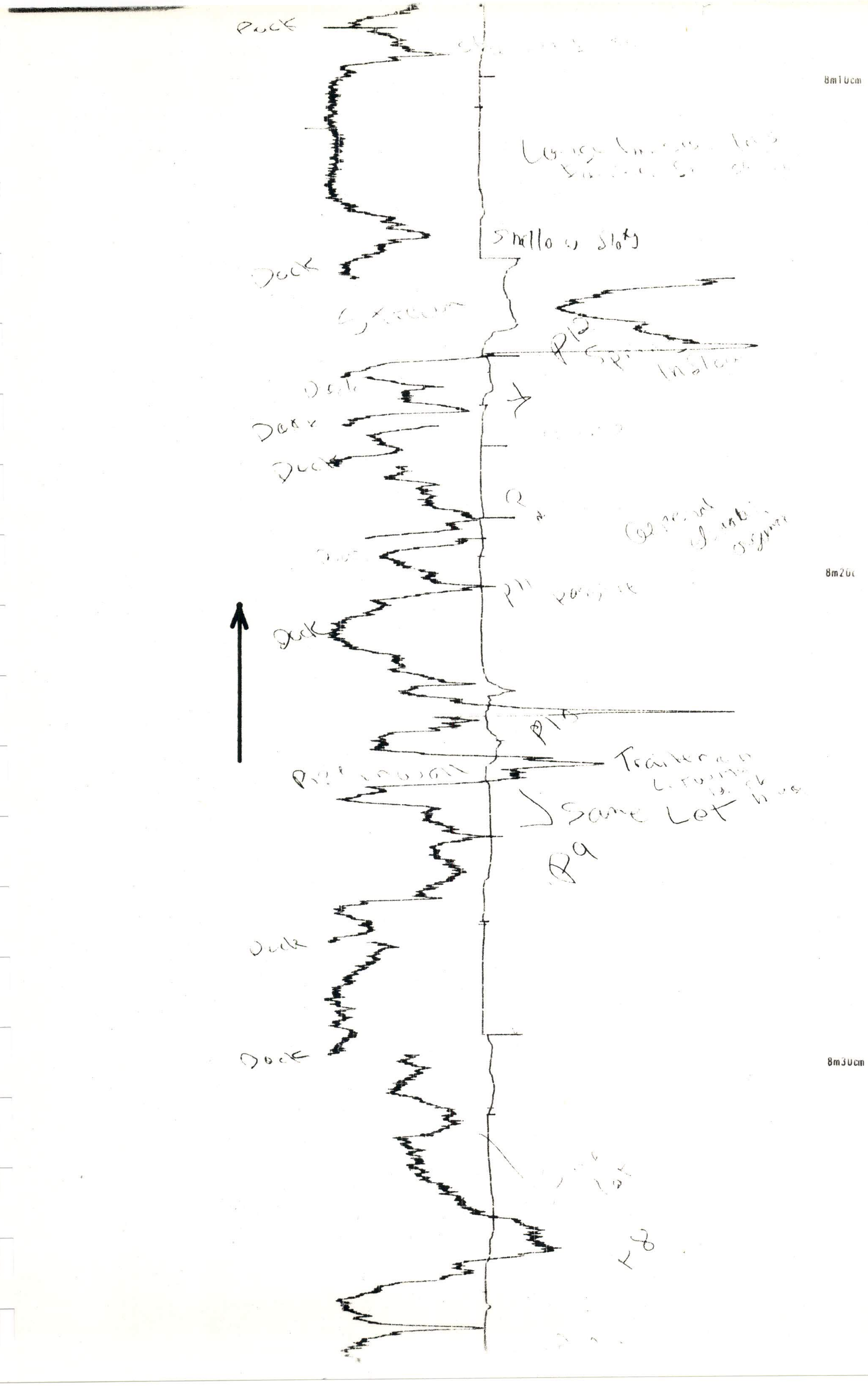

Big Platte Lake
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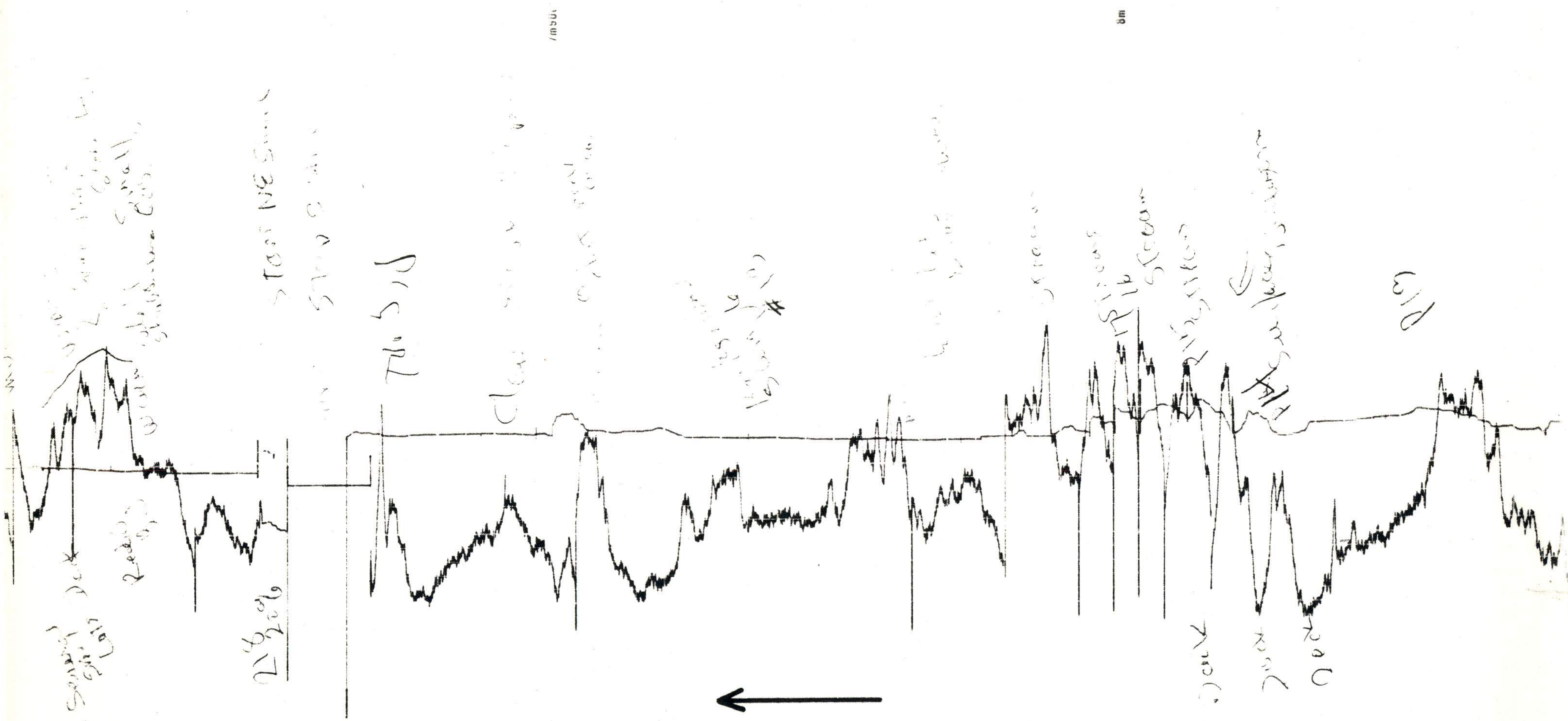

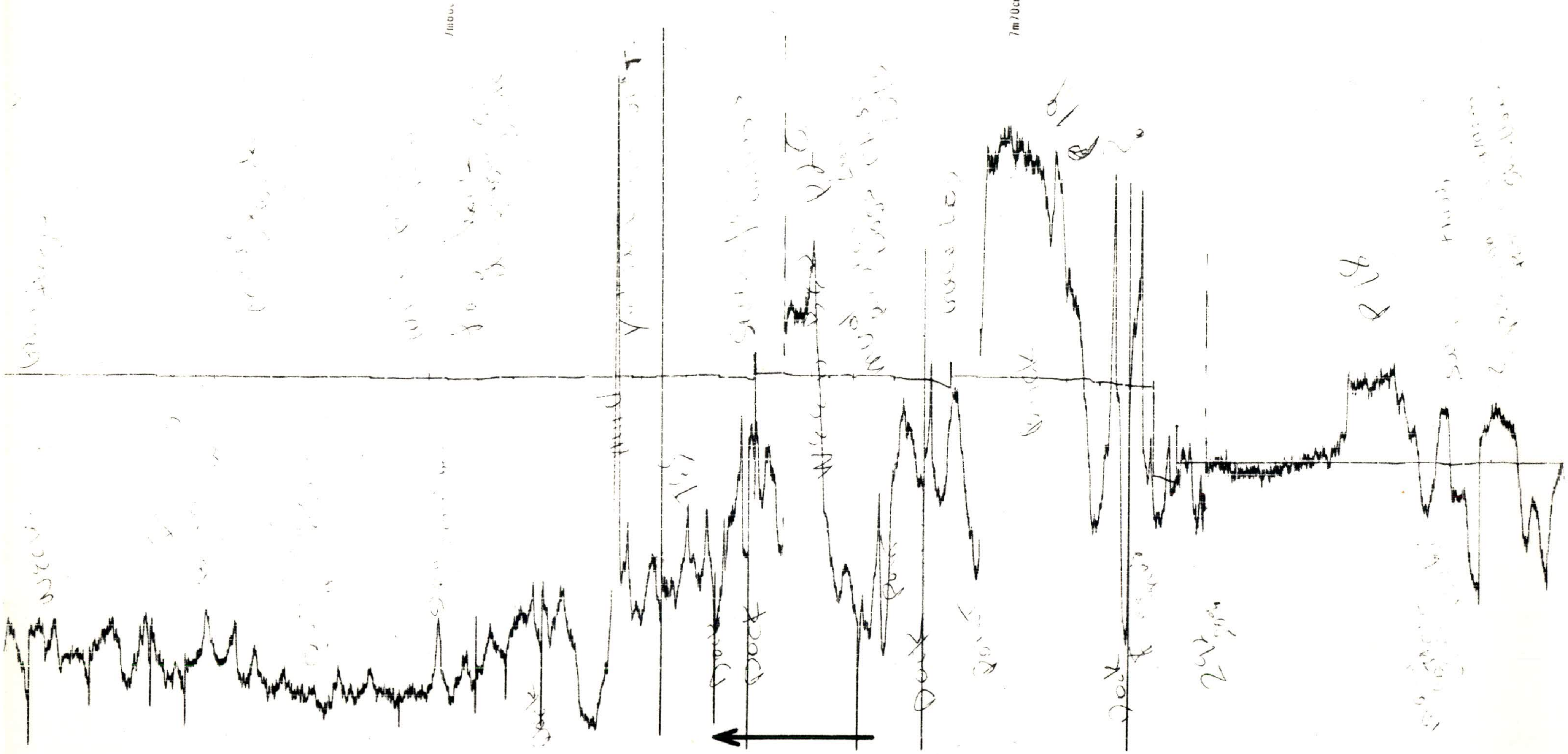
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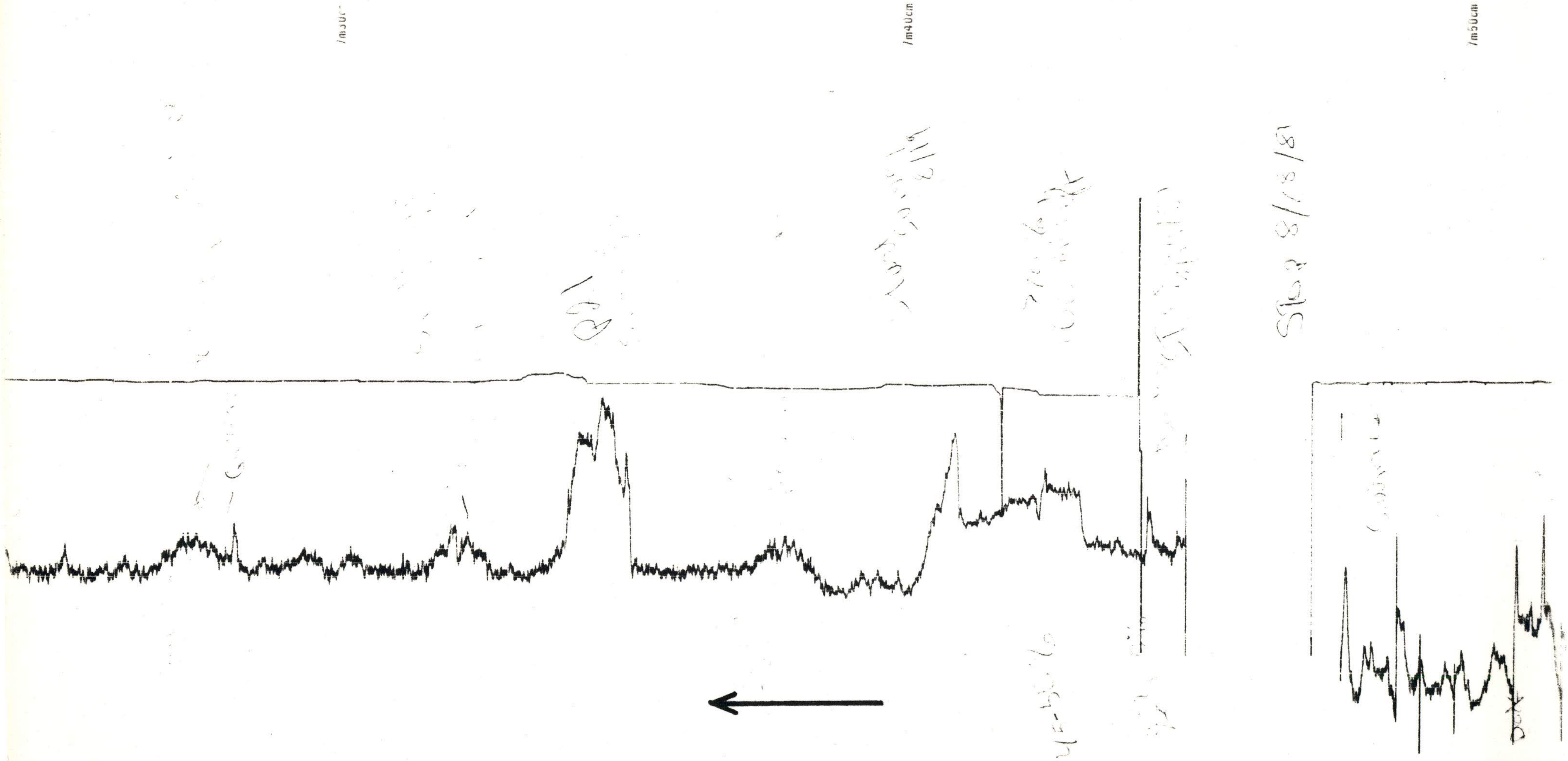
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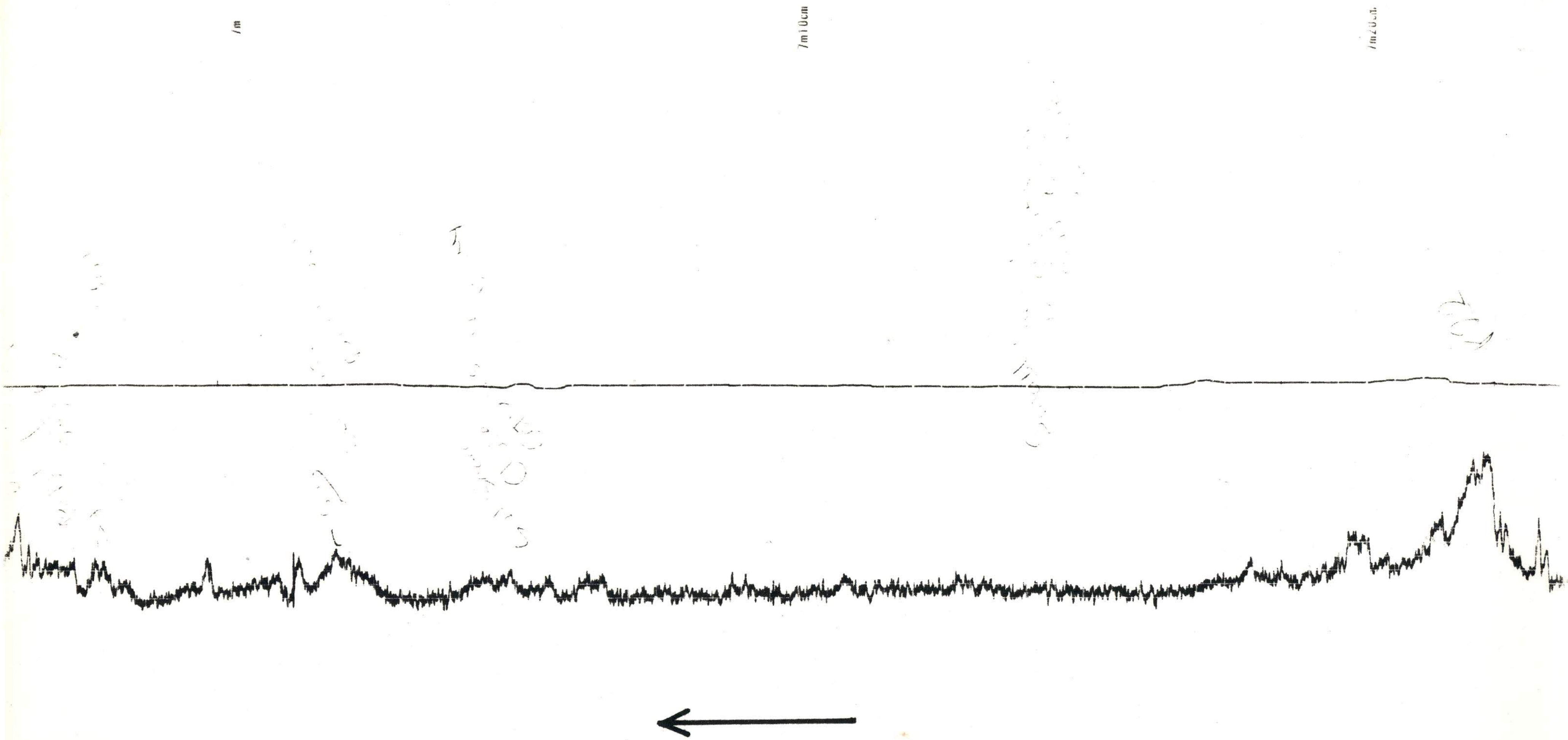
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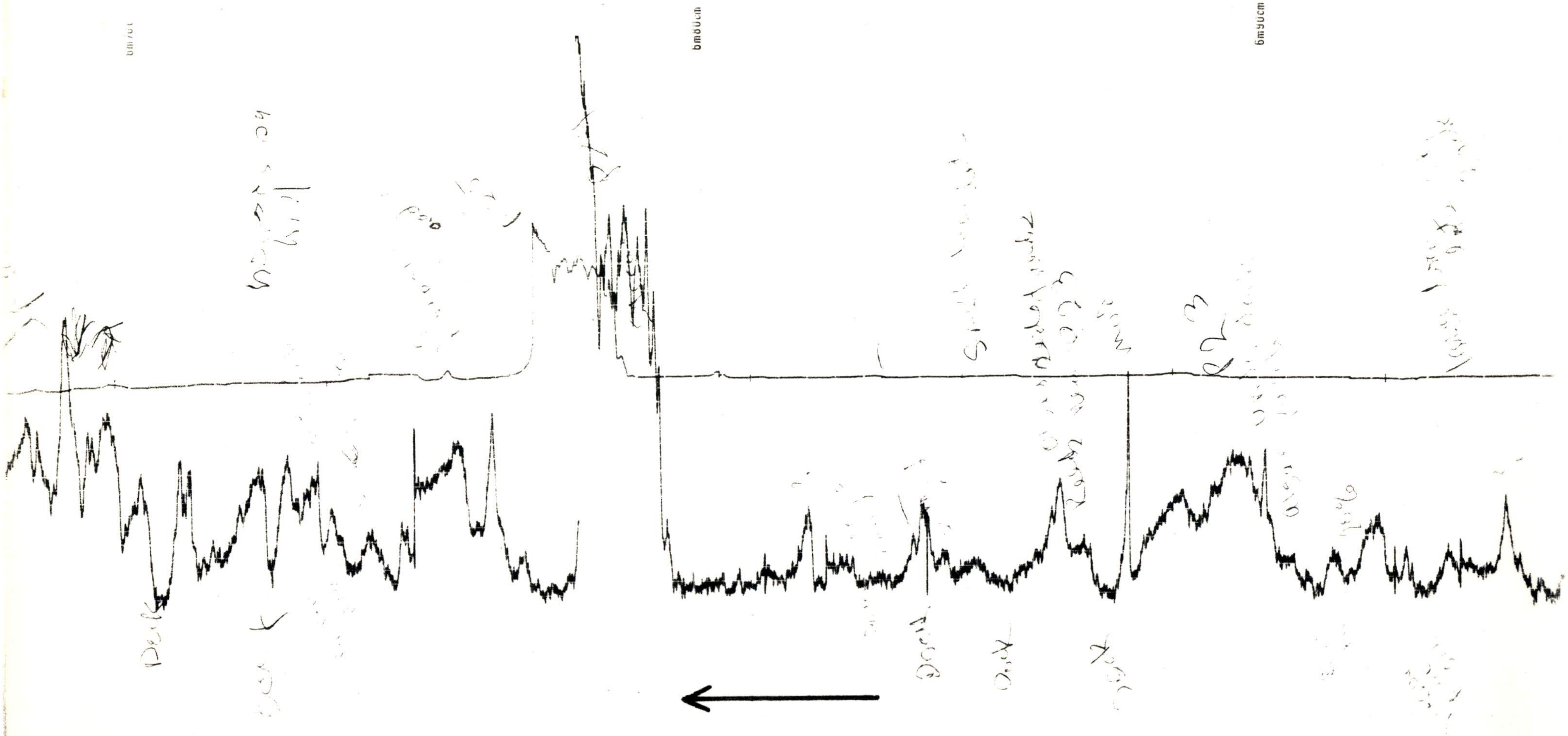
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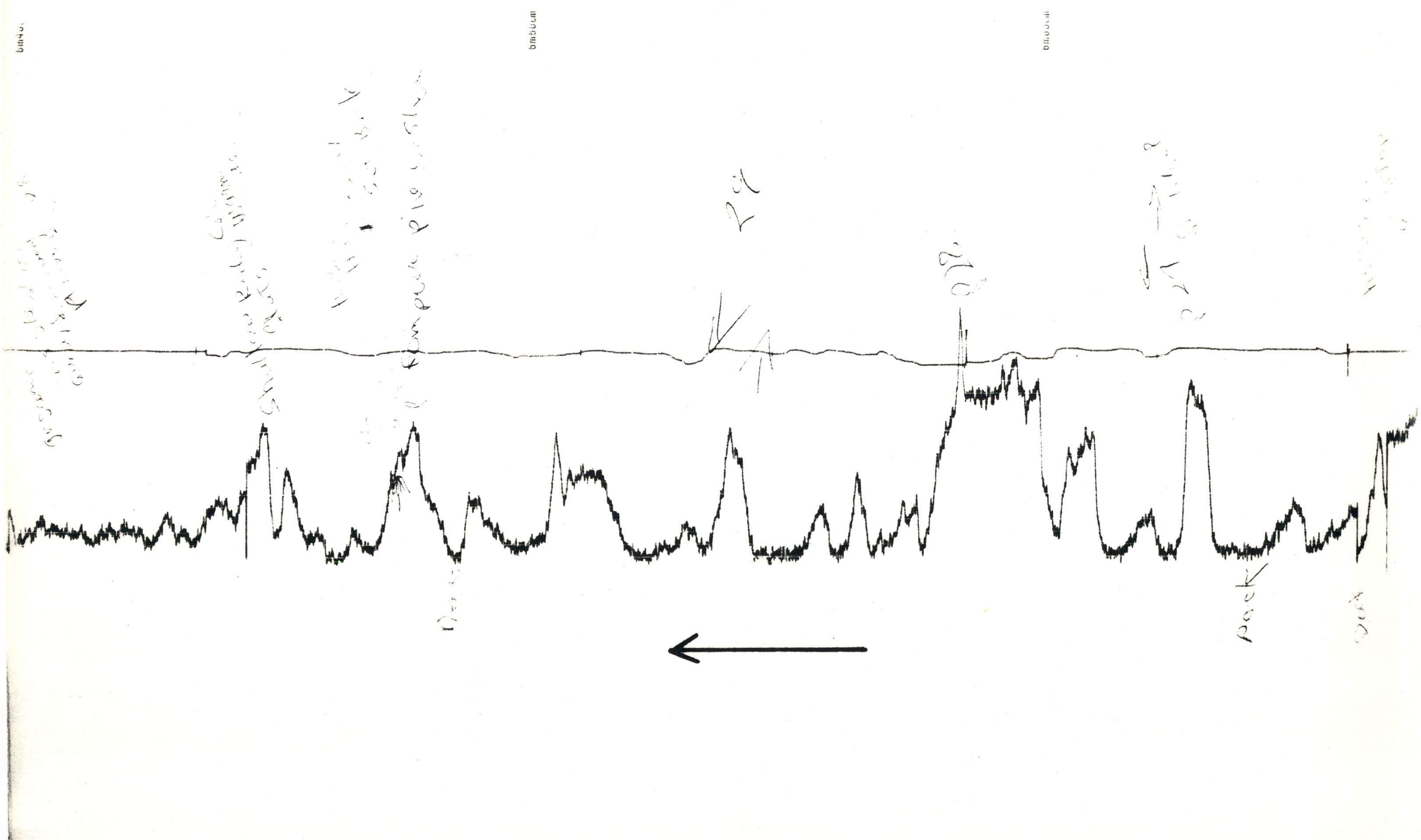

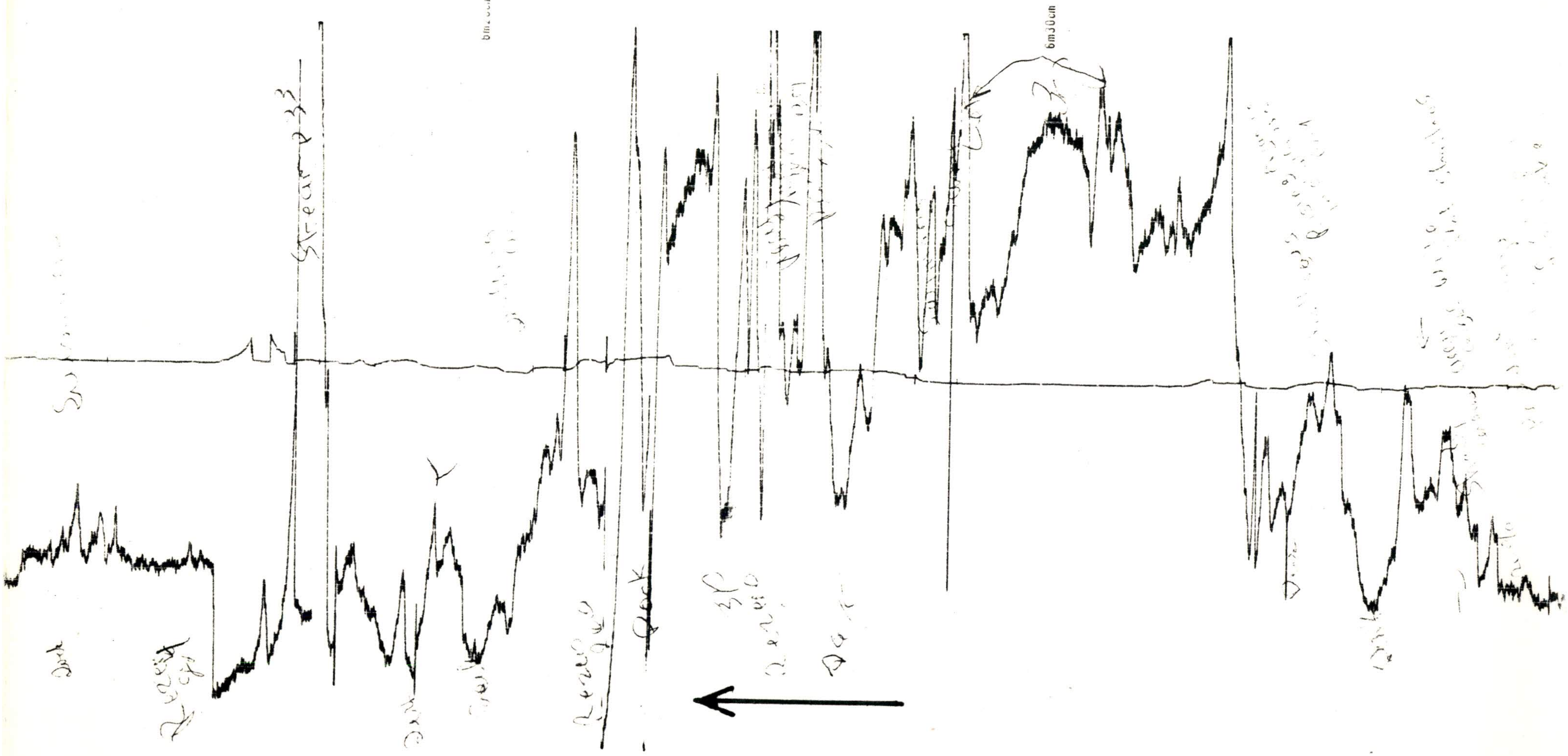
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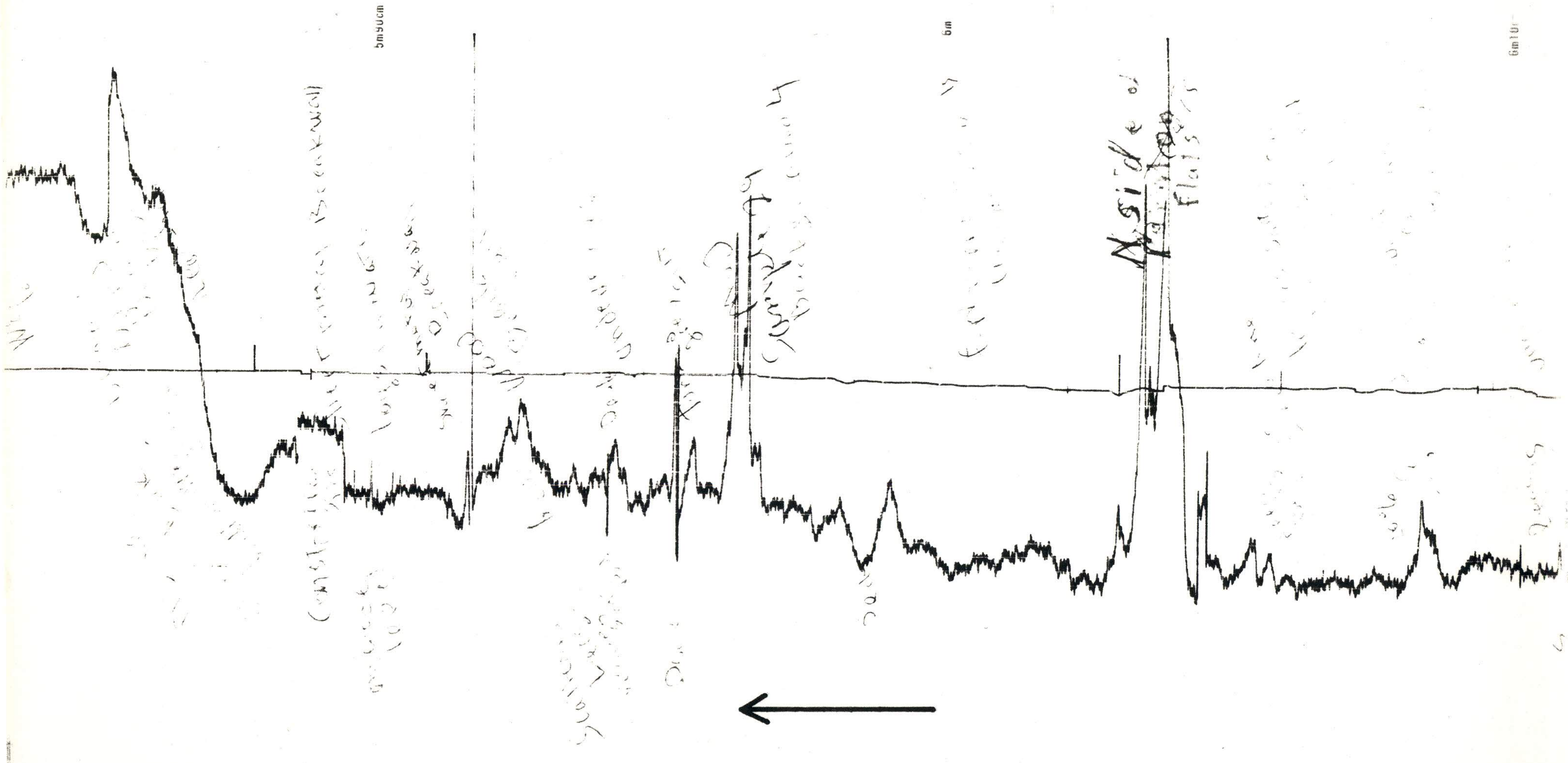
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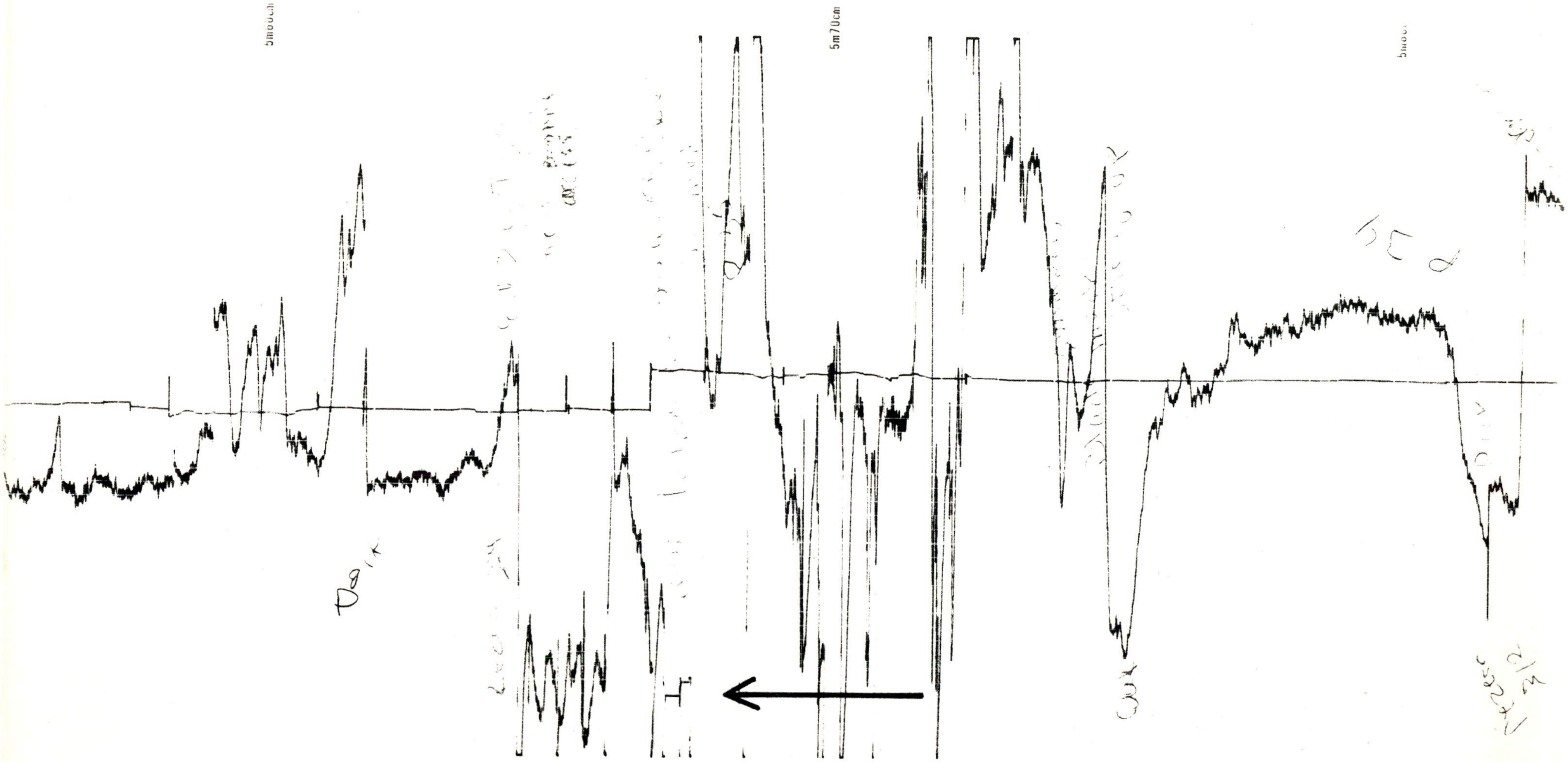
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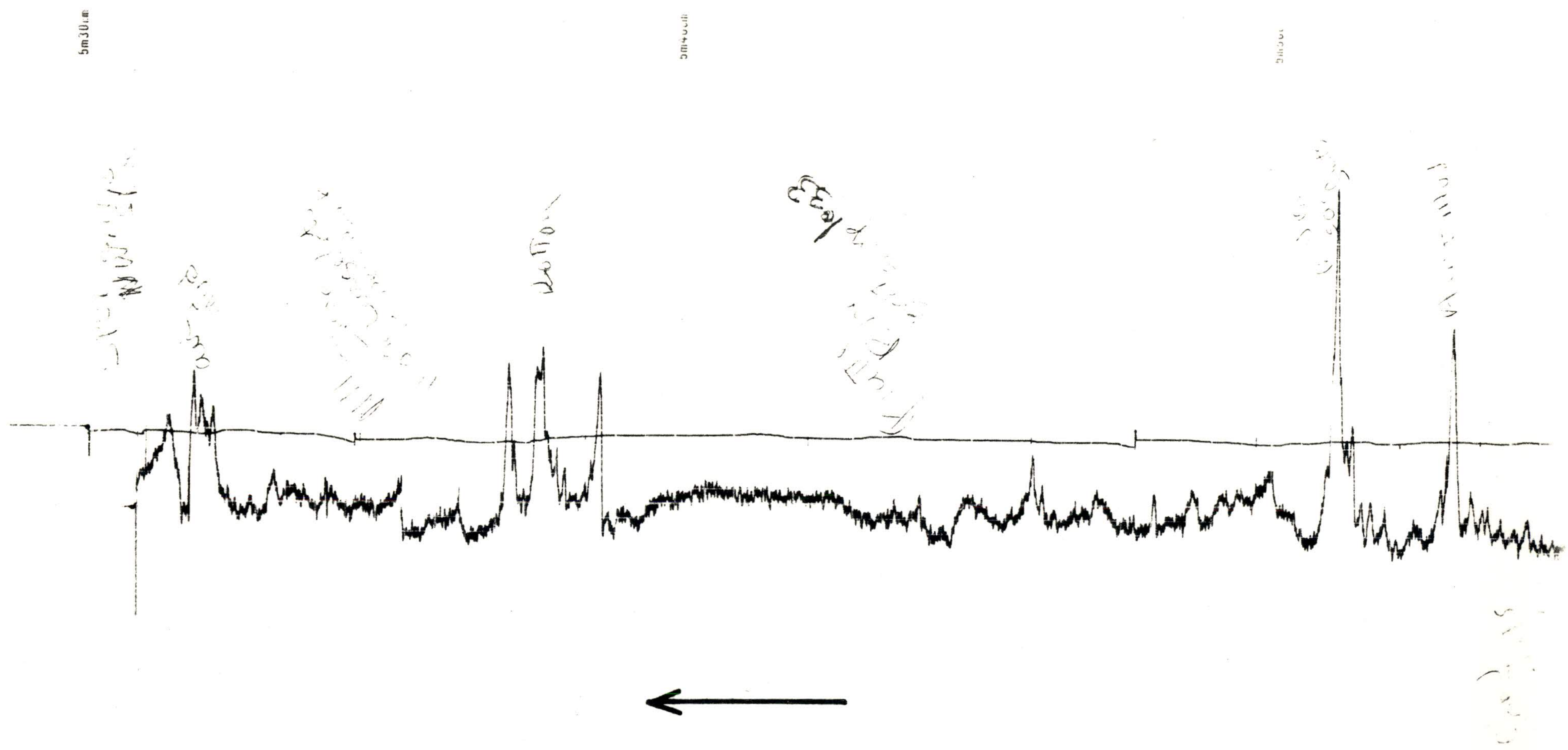

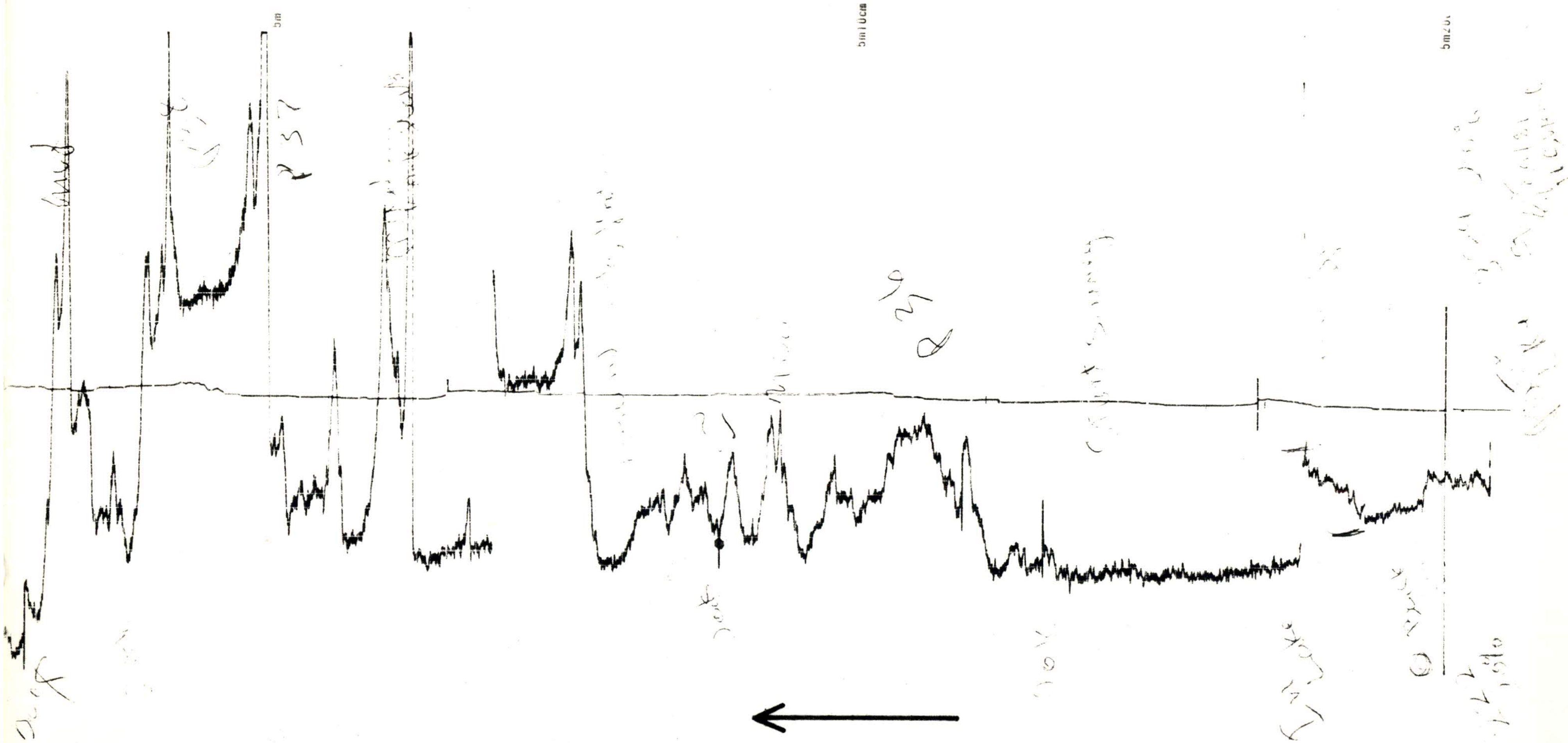
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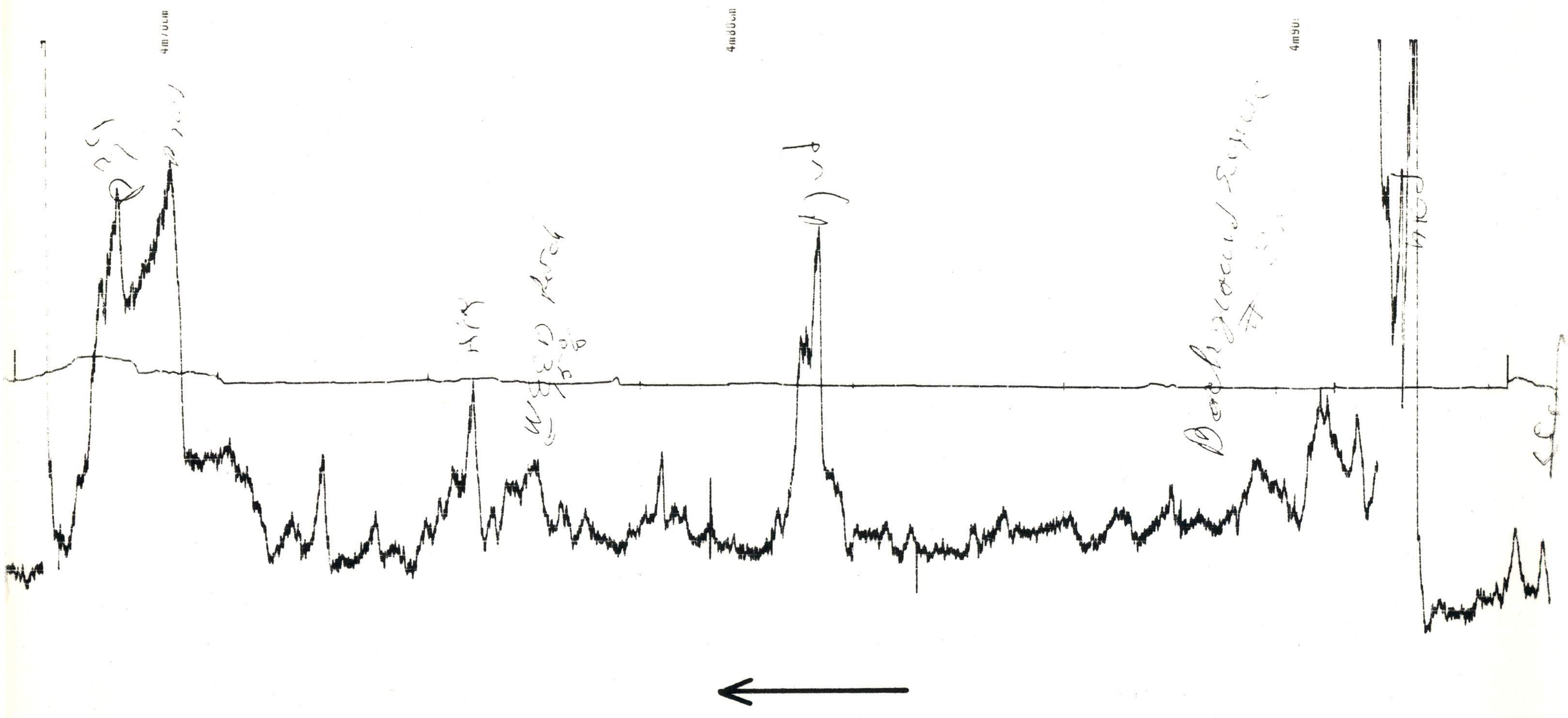
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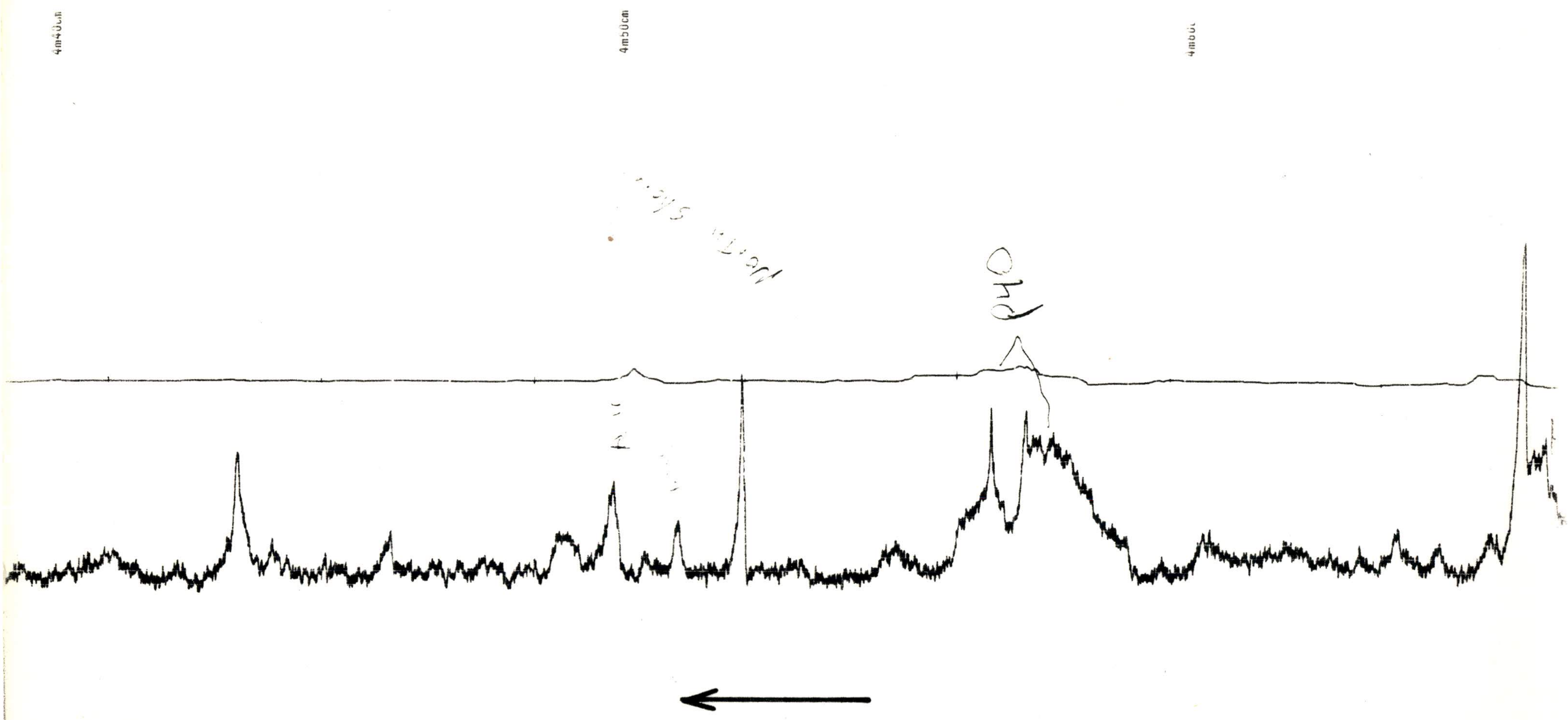
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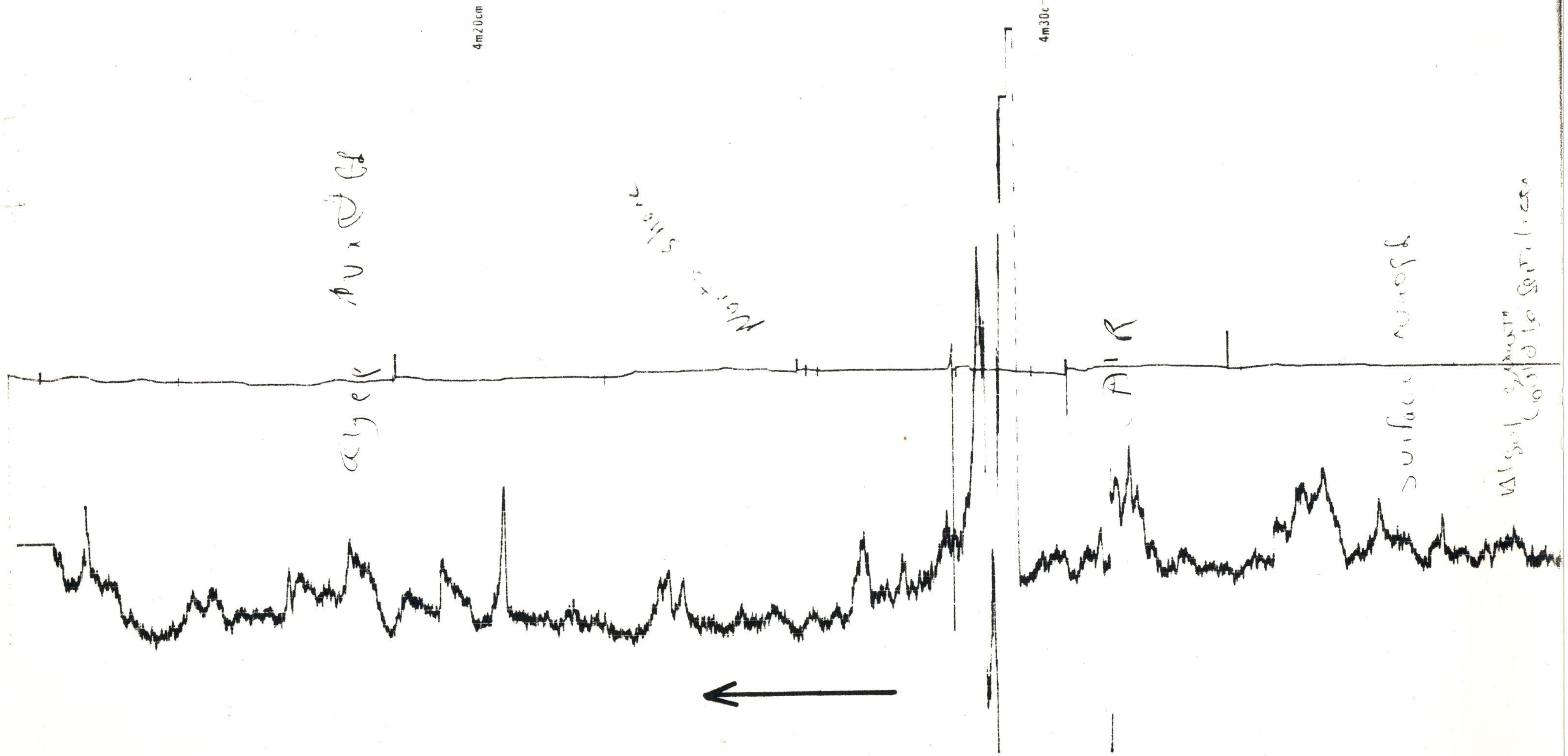
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