HYDROGEOLOGIC CONDITIONS DURING KOKANEE SPAWNING, EGG INCUBATION AND FRY EMERGENCE AT SELECTED SITES, FLATHEAD LAKE, MONTANA

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by

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ABSTRACT

Fifteen study sites were studied over the last two years. The hydrogeologic conditions of each site during periods of spawning (October through December), egg incubation (January through March) and fry emergence (April through May) are described. Parameters of groundwater water table fluctuation, apparent velocity, generally chemistry and dissolved oxygen are presented. Site grouping by water table response to lake stage fluctuation was attempted and hydrogeologic parameter characteristics of three groups were compared and contrasted. Statistical analyses of the influence of lake stage changes on hydrogeologic parameters were also attempted.

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INTRODUCTION

Since 1982 we have been assisting the Montana Fish, Wildlife and Parks (FWP) research staff with hydrogeologic investigations at identified kokanee salmon spawning sites. FWP hypothesizes that the shoreline groundwater flow system is important to site selection and success of salmon spawning. They requested that we characterize the groundwater properties of identified spawning sites and selceted historical spawning areas. This report will serve as a compilation of the hydrogeologic data collected at 15 study sites (Figure 1). This report begins with a brief methodology section and ends with a section of recommendations. The body of the report deals with the hydrogeologic characterization of study areas and is organized in three sections: 1) site specific characterization; 2) grouping correlations ; 3) prediction of apparent velocities. First however, we will describe the procedures used to summarize and analyze the data.

METHODOLOGY

The methods used to collect the data for this analysis are described in our previous report (Woessner and Brick,1983). The focus of this report is to evaluate the data and attempt to characterize and the hydrogeology at individual sites and three areas with similar physical or hydrologic parameters. As a result, data are grouped and summarized. The information is organized into three categories for discussion and characterization: 1) spawning period, October through December; 2) incubation period, January through March and 3) emergence, April through May. Apparent velocity, general water chemistry and dissolved oxygen (DO) are then described for each site.

At each site the actual spawning area was determined from the maps in our previous report (Woessner and Brick, 1983) and field visits of study sites in 1983-1984. The groundwater flow rates during spawning are reported as apparent velocities or seepage velocities in cm/hr and are summarized by averaging the seepage meter data and reporting the mean, range and number of data points. Using average values to summarize seepage meter velocities will understate the actual mean because the velocity relationships are more logarithmic, decreasing with distance from shore. Seepage meter data also poses an additional analysis problem. Because the seepage rate decreases logarithmically with distance from shore, the mini seepage meters, 15 cm indiameter, located close to shore record seepage rates an order of magnitude greater that the standard meters. Since mini meter data are available at some sites and not at others, the means and ranges are not easily comparable. As a result the mini meter data are excluded from the analyses.

Characteristic velocities during incubation and emergence are derived from on-shore well data at exposed sites and from seepage meter data for submerged sites. The on-shore velocity information collected in the 1983-1984 season was derived by conducting aquifer tests in sandpoint wells, calculating hydraulic conductivity and combining the conductivity data with hydraulic gradients. Apparent velocity data derived from seepage meters over both

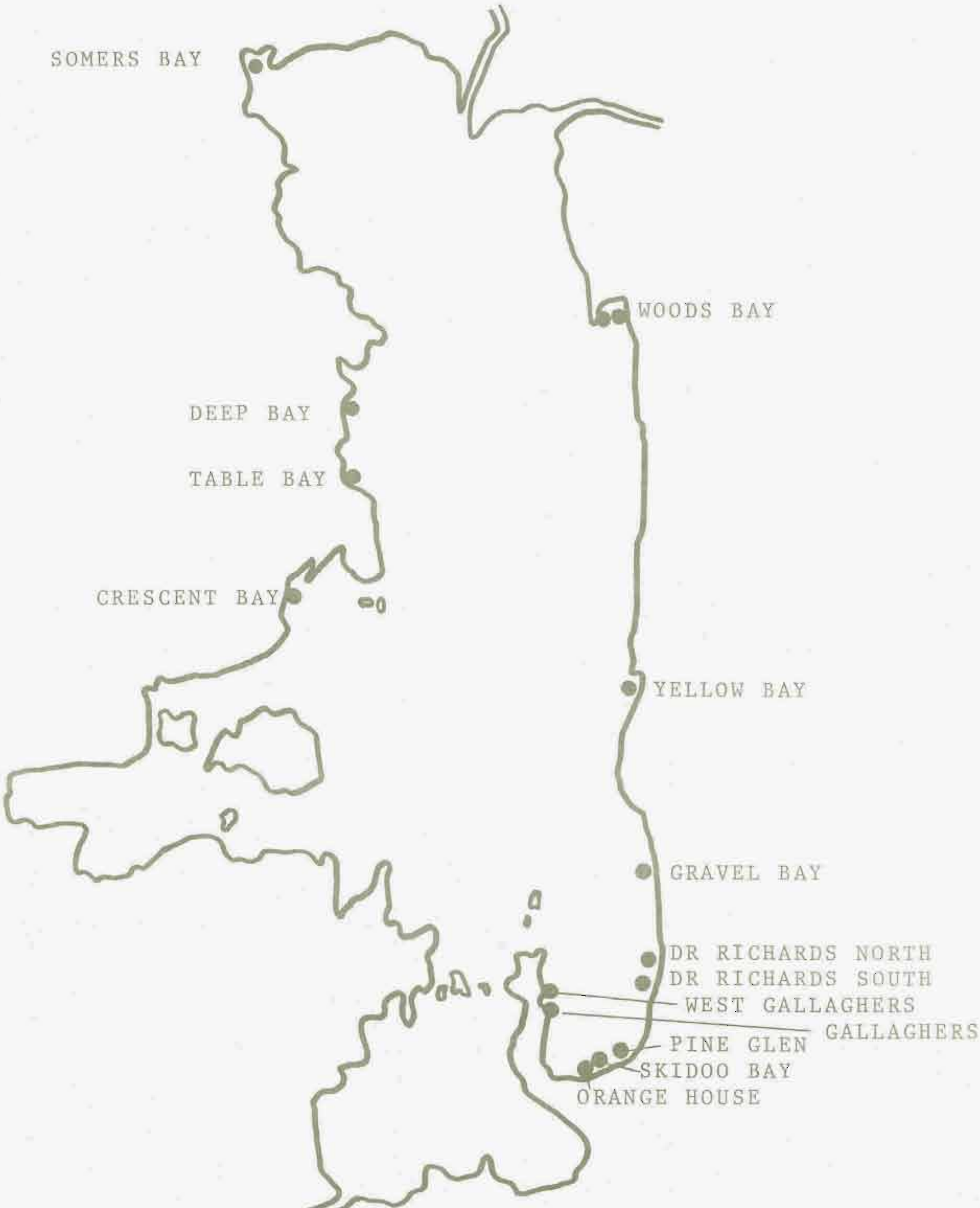

Figure 1: Site location map

project years are utilized . The 1983-1984 on-shore velocity data are selected for analysis, mainly because this data base is much more complete than that of the previous year. On-shore velocity data from five 1982-1983 sites are presented in individual site description sections principally for assessment of lake operation effects. Water chemistry data for seepage meter, sandpoint and DO transect samples are summarized by averaging data and reporting means, ranges and the number of data points. Water chemistry data collected over both project years are used in the analysis. Water quality data are also reviewed to determine if nitrates and chlorides appeared to exceed background values thus indicating possible contamination from septic systems or other sources. A compilation of the data used for characterization of the groundwater systems at study sites during prescribed times is presented in Table 1.

We were also requested to determine if the variation of lake stage noticably affected the ground-water system in the study sites. This is difficult to accomplish because the shallow unconfined system apparently shows effects of regional recharge in addition to lake stage change. However, comparisons of 1982-1983 and 1983-1984 data are made and related to lake operation differences when believed appropriate.

Data trends are examined by grouping sites with similar water table responses to lake stage change and comparing and contrasting hydrogeologic characteristics, and by examining statistical relationships between individual and groups of hydrogeological parameters. Linear correlation coefficients for lake stage plotted against seepage meter velocity and on-shore velocity were calculated. Additional relationships are examined by attempting to correlate DO with seepage meter velocity and on-shore velocity, portable seepage meter velocities with spacing and seepage meter apparent velocities with distance from shore.

Prediction of groundwater response to past and future lake stage fluctuation patterns is not an easy task. For this report only the proposed methodology will be described. Later data analyses will hopefully yield ground water response prediction.

SITE CHARACTERIZATION

The discussion of the groundwater characteristics at each study site will be subdivided by time increments representing the spawning period, egg incubation and fry emergence. Tables 2, 3 and 4 present an overall summary of the apparent velocity, gross chemistry and DO information. Tables of apparent velocity data calculated all seepage meter and onshore wells at each site are presented in Appendix A. Individual chemical analyses collected at study sites are presented in Appendix B. DO transect information is presented in Appendix C. Site by site discussion follows in the order the sites are presented on Tables 2, 3 and 4. These tables summarize the hydrogeologic data for each site and are discussed in detail in the following sections. They will not be referenced continually in the text.

Table 1. Data used to compile Tables 2, 3, and 4.

Site	Spawning			Incubation			Emergence		
	Apparent velocity	Water quality	DO	Apparent velocity	Water quality	DO	Apparent Velocity	Water quality	DO
Dr. Richards S	No data	No data	No data	W-DRS 2,3	W-DRS 2	T,**W-1,2	W-DRS 2,3	W-DRS 2	W-2
Woods Bay East	No data	No data	T	W-WBW 1,3	W-WBW 2	W-1,2	W-WBW 1,3	W-WBW 2	W-2,3
Woods Bay West	No data	No data	T	W-WBE 1,3	W-WBE 2	W-1,2	W-WBE 1,3	W-WBE 2	W-3
Gravel Bay	SM-***1,2S, 3,2C,2N	SM-1,4	T	SM-1,2S,3, 2C,2N	SM-1,Middle Deep	T	No data	No data	No data
Gravel Bay Ex	No data	No data	No data	W*-GB 2,3	W-GBS 1,2	W-2,3	W-GB 2,3	W-GB 2	W-2
Pine Glen	No data	No data	T	W-PG 2,3	W-PG 2A,2	W-1,2	W-PG 2A,2	W-PG 2	W-2
Somers Bay	SM-1,2	SM-1,2	T,SM-Deep	No data	W-Somers 1	No data	No data	W-Somers 1	W-1
Skidoo Bay	SM-1E,1C,1W	SM-Shallow	T	W-SK2,3A	W-SKB-1,2A, 2,2B,SM-Shallow	T-W-3A,3B	W-SK2,3A	W-SKB-1,2,3	W-2,3A
Orange House	No data	No data	No data	W-2,3	W-2	W-2	W-2,3	W-2	W-2,3
Yellow Bay	SM-1,2,3,4,5	SM-1,2,3,4,5	T	SM-1,2,3,4,5	SM-1,2,4,5	T	SM-1,2,3,4,5	No data	T
Yellow Bay Ex	No data	No data	No data	W-YB 2B,3	W-YB,2A,3	W-1,2A,2B	W-YB,2B,3,4	W-YB,2A,3	W-2B
Dr. Richards N	No data	No data	T	W-1,2B,3,4	W-1,2A,3	T,W-2A,2B	W-1,2B,3,4	W-1,2,3	W-2B
Gallaghers	No data	No data	T	W-GAL 2,3	W-GAL 2	W-2	W-GAL 2,3	W-GAL 2	W-2
W. Gallaghers	No data	No data	T	W-1,2,3	W-W GAL 2	W-1,2	W-1,2,3	W-W GAL 2	W-2
Crescent Bay	SM-1,2,3	SM-1,2,3	SM-A,1,2	W-CRES 1,2	W-CRES 1	T	W-CRES 1,2	W-AR,1A,1B, 3,4,CRES 1	W-2,AR,1A
Deep Bay	SM-Deep	SM-Deep	SM,Shallow,Deep	No data	No data	No data	No data	No data	No data
Table Bay	SM-Shallow, Middle,Deep	SM-Shallow, Middle,Deep	SM,Middle,Deep	No data	No data	No data	No data	No data	No data
Woods Bay	SM-S1,S2,S3, C1,C2,C3,N1, N2,N3	No data	SM 1,2,3	No data	No data	No data	No data	No data	No data

*W = Well **T = DO transects 1 to 3 line perpendicular to shore ***SM = Seepage Meter

Table 2. Summary of hydrogeologic conditions during spawning (October through December).

	Apparent velocity (cm/m)			Water quality (mg/l)								
				TDS			Cl			DO		
	Range	Mean	n	Range	Mean	n	Range	Mean	n	Range	Mean	n
Group I												
Dr. Richards S	-	-	-	-	-	-	-	-	-	-	-	-
Woods Bay West	-	-	-	-	-	-	-	-	-	8.1-10.4	9.6	6
Woods Bay East	-	-	-	-	-	-	-	-	-	9.4-11.4	10.6	6
Gravel Bay	0.05-0.37	0.18	19	137-275	206	2	0.20-0.28	0.24	2	1.0- 9.8	8.2	19
Gravel Bay Ex	-	-	-	-	-	-	-	-	-	-	-	-
Pine Glen	-	-	-	-	-	-	-	-	-	7.5-10.2	9.0	9
Somers	0.11-0.32	0.19	4	-	142	1	-	0.34	1	10.1-12.1 7.5-10.5	11.1 9.6	3 4
Group II												
Skidoo Bay	0.13-0.49	0.22	12	-	156	1	-	0.30	1	5.4-12.8	9.0	27
Orange House	-	-	-	-	-	-	-	-	-	-	-	-
Yellow Bay	0.02-0.38	0.22	10	136-279	173	5	0.20-0.69	0.32	5	0.3- 9.6	3.4	33
Group III												
Dr. Richards N Hochmarks	-	-	-	-	-	-	-	-	-	7.8-11.5	10.1	6
Gallagher	-	-	-	-	-	-	-	-	-	3.7- 6.4	4.8	6
W. Gallaghers	-	-	-	-	-	-	-	-	-	6.1-11.4	8.4	6
Crescent Bay	0.02-0.60	0.22	18	114-297	214	7	0.21-0.69	0.50	7	6.1-10.8	8.9	7
Others												
Deep Bay	0.05-0.17	0.11	2	144-147	146	2	0.21-0.25	0.23	2	7.4- 9.5	8.4	2
Table Bay	0.04-0.34	0.18	8	136-138	137	4	0.19-0.33	0.24	4	8.8-10.5	10.1	6
Woods Bay	0.02-0.51	0.23	15	-	-	-	-	-	-	9.3-11.5	10.2	11

Table 3. Summary of hydrogeologic conditions during egg incubation (January through March).

	Apparent velocity (cm/hr)			Water quality (mg/l) TDS			Cl			DO		
	Range	Mean	n	Range	Mean	n	Range	Mean	n	Range	Mean	n
Group I												
Dr. Richards S	0.10- 1.20	0.67	9	145-400	273	2	0.37-9.90	5.20	2	8.7-11.2	10.2	7
Wells										5.3- 8.0	6.6	2
Woods Bay West	0.60- 3.70	2.20	8	-	191	1	-	1.74	1	4.1- 4.9	4.5	2
Woods Bay East	0.03-18.60	3.2	10	-	213	1	-	0.65	1	3.6- 8.7	6.2	2
Gravel Bay												
*Deep	0.03- 0.60	0.20	33	119-290	208	5	0.20-1.12	0.53	5	0.0-12.1	9.5	26
Exposed	1.40-36.20	8.20	10	141-286	213	2	0.24-1.04	0.64	2	7.5-13.6	9.7	3
Pine Glen	0.60-32.50	16.70	12	285-315	299	3	0.60-1.74	1.13	3	8.5- 9.5	9.2	7
Wells										7.7-10.0	8.5	4
Somers	-	-	-	-	440	1	-	18.00	1	-	-	-
Group II												
Skidoo Bay	2.20-52.70	12.10	11	185-280	216	5	0.45-1.08	0.65	6	6.1- 9.7	8.7	16
Wells										1.2- 8.4	6.2	5
Orange House	0.90- 3.40	2.30	13	229-265	247	2	0.88-1.23	1.06	2	6.2-10.0	8.1	2
Yellow Bay												
*Deep	0.08- 0.62	0.31	15	137-270	166	5	0.20-0.65	0.31	5	0.4-11.8	8.9	13
Exposed	2.20- 5.20	3.90	15	181-210	203	4	0.36-0.86	0.68	4	5.2-11.1	8.3	5
Group III												
Dr. Richards N Hochmarks	0.90-14.80	3.80	32	102-181	138	4	0.38-1.20	0.61	4	8.5-11.7	10.5	11
Wells										0.9- 9.3	4.2	8
Gallagher	0.50- 1.50	1.00	13	289-290	290	2	0.75-1.24	0.99	2	3.6- 5.1	4.5	3
W. Gallagher	0.10- 1.40	0.64	23	273-277	275	2	0.72-1.01	0.86	2	5.8- 7.8	6.9	3
Crescent Bay	0.40- 6.40	2.60	17	323-324	324	2	1.22-1.84	1.53	2	0.0-10.7	6.6	22
Others												
*Deep Bay	-	-	-	-	-	-	-	-	-	-	-	-
*Table Bay	-	-	-	-	-	-	-	-	-	-	-	-

*All well data except * which is seep meter data.

Table 4. Summary of hydrogeologic conditions during fry emergence (April through May).

	Apparent velocity (cm/hr)			Water quality (mg/l)								
				TDS			Cl			DO		
	Range	Mean	n	Range	Mean	n	Range	Mean	n	Range	Mean	n
Group I												
Dr. Richards S	0.04- 2.40	0.68	9	100-314	207	2	0.23-3.01	1.62	2	3.4- 5.5	4.5	3
Woods Bay West	0.27- 3.50	1.60	7	-	172	1	-	1.40	1	3.7- 5.2	4.3	3
Woods Bay East	0.01- 3.30	1.80	6	-	190	1	-	0.79	1	3.7- 9.5	5.7	3
Gravel Bay												
*Deep	0.00- 0.36	0.17	20	-	-	-	-	-	-	-	-	-
Exposed	1.40-56.80	12.60	10	-	277	1	-	0.57	1	7.1-11.2	9.1	2
Pine Glen	1.00-40.60	18.40	10	-	296	1	-	0.72	1	7.4-11.2	9.5	3
Somers	-	-	-	-	1816	1	-	8.30	1	-	3.2	1
Group II												
Skidoo Bay	1.30-35.30	6.50	10	204-222	215	3	0.47-0.74	0.60	3	1.7- 7.9	5.3	5
Orange House	0.40- 3.00	1.60	10	-	245	1	-	0.79	1	3.7- 7.5	6.1	3
Yellow Bay												
*Deep	0.27- 0.30	0.29	2	-	-	-	-	-	-	0.6-10.9	7.8	17
Exposed	2.10- 5.20	3.70	12	181-207	194	2	0.36-0.83	0.60	2	-	-	-
Group III												
Dr. Richards N Hochmarks	0.90-13.70	3.80	23	102-157	138	3	0.24-0.43	0.34	3	1.2- 7.5	3.5	3
Gallagher	0.20- 1.70	0.80	10	-	279	1	-	0.89	1	3.9- 4.7	4.3	3
W. Gallagher	0.10- 1.30	0.51	16	-	270	1	-	0.77	1	5.9- 8.4	6.9	3
Crescent Bay	0.50- 5.80	2.90	12	194-422	348	5	1.10-2.80	1.80	5	0.5-10.0	5.8	5
Others												
*Deep Bay	-	-	-	-	-	-	-	-	-	-	-	-
*Table Bay	-	-	-	-	-	-	-	-	-	-	-	-
*Woods	0.70-0.38	0.18	8	-	-	-	-	-	-	1.7-11.7	6.9	33

*All well data except * which is seep meter data.

Lake Stage Variation

Information on the lake stage variation during the two years of study was evaluated with respect to changes in ground-water flow in spawning areas. Figure 2 presents the November through May hydrograph of Flathead Lake as recorded at Kerr Dam for 1982-1983 and 1983-1984. Operation during the two periods was similar with the lake stage generally declining until late March to early April and then rising after a brief period at mimium pool. However, pool decline in 1983 during spawning was more rapid than in 1982. The stage also appears to have fluctuated more in the 1983-1984 period reaching its mimium in April in contrast to late March during 1983. Figure 2 should be referred to when discussion of the possible effects of lake operation on ground-water conditions at individual sites are addressed.

Dr. Richards South

Apparent velocity and water quality data were not collected at this site during spawning. In 1984, as the lake stage fell three sandpoint wells were installed. Water level records for the wells show that the water table in the spawning area mirrored the lake stage fluctuation during the February through May operation period. In January only a one to one and one half of a meter wide area adjacent to the lake remained wetted within redd depth(15 cm)(Figure 3). February water table levels kept a three meter wide redd zone adjacent to the lake shore bathed in groundwater. This trend appears to continue until the lake stage begins to rise in late April. Similar tends were observed in 1983. As the stage fell the water tahle remained fairly flat. On the average a band on shore one meter wide remained ground water wetted as the stage fell and rose.

Figure 4 presents the on-shore apparent velocity data for wells DRS2 and DRS3. Velocities show an increase in late February and then basically a leveling off until late April when they decrease initially then increase as lake stage is brought back up to full stage. The large change in velocity recorded at wellsite DRS2 is a result of the hydraulic conductivity being greater at that site than at DRS3. Incubation apparent velocities for redds in the groundwater system average 0.67 cm/hr and 0.68 cm/hr from April through May during emergence. Note however, that these values are only based on two data points in both periods.

On shore velocity calculations at the site for one sandpoint in 1983 are presented in Figure 5 for comparison. Velocities are of the same magnetude though higher because of a larger hydraulic conductivity value. Apparent velocities in late February and early March were greatest with a decline into April after which velocity values increase and decrease parallel with stage change. In both years peaks in on shore velocities occured during almost the lowest lake stage and velocity minimums corresponded with sharp rises in lake stage. The system appears very sensitive to lake stage fluctuation during both years.

Groundwater flowing through redds during incubation has a mean TDS of 273 mg/l, Cl concentration of 5.2 mg/l and a mean DO of 10.7 mg/l. A water sample

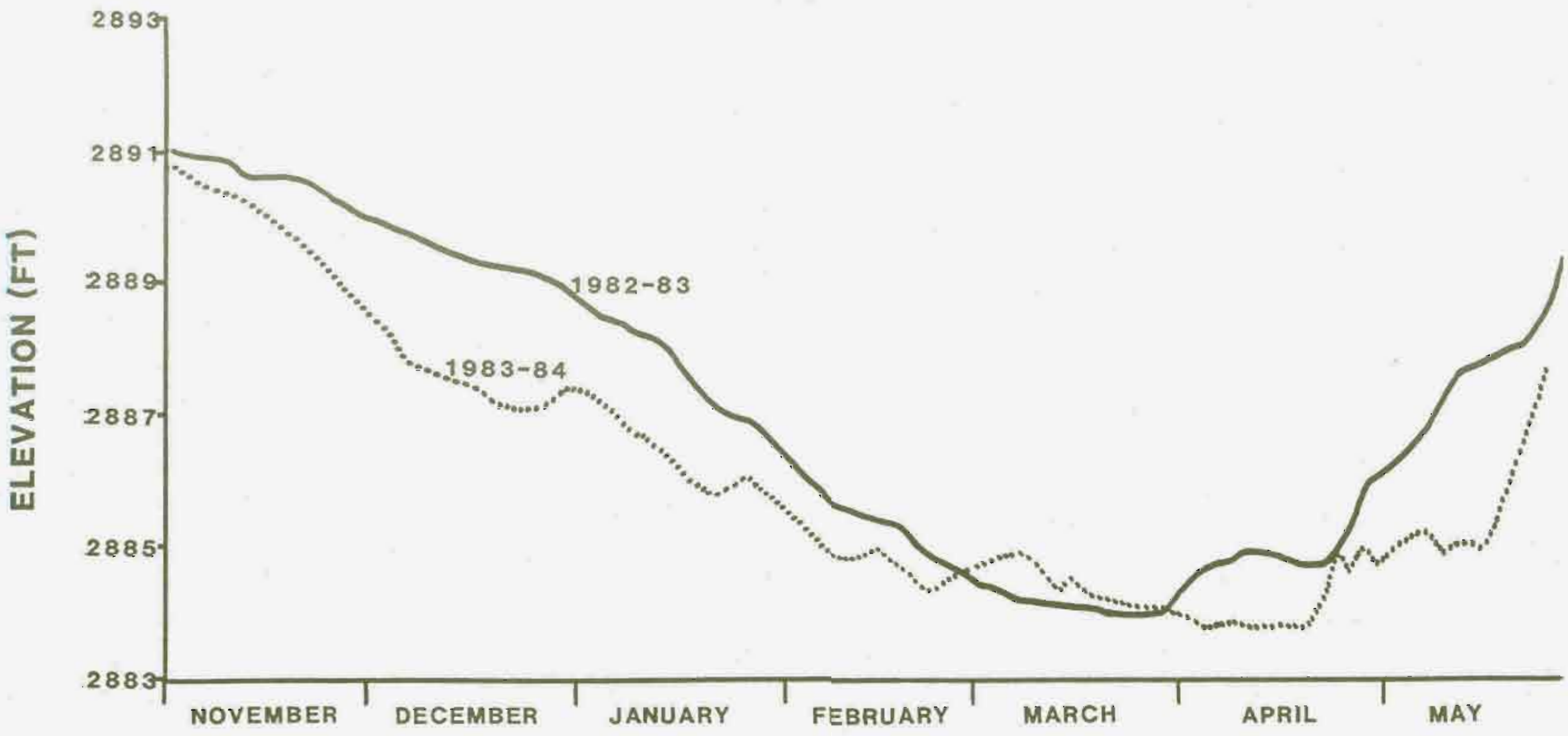

Figure 2: Flathead Lake hydrographs, 1982-1984

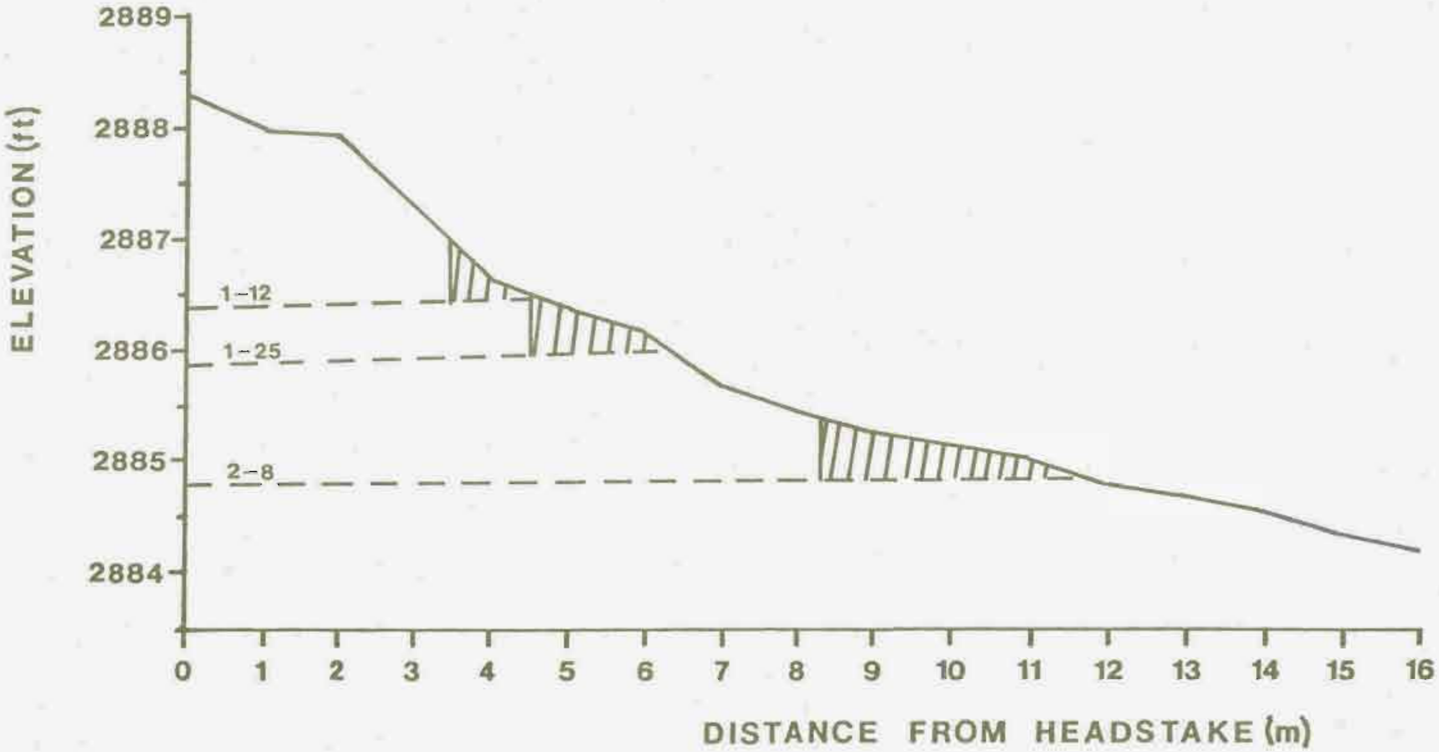

Figure 3: Water table profile, Dr.Richards Bay South

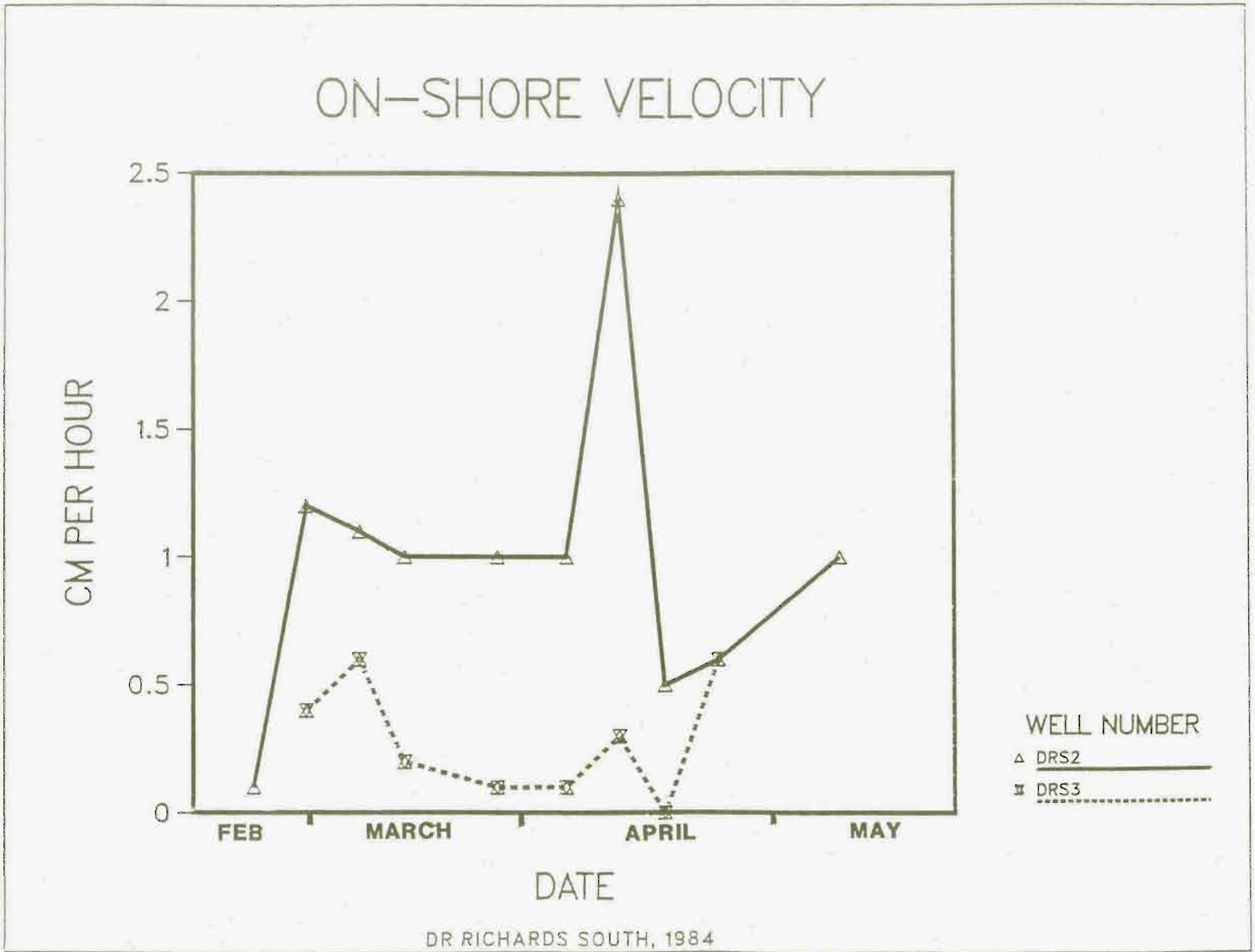

Figure 4: On-shore Velocity vs. Date, Dr. Richards South

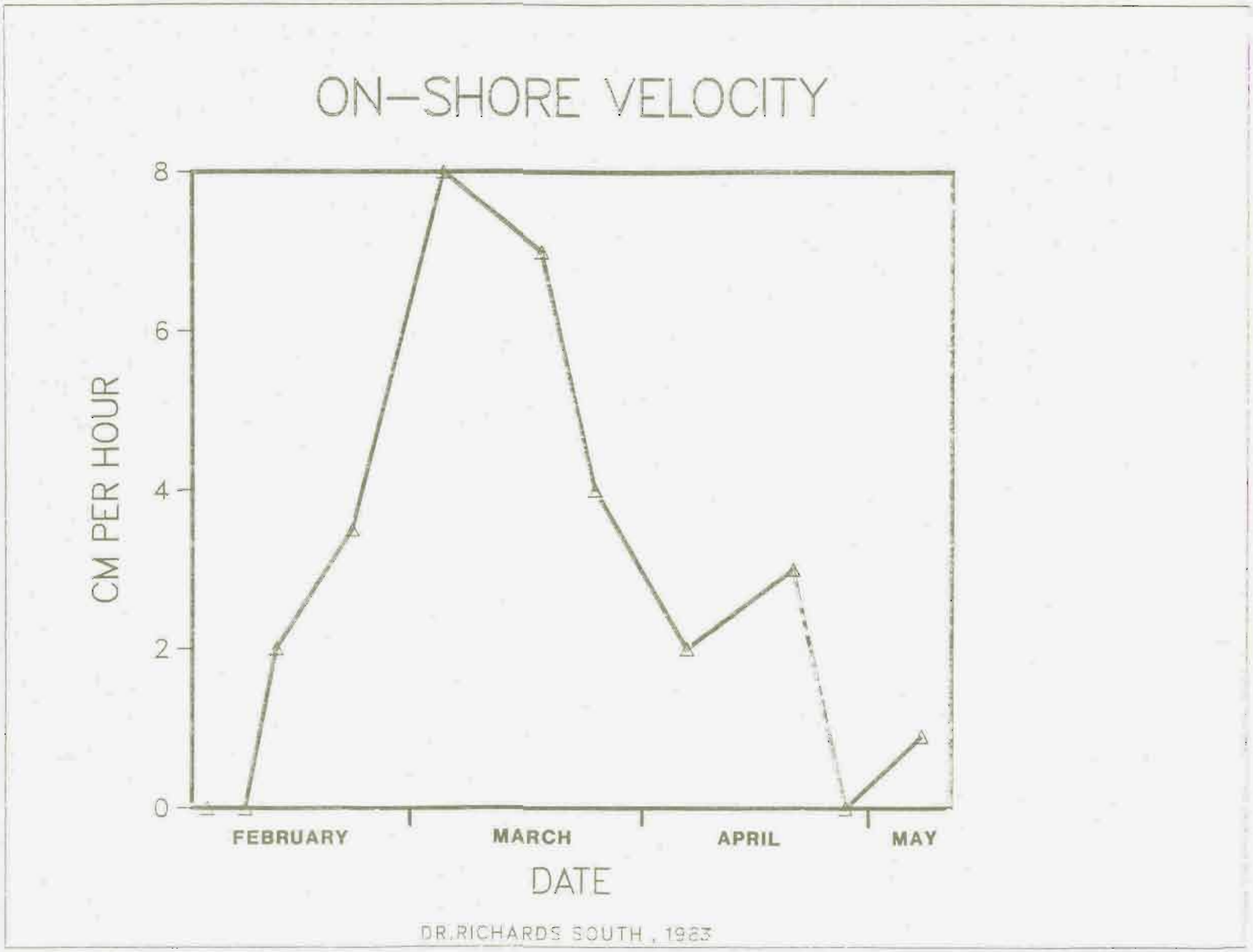

Figure 5: On-shore velocity vs. date, 1983, Dr. Richards Bay South

from DRS2 on 3-28-84 contained 9.9 mg/l Cl and a TDS of 400 mg/l which indicate groundwater contamination above a background quality, 3-28-83, of .37 mg/l Cl and 145 mg/l TDS. High Cl and TDS are characteristic of domestic sewage and septic systems. Nearby residents are likely sources of the apparent groundwater contamination. Groundwater passing through redds during emergence is similar in quality although TDS and Cl are slightly lower in concentration. DO is about one half the value found during incubation. A water sample from well DRS2 is elevated in TDS, 314 mg/l, and Cl, 3.0 mg/l, indicating the presence of groundwater pollution at the site on 5-15-84. DO concentrations are lower than during incubation even though apparent velocities were increasing in late April and early May (Figure 4). DO sampling representing emergence is based on well sampling and possibly well casing - DO interacting reduced DO in the sample. This would only occur if wells were not pumped to remove the well casing water before sampling.

Woods Bay West

Apparent velocity and general water quality data were not collected at this site during spawning. Only DO data were gathered from a seven station transect. Mean DO was 9.6 mg/l.

As the lake stage fell three sandpoint wells were installed. Water level records for one well started in December, 1983 and for a second well started in January, 1984, during egg incubation show that the water table mirrored the lake stage fluctuation from December through May. Water table position profiles for late December to mid January show only a one and one half meter wide area adjacent to the lake shore remained wetted within redd depth (Figure 6). By late January and February the wetted zone expanded to about three meters. This trend appears to continue through the rest of the incubation period until lake stage rise in late April.

Figure 7 presents the on-shore apparent velocity data for wells WBW1 and WBW3. Velocities appear to decrease in mid January, increase in late February-early March and then generally decline at WBW1 until it begins to rise again in late April during lake stage rise. The fluctuations seen at WBW3 in part reflect its closeness to the lake and the influence of small lake stage changes on the groundwater system. Apparent velocities during incubation for those redds in the groundwater system averaged 2.2 cm/hr and emergence velocities averaged 1.6 cm/hr during April and May. It appears from Figure 7 that groundwater flow through redds located below the water table is slightly higher during incubation than emergence.

Groundwater affecting redds during incubation and emergence is similar in overall quality with TDS and Cl values of 172 to 191 mg/l and 1.4 to 1.7 mg/l, respectively. Note that only one chemical analysis is available. However, the incubation period DO concentrations were over 50% greater, 10.2 mg/l, than the 4.5 mg/l figure for emergence. Again DO values used to characterizeemergence were collected from a sandpoint well. Chloride and nitrate concentrations for WBW2 appeared to be slightly higher than back ground of less that 1 mg/l, however, not enough data are available to determine if groundwater degradation is occuring.

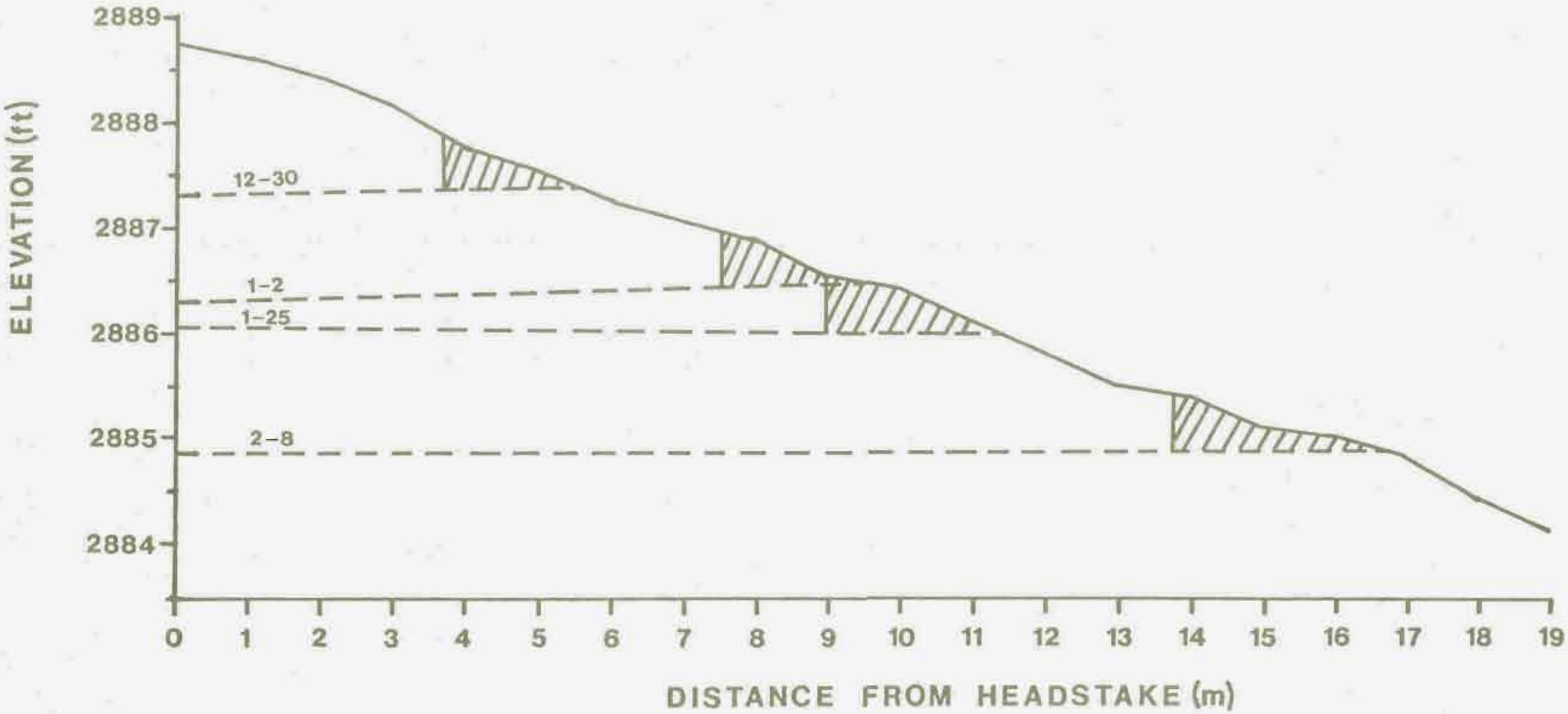

Figure 6: Water table profile, Woods Bay West

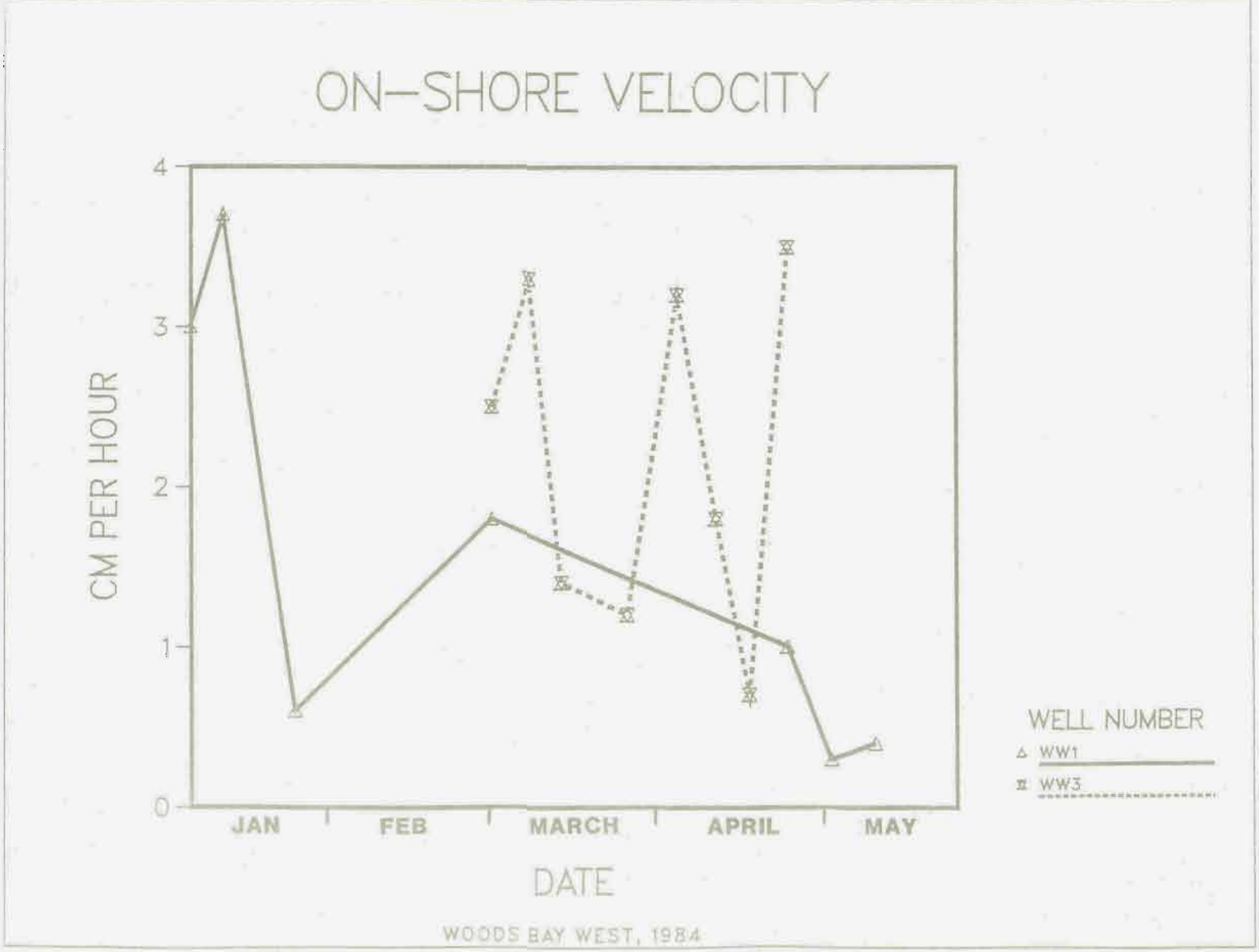

Figure 7: On-shore Velocity vs. Date, Woods Bay West

Woods Bay East

Apparent velocity and general water quality data were not collected during the spawning period. A DO transect was completed and a mean value of 10.6 mg/l characterizes the groundwater during October through December.As the stage fell three sandpoint wells were installed. Water level records begun in December, 1983 and January, 1984, show the water table mirrored lake stage decline through the incubation and emergence periods. Water table profiles presented in Figure 8 show that from two and one half to three meter wide areas adjacent to the lake remained wetted to redd depth during incubation. A zone of about two and one half meters appears to remain during emergence until lake stage rise in April.

Figure 9 presents the on-shore apparent velocity for wells WBE1 and WBE3. At the scale plotted, the well farthest from shore (WBE1) shows little change during both incubation and emergence. The apparent velocity at WBE3, located closest to the lake shore, shows a large increase in velocity in late February which corresponds to a slight rise in lake stage. Mean apparent velocities during the two periods are 3.2 and 1.8 cm/hr, respectively.

Groundwater quality during incubation and emergence is very similar. TDS and DO are only slightly higher during incubation than emergence (Table 3 and 4). Concentrations of nitrates and chlorides do not indicate the possible presence of contamination. Note, however, that only one sample for each period is available for analysis.

Gravel Bay

Seepage meter data were operated at the site and apparent velocity and quality data are available for the spawning period. Figure 10 presents apparent velocity data collected at the site from November, 1982 through March, 1983. In the 1982 and 1983 spawning period velocities increased with the decline in stage. The overall mean groundwater apparent velocity during spawning is 0.18 cm/hr. Mean water quality parameters show the water has a TDS of 206 mg/l, a Cl content of 0.24 mg/l and a DO concentration of 8.2 mg/l. The concentrations of constituents do not indicate the presence of pollution.

Seepage meter apparent velocities during spawning, incubation and emergence were generally higher in 1982-1983 than in 1983-1984. If this is principally related to lake stage operation it would be implied that the more rapid decline in stage during 1983 resulted in lower velocities during spawning. This is contrary to an anticipated increase in velocity if lake stage fluctuation is the sole factor controlling the shore line ground-water system.

As the lake stage fell three sandpoint wells were installed and operated in conjunction with the seepage meters. The shore groundwater system mirrored lake stage decline and rise during the December, 1983 through May, 1984,

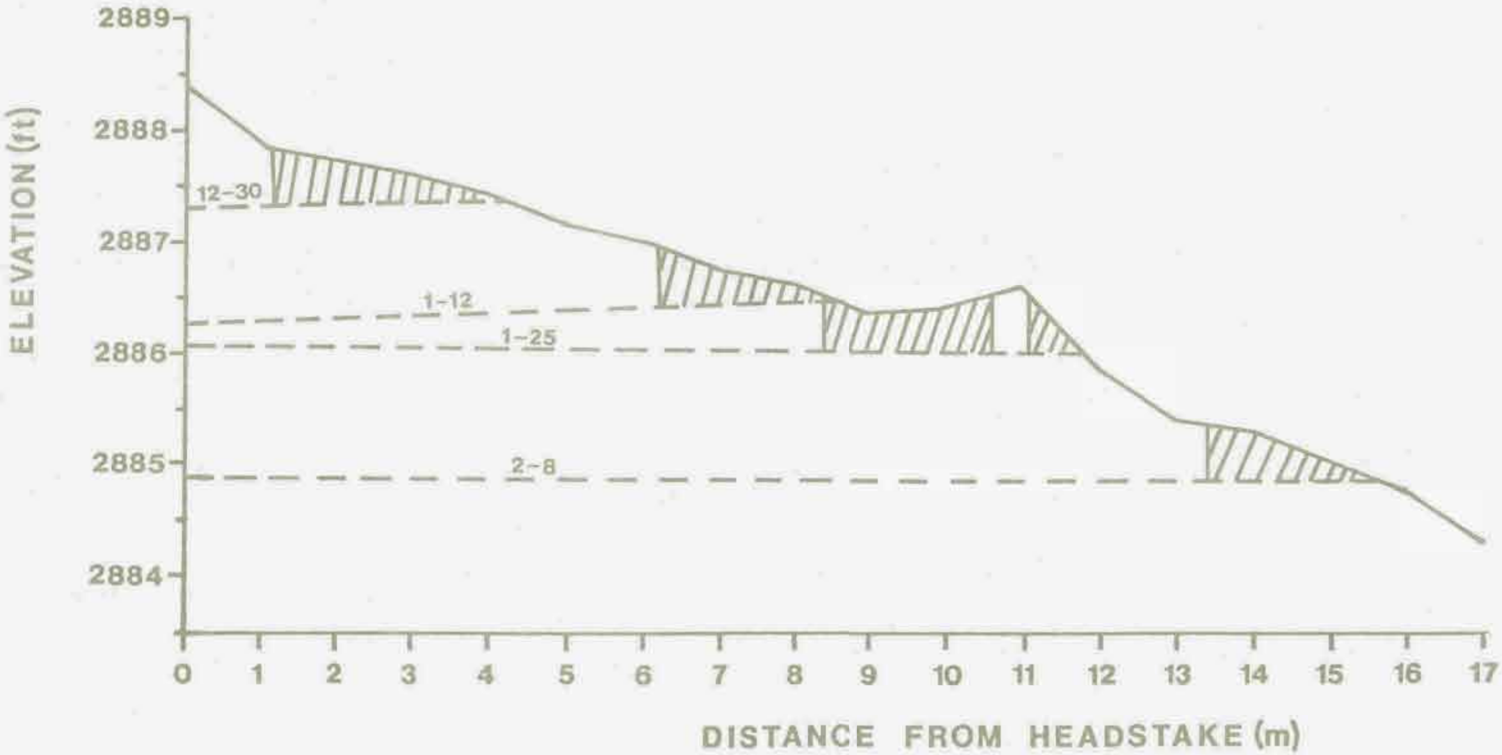

Figure 8: Water table profile, Woods Bay East

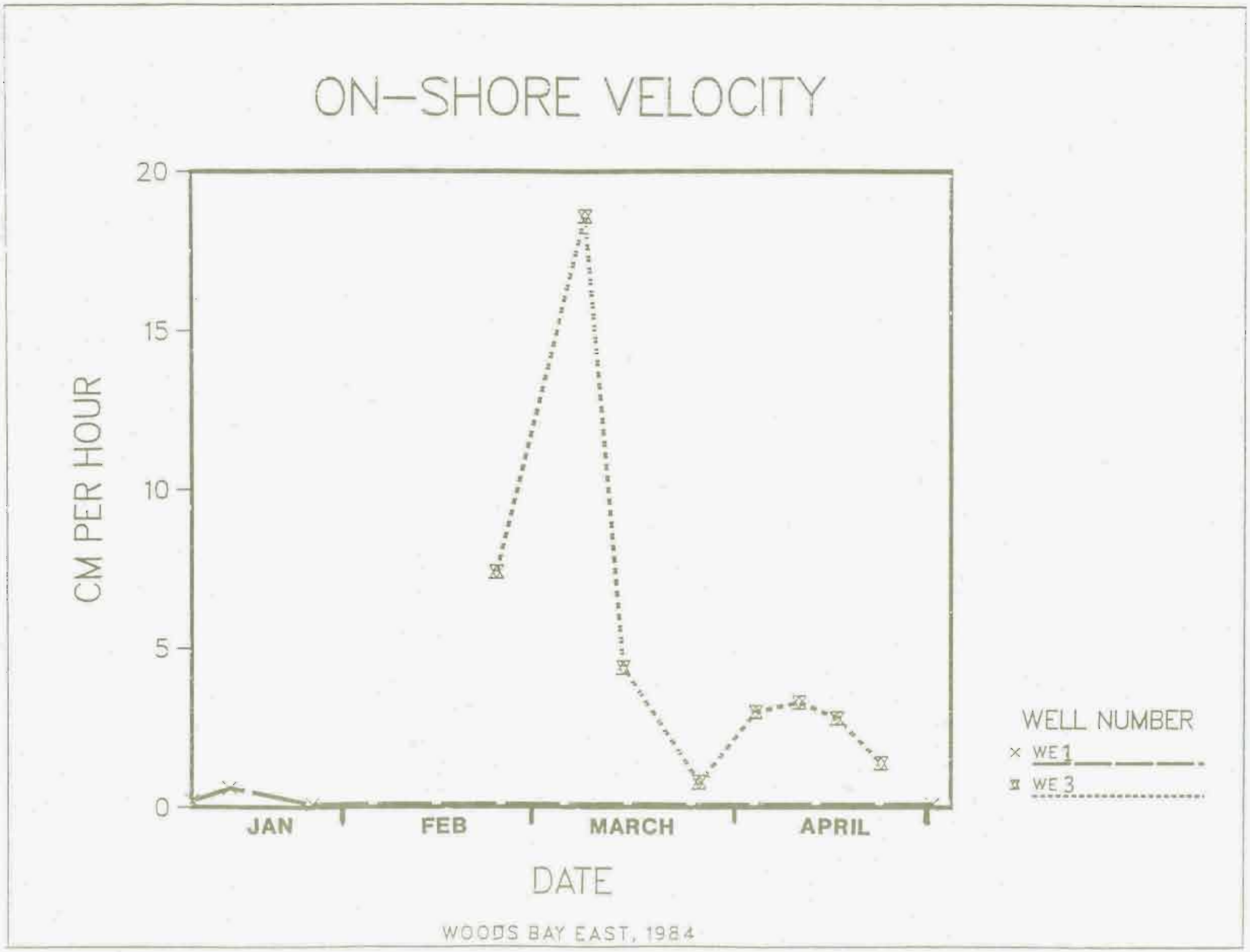

Figure 9: On-shore Velocity vs. Date, Woods Bay East

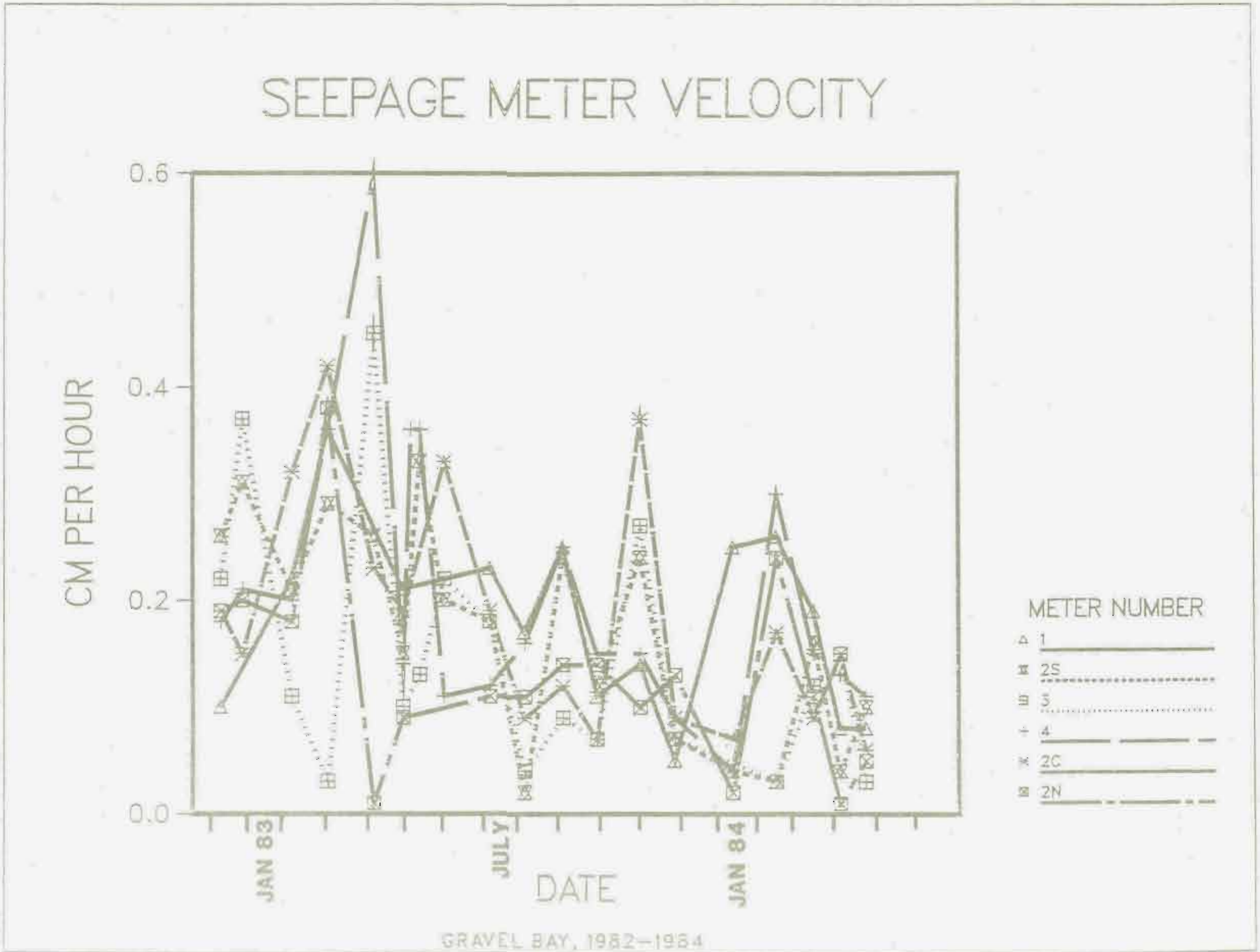

Figure 10: Seepage Meter Velocity vs. Date, Gravel Bay

operation of the wells. Figure 11 presents water table profiles used to examine the areas wetted to within 15 cm of land surface during stage decline. Generally, a one meter wide area adjacent to the lake contained a water table within the designated range for the entire time.

Apparent velocity values based on well data for the incubation and emergence periods are presented in Figure 12. On-shore or exposed site velocities rise and fall with lake stage. The peak in late February and early March is mirrored with a rise and fall in lake stage. The on-shore apparent velocities increase again in late April as lake stage rises. Seepage meter data presented in Figure 10 shows a general increase in velocity through February and then a decline into March. The velocities appear to continue to decline until lake stage rise in late April during emergence. The highest seepage rates are recorded in late April and May. After the lake reaches the maximum stage in late May seepage rates generally decline until late October when rates increase with lake stage decline.

Mean velocity values for the incubation period are 0.20 cm/hr for the deep seepage meter data site and 8.2 cm/hr at the exposed well data site. Emergence apparent velocities are characterized by means of 0.17 cm/hr at the deep submerged site and 12.6 cm/hr at the on-shore site. Interestingly, installation of portable seepage meters parallel to shore in the previous year of study and this year of study produced data that indicates that the submerged spawning site at Gravel Bay does not have the highest groundwater apparent velocities in the bay area (Figure 13). In fact, during early fall and the periods of incubation and emergence it has the lowest velocities when compared to data collected to the north and south of the site.

The groundwater quality flowing through the deep and exposed sites during incubation is characterized by mean values of TDS of 208 and 213 mg/l, respectively. Chloride and DO mean values are also very similar. Groundwater quality data for the on-shore area was the only data collected to characterize the emergence period. The mean TDS shows and increase to 277 mg/l for the single sample available. However, the Cl and DO values are similar to those reported during the incubation period for both the deep and exposed site. We assume that the deep site emergence water quality is similar to the on-shore data. Well GB2 contained water in February which had a Cl concentration of 1.40 mg/l and 0.8 mg/l nitrates. These parameters appear to be slightly above background but probably do not indicate groundwater pollution.

Pine Glen

Apparent velocity and general chemistry data were not collected at this site during the spawning period. DO transect data were collected and the mean concentration of DO in the spawning area groundwater is 9.0 mg/l. As the lake stage fell three sandpoint wells were installed. Water level records initiated in December, 1983, indicate that for well PG1 the water table mirrored lake stage decline. The water table at the other two wells which were installed in February, 1984, lagged slightly behind lake stage and showed a lower amplitude in response to lake stage fluctuation. Water table profile data based on PG1 are presented in Figure 14. The records for well PG1 are puzzling as they indicate the slope of the water table was away from the lake for the entire incubation period. A slope of the water table away from the

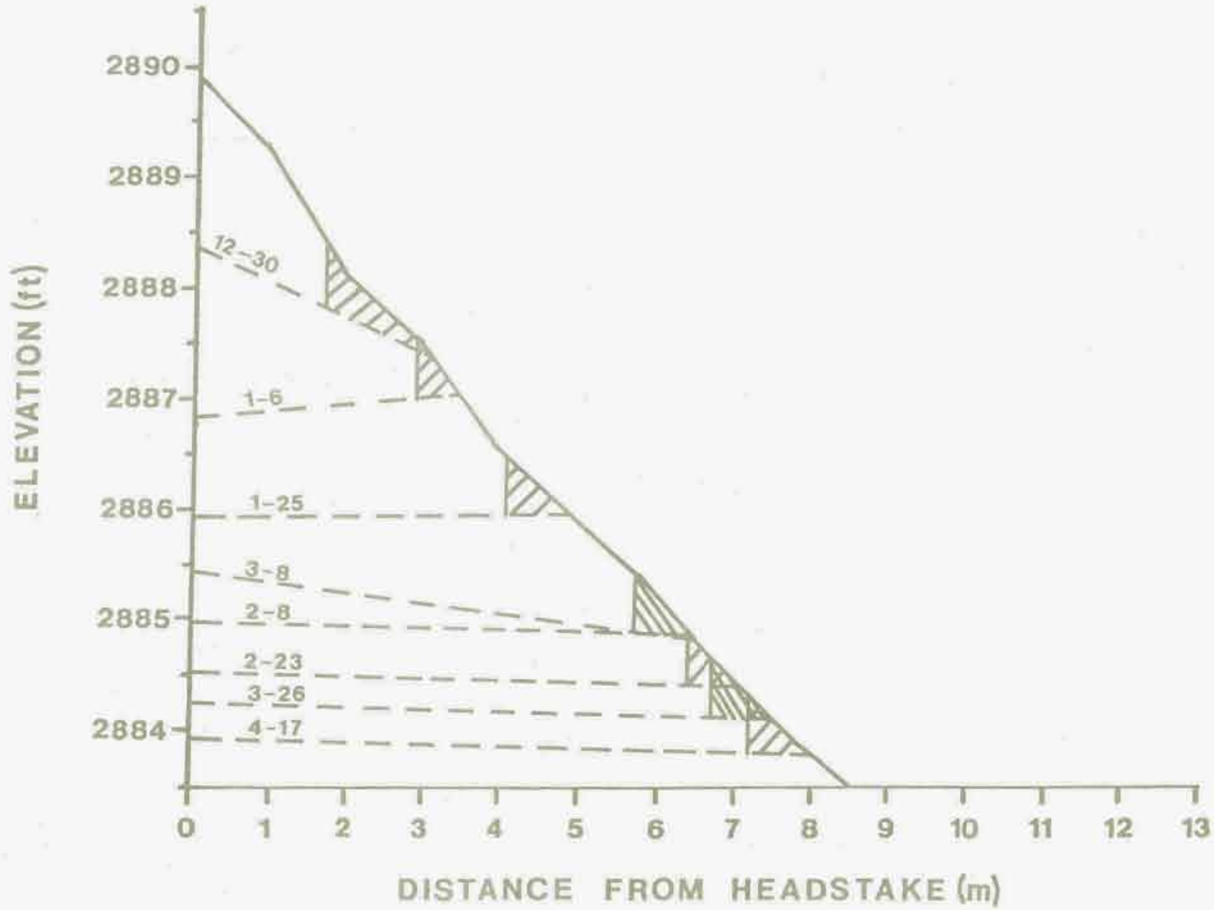

Figure 11: Water table profile, Gravel Bay

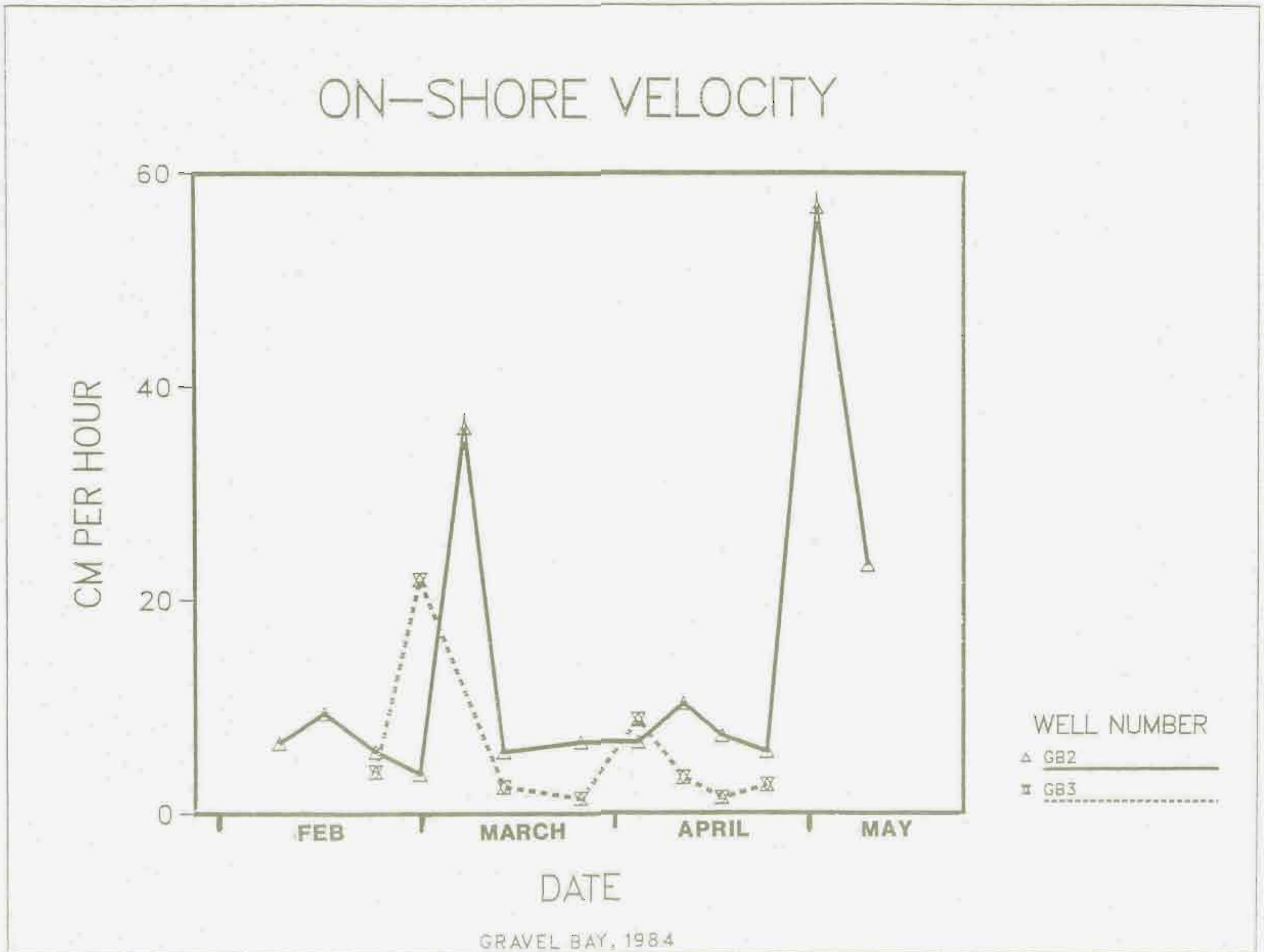

Figure 12: On-shore Velocity vs. Date, Gravel Bay

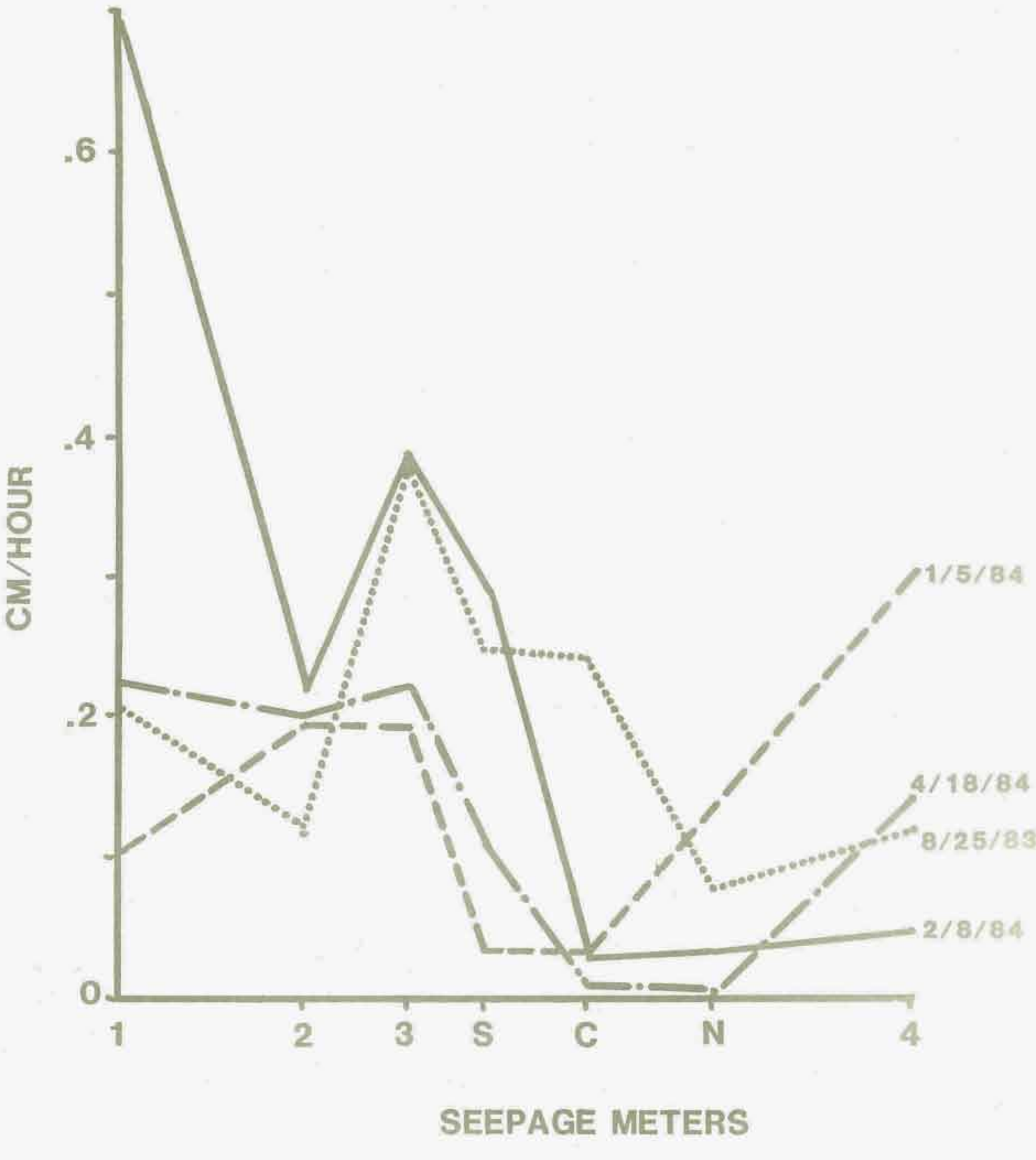

Figure 13: Seepage Variation Parallel to Shore
Gravel Bay

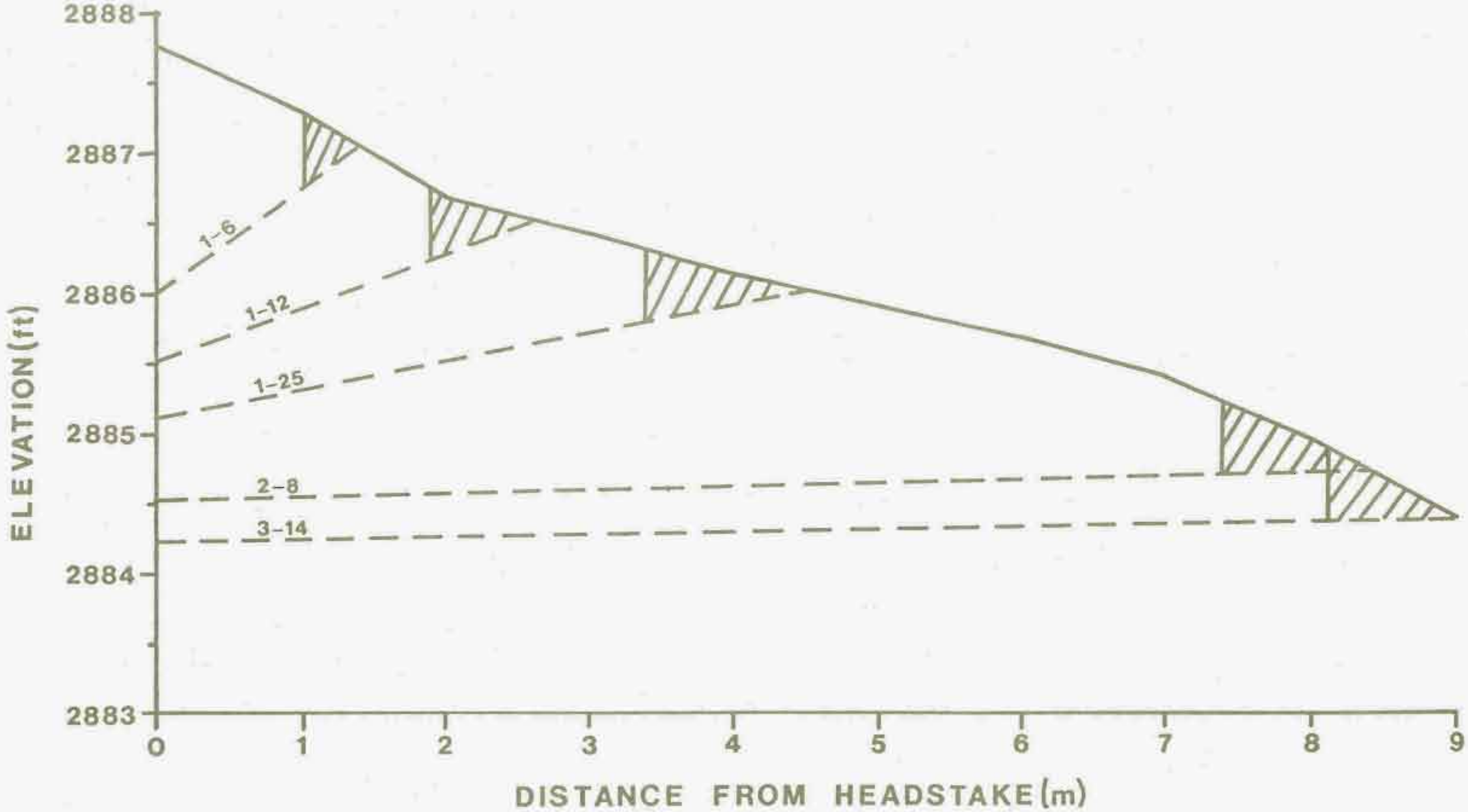

Figure 14: Water table profile, Pine Glen

lake would require a large hydraulic sink for the lake water. However, unless there are large production wells near the site which could draw down the water table sufficiently to reverse the gradient to the lake, the data for PG1 seems suspect. Such a well or sink is not identifiable in the area. Even with this questionable data it appears that an area about one meter wide adjacent to the lake would remain wetted by the water table to a depth of less than 15 cm. This trend appears to continue until at least the lake stage begins to rise in April.

Figure 15 presents the on-shore apparent velocity data for wells PG2 and PG3. Velocities decreased during incubation with the exception of a rise in late February-early March which corresponds to a rise in lake stage. Apparent velocities increased during emergence mainly in response to lake stage rise in late April. Mean apparent velocities during the two periods are 16.7 and 18.4 cm/hr, respectively.

Water table position in 1983 maintained a one meter zone wetted to within redd depth adjacent to shore. Figure 16 presents on shore velocity data for a sand point installed during the 1983 incubation and emergence period. The velocities are within the same order of magnetude as the 1984 data. A different hydraulic conductivity value used for the 1983 calculations accounts for the difference. Data for 1984 mirrors lake stage where 1983 velocities are greatest during lowest lake stage and lowest during lake filling in April and May. This would imply that regional or local recharge to the near shoreline ground-water system may have over powered the effects of lake stage change in 1983.

Groundwater flowing through the redds during incubation has a mean TDS of 299 mg/l, a mean Cl content of 0.64 mg/l and a mean DO of 9.2 mg/l for transect data and 8.5 mg/l for well samples. Water quality during emergence is similar in quality (Table 4). Groundwater quality data does not clearly indicate unnatural degradation.

Somers Bay

Seepage meters were operated at this site during the October through December spawning period. Apparent velocity values derived from the seepage meter data are presented in Figure 17. Velocities appear to decrease from October through November at one site and increase a the second site. However, the range of values is from 0.11 to 0.32 cm/hr. The mean velocity which characterizes the spawning period is 0.19 cm/hr. One water quality sample is available to characterize the spawning period. The groundwater TDS is 142 mg/l and the Cl concentration is 0.34 mg/l. DO transect data show the mean groundwater DO during spawning is 11.1 mg/l and seepage meter data suggests a mean value of 9.6 mg/l.

As lake stage declined one sandpoint well was installed. The water level mirrored lake stage decline. However, water level records are intermittent because during January and February, 1984, the water in the well was frozen. Figure 18 presents water table profiles for the site. The profile for December indicates a gradient from the lake to the well existed. Possibly, the well was not properly developed and the screen became plugged, thus

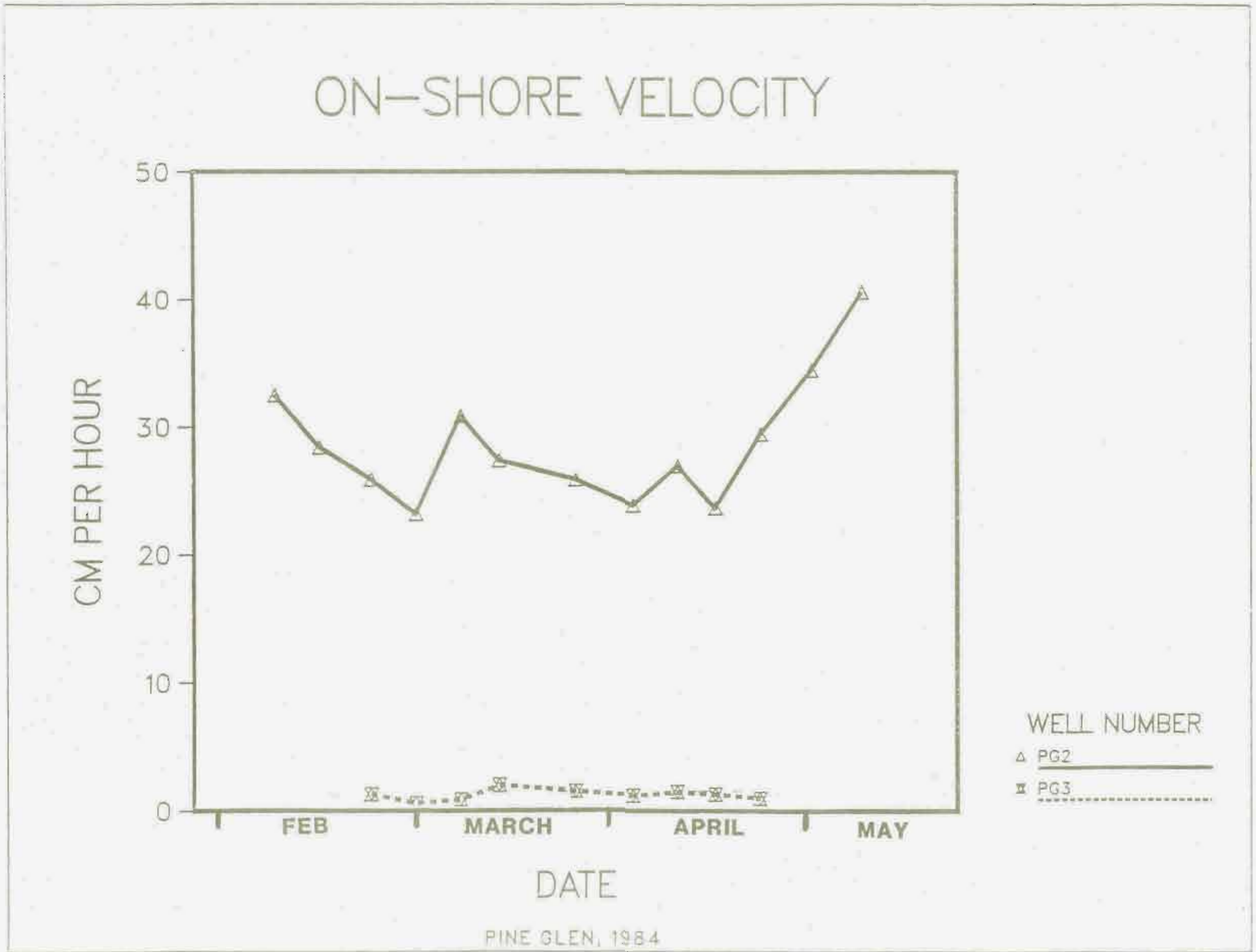

Figure 15: On-shore Velocity vs. Date, Pine Glen

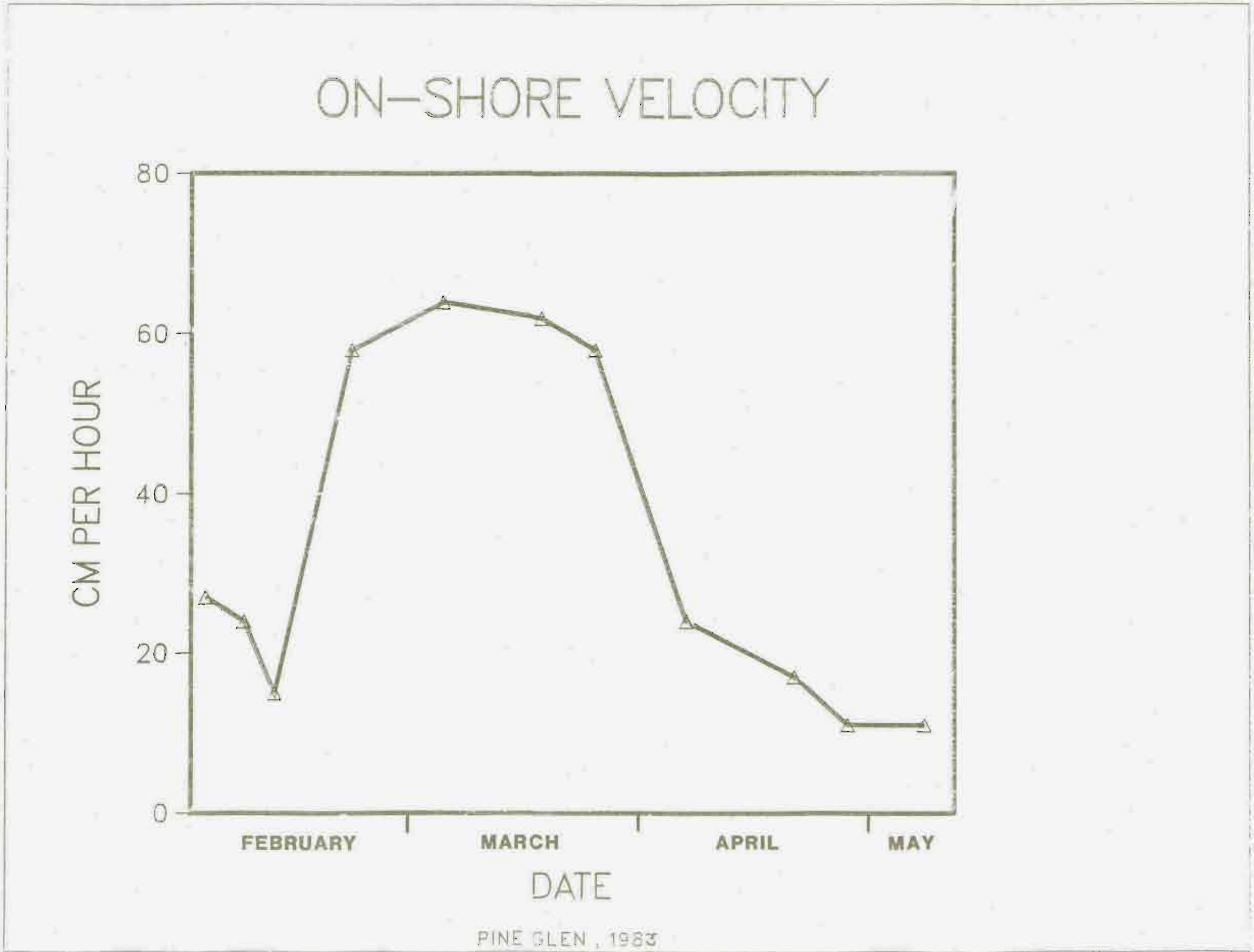

Figure 16: On-shore velocity vs. date, 1983, Pine Glen

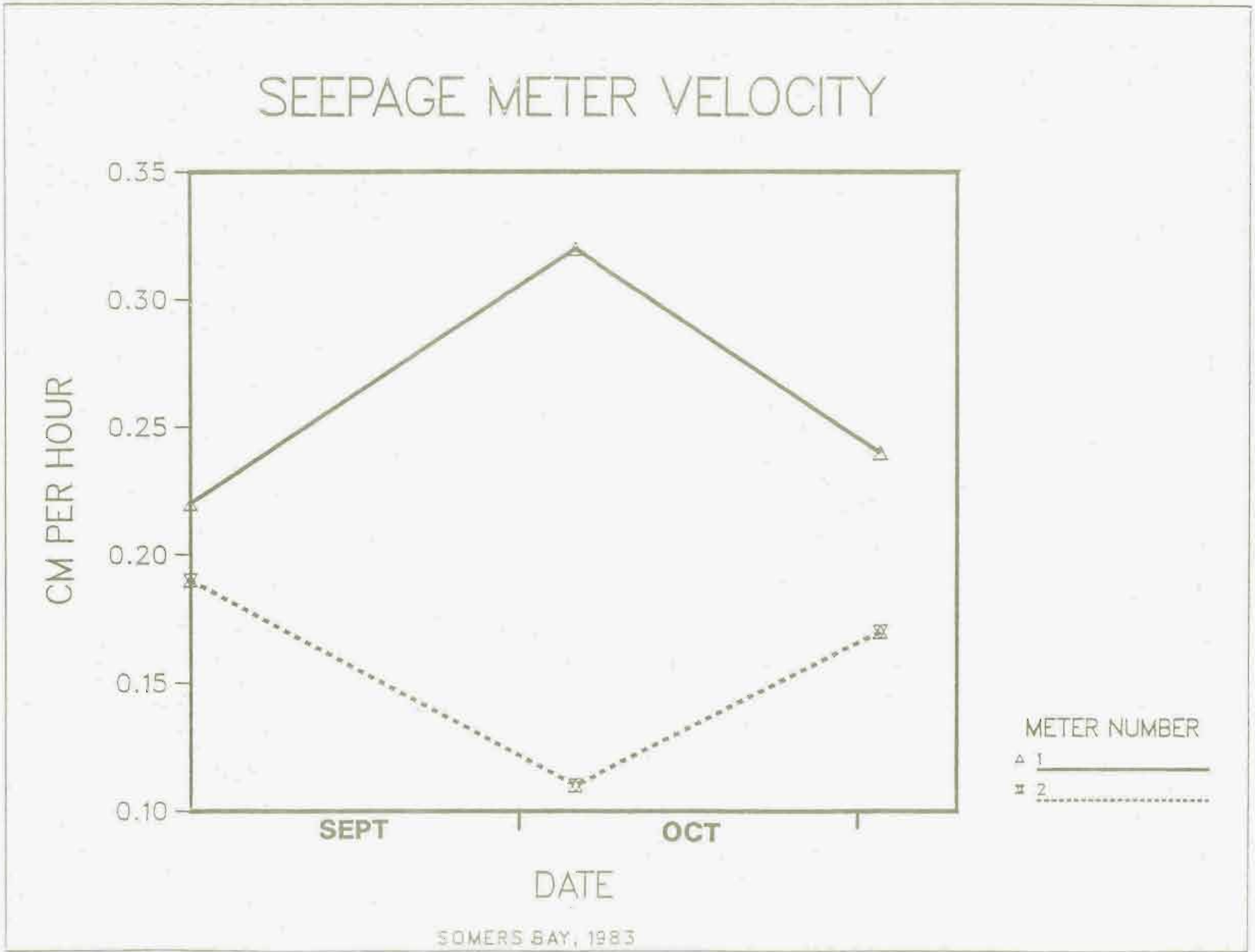

Figure 17: Seepage Meter Velocity vs. Date, Somers Bay

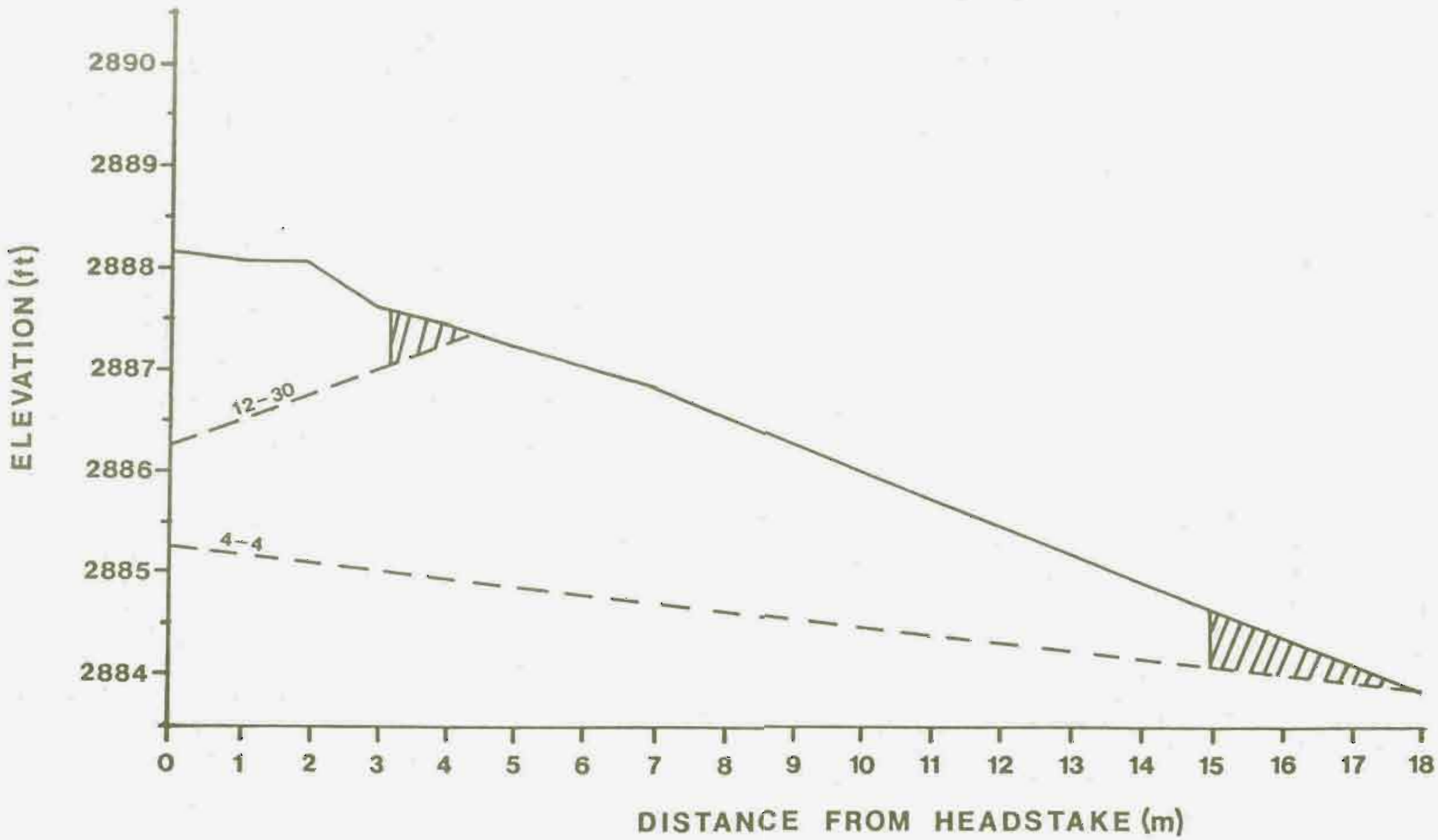

Figure 18: Water table profile, Somers Bay

stagnating the water which could produce the appearence of a reversed gradient and permit freezing of the water in the well. Usually, wells which penetrate the water table do not freeze because of the constant groundwater temperature and insulating effects of the soil. For the water to freeze it would have to be influenced mainly by air temperature and isolated from the groundwater system. Figure 18 does indicate that as the shore area becomes exposed by lake stage decline the slope of the shore and position of the water table leaves an area about three meters wide adjacent to the lake wetted at or above typical redd depth. Because of the frozen period, hydraulic conductivity tests could not be conducted on the well and on-shore apparent velocities for the incubation and emergence periods could not be calculated.

A single groundwater quality sample was collected to characterize the quality of water during incubation and emergence. Samples of goundwater for both periods were high in TDS, 440 and 1,816 mg/l, respectively, and Cl, 18 and 8.3 mg/l, respectively. The pH of the sample representing emergence had a pH of 12.2. These values indicate groundwater pollution. A seepage meter sample collected in September, 1983, showed a TDS of 530 mg/l, a Cl concentration of 71 mg/l and a nitrate concentration of 1.93 mg/l. This sample also indicates groundwater pollution. The most likely source would be domestic sewage, however, the high pH recorded in May, 1984 is puzzling. It may be explained if the contamination results from septic tank wastes and the owner treated his system with a lye or similar material sometime prior to sampling.

Skidoo Bay

Seepage meters have been operated at this site since April, 1982. Apparent velocity data derived from the meters is presented in Figure 19. The data collectd in 1982 through 1983 provides a fairly complete picture of apparent velocity trends. During spawning periods, velocities were declining both years in October until the lake stage began to decline in late October to early November. The apparent velocity then increased through December. Mean apparent velocity during spawning, based on 22 data points, is 0.22 cm/hr. The groundwater quality is only indicated by one sample which has a TDS of 156 mg/l and a Cl content of 0.30 mg/l. A number of DO transects have been completed during the spawning period and the groundwater DO concentration can be characterized by a mean value of 9.0 mg/l. During spawning periods in 1982 and 1983 lake stage operation did not appear to alter the seepage meter apparent velocities.

As the lake stage declined, four sandpoint wells were installed. Water level records for the wells show that the water table fluctuations are lower in amplitude and lag behind the lake stage change. This occurs from late December until lake stage rise in late April when the water table more closely mirrors rising lake stage. A water table profile for the site during late spawning time, incubation and emergence is presented in Figure 20. An area from one to two meters wide adjacent to the lake remains wetted by groundwater to redd depth during incubation and emergence. In 1983 a zone 3.5 meters in width remained wetted adjacent to the lake to a depth of 15 cm.

Figure 21 presents on-shore apparent velocity values. On-shore velocities remain fairly constant during incubation and emergence. The two

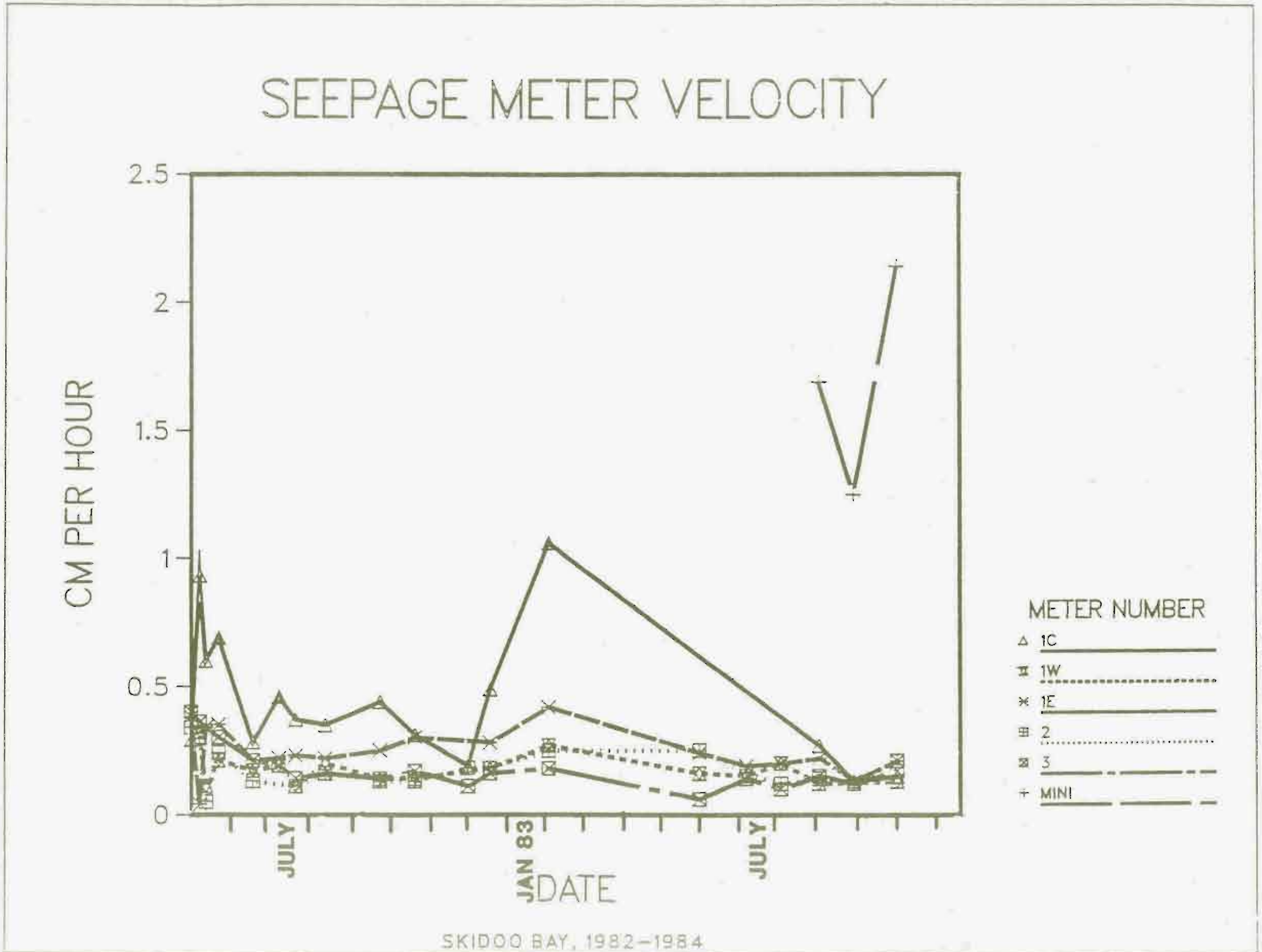

Figure 19: Seepage Meter Velocity vs. Date, Skidoo Bay

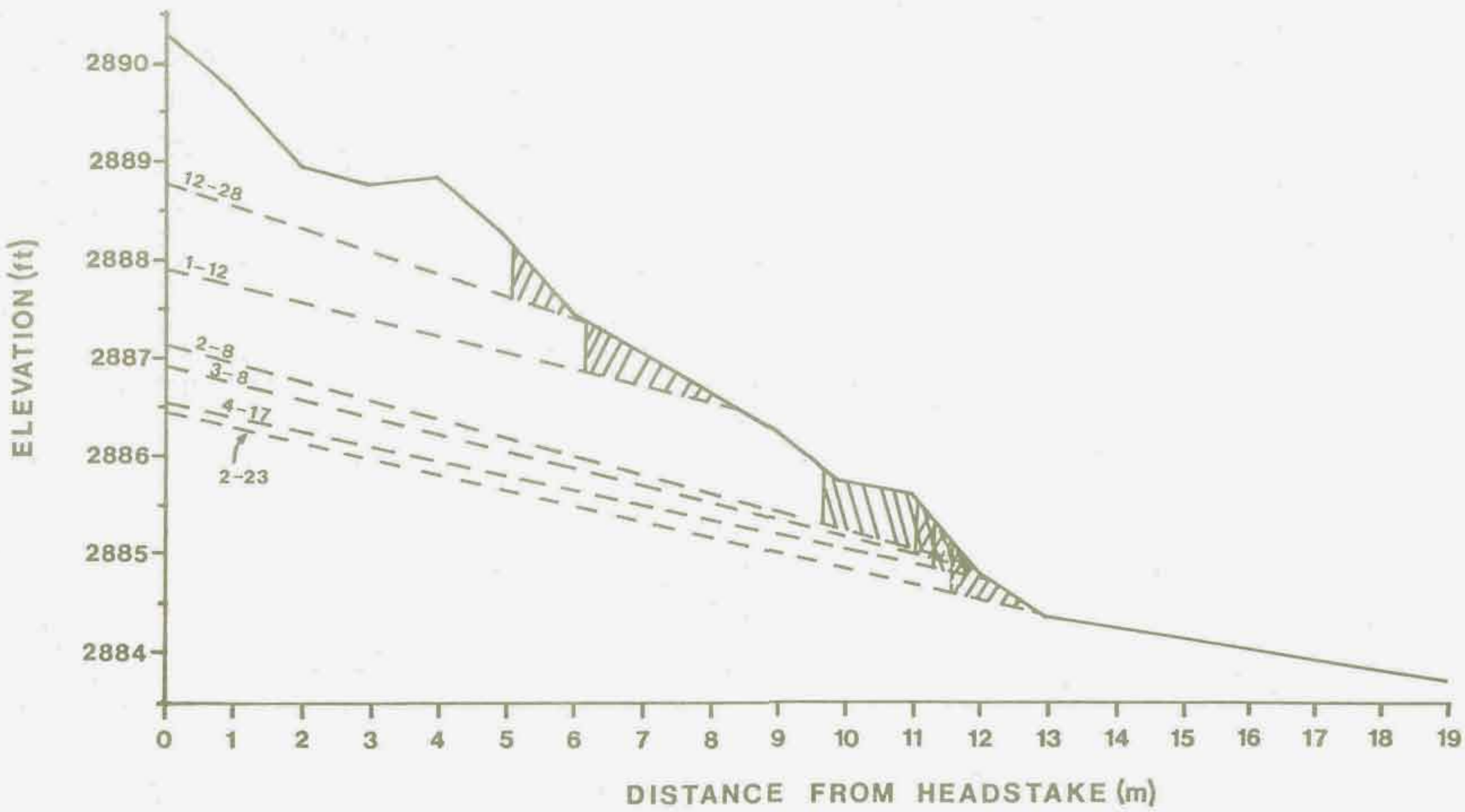

Figure 20: Water table profile, Skidoo Bay

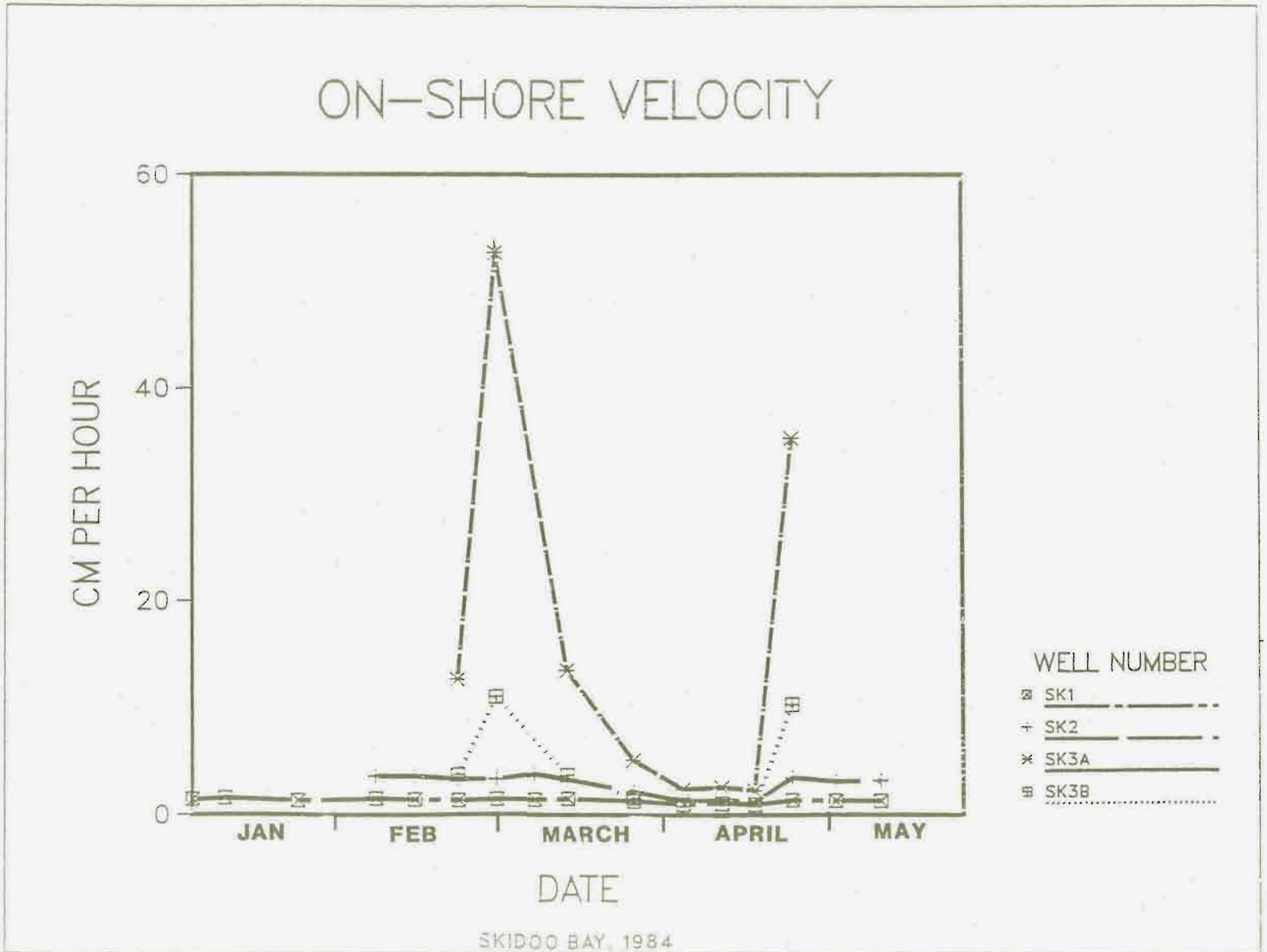

Figure 21: On-shore Velocity vs. Date, Skidoo Bay

data points closest to the lake shore, SK3A and SK3B, show the effect of a lake stage rise in late February- early March. These same wells are the first to respond to lake stage rise in late April during emergence. Seepage meter data show a rise in April, 1982, which corresponds to lake stage rise. The apparent velocities at seepage meter sites then decline rapidly once the stage has reached its maximum and remain fairly constant until the stage begins to decline during the spawning season. Average apparent velocity characterized by on-shore well data is 12.1 cm/hr during incubation and 6.5 cm/hr during emergence.

On shore velocity data for 1983 is presented in Figure 22. Values are similar to the majority of velocities recorded in 1984. !983 values generally decrease and then rise in April in response to lake filling. A similar trend is seen for the 1984 data. Effects of lake stage operation variations during the two years are not obvious.

Figure 23 presents portable seepage meter data from instruments placed parallel to shore. The apparent velocity data collected in October during spawning and in March during incubation indicate that for the 1983- 1984 season the maximum velocity areas were to the west of the spawning site(meters 1W, 1C and 1E). Our previous study examined portable meter data for October, December and August. That information showed the highest velocities for two of the dates to be at 1C. The October data showed a peak velocity at 2W which corresponds to the location of the 1983- 1984 peak. It is unclear what caused this apparent shift in groundwater velocity.

Figure 24 presents the variation of apparent velocities parallel to shore in the 1982 and 1983 spawning period. Seepage rates were lower at meter 1W and the east meters and higher at the four remaining west meters in 1983. Again the direct influence of lake stage operation differences during the two years is not discernible.

Groundwater in contact with redds during incubation has a mean TDS of 216 mg/l and a mean Cl concentration of 0.65 mg/l. The mean DO concentration is 8.7 mg/l based on transect data and 6.2 mg/l based on well data. The groundwater quality during emergence is similar to the quality during incubation. It has a mean TDS of 215 mg/l, a mean Cl concentration of 0.60 mg/l and a mean DO concentration of 5.3 mg/l. A number of groundwater samples from wells and one November seepage meter sample showed nitrates in the 0.38 to 0.68 mg/l range and Cl values in the 0.58 to 1.08 mg/l range which appear to be slightly elevated above background. However, a clear interpetation of groundwater pollution can not be made based on the available data.

Orange House

Apparent velocity and water quality data were not collected at the Orange House site on Skidoo Bay during spawning. As lake stage declined, three sandpoint wells were installed. Water level records for the wells show that the water table in the spawning area generally followed lake stage decline with a lag and lower amplitude fluctuation. Water table profiles for well OH1 are presented Figure 25. During incubation and early emergence a two to two and one half meter wide area adjacent to the lake shore remained wetted to

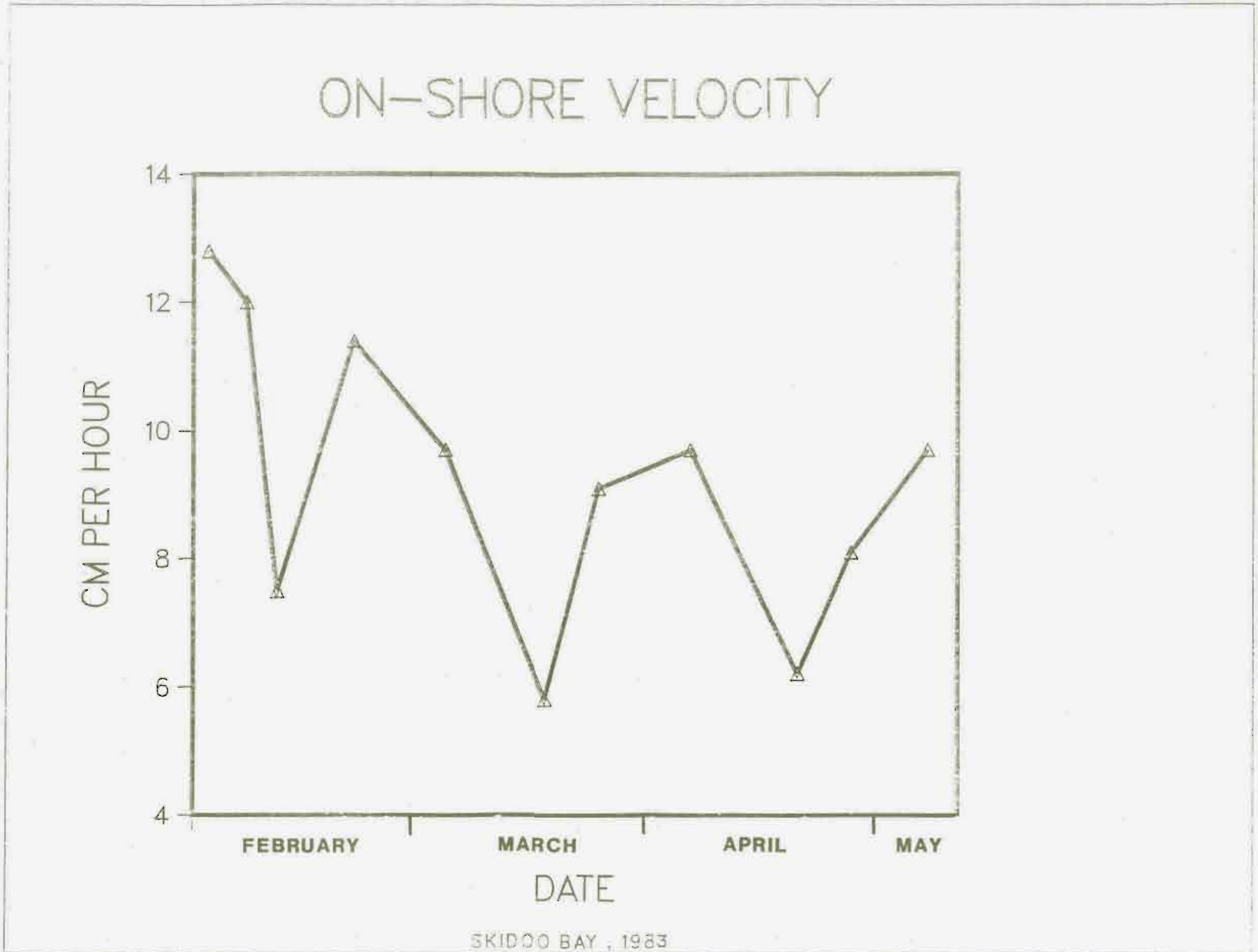

Figure 22: On-shore velocity vs. date, 1983, Skidoo Bay

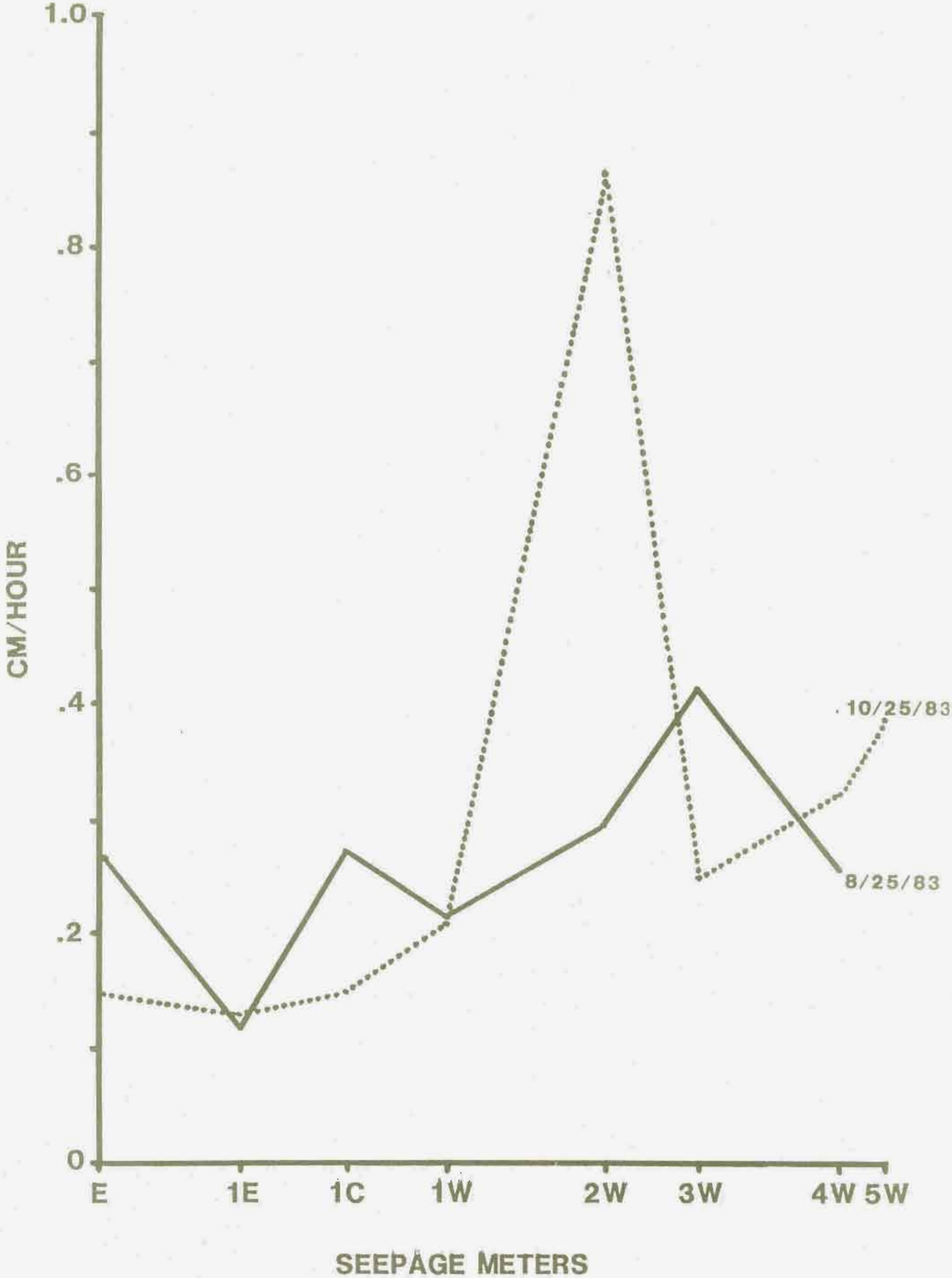

Figure 23: Seepage Variation Parallel to Shore
Skidoo Bay

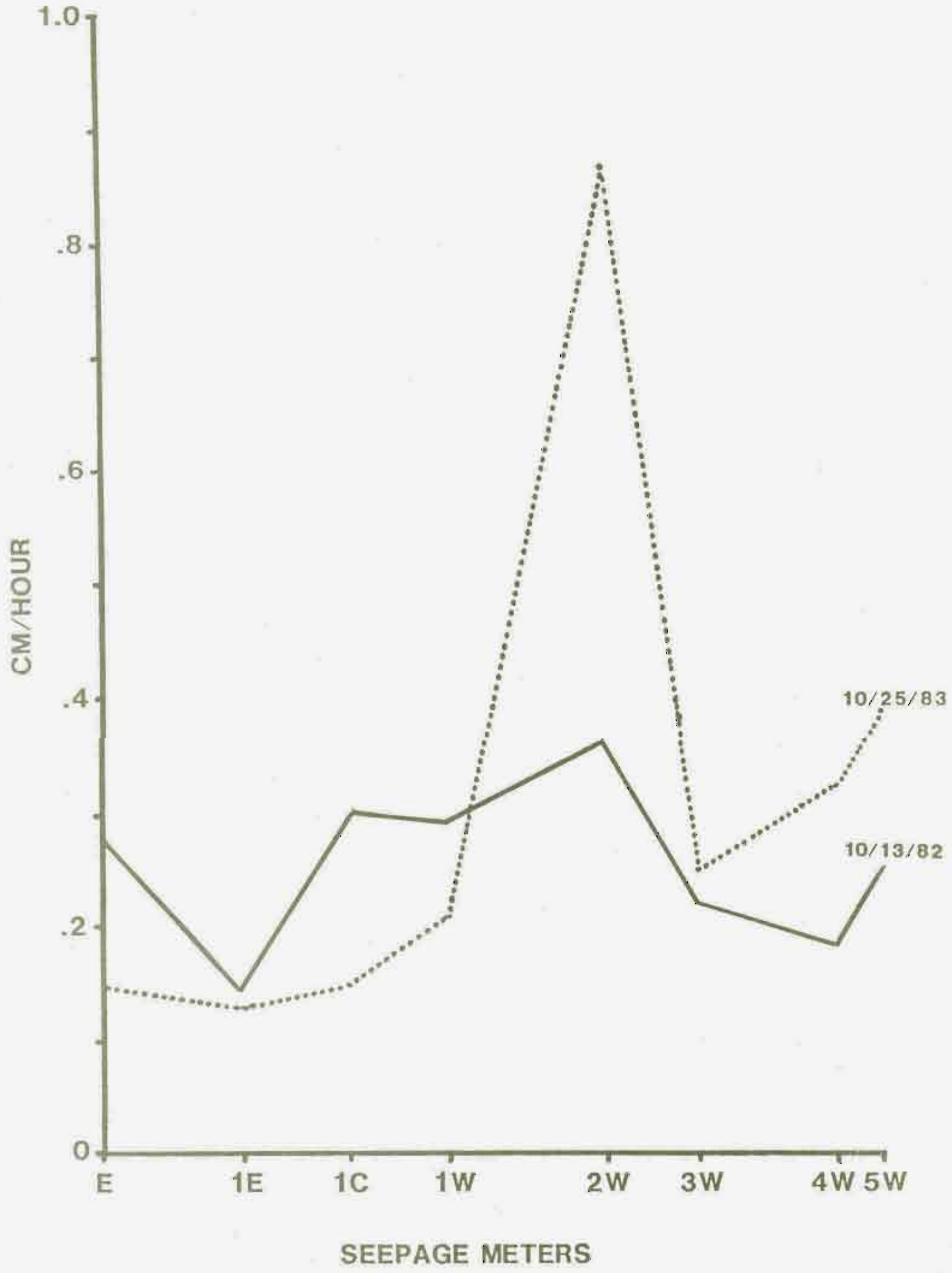

Figure 24: Seepage variation parallel to shore, Skidoo Bay, 1982 and 1983 spawning period

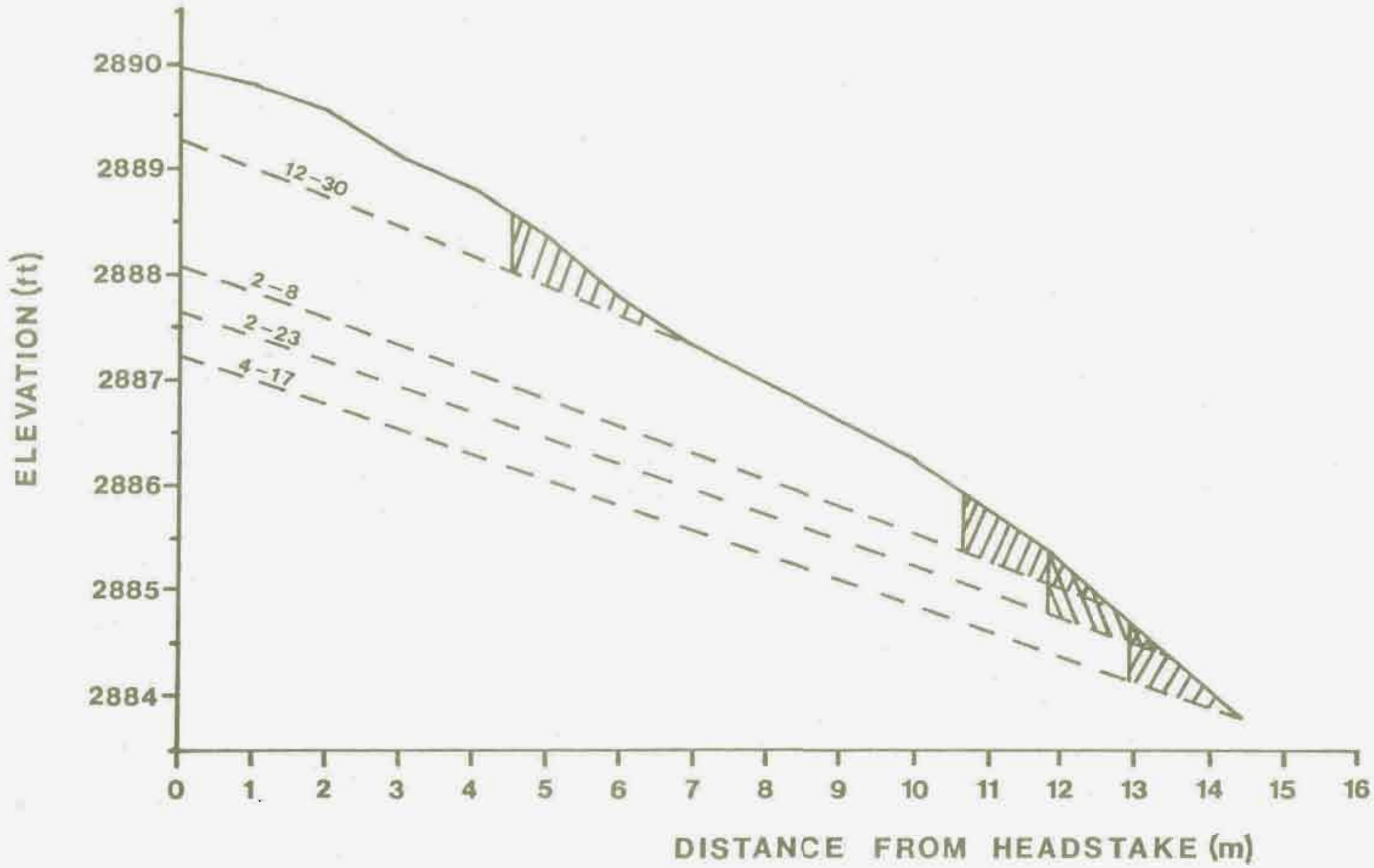

Figure 25: Water table profile, Orange House

maximum redd depth.

Figure 26 presents the on-shore apparent velocity data for wells OH2 and OH3. Velocities generally declined during incubation, and increased only in late February-early March when lake stage rose slightly then declined. Apparent velocities also declined in the early part of emergence and then increased sharply as lake stage increased in late April. Mean apparent velocities during incubation and emergence were 2.3 and 1.6 cm/hr, respectively.

Groundwater flowing through the redds during incubation has a mean TDS of 247 mg/l, a mean Cl content of 1.06 mg/l and a mean DO of 8.1 mg/l. Note that only two samples are available for evaluation of general chemistry. Only one sample of groundwater was taken during the emergence period. The water quality is generally the same as during incubation with a TDS of 245 mg/l and a Cl concentration of .79 mg/l. The DO is lower at 5.3 mg/l. Available chemistry data does not clearly indicate the presence of contamination, however only three samples were taken.

Yellow Bay

Seepage meters were installed at the site in April, 1982 and operated through April, 1984. Apparent velocity data calculated from the meters are presented in Figure 27. During the 1982 and 1983 spawning, the apparent velocities generally increase with lake stage decline in late October. The mean velocity for the two years is 0.22 cm/hr. Comparison of the seepage velocities in 1982 and 1983 shows values are similar. Apparently the more rapid decline in lake stage in 1983 did not result in groundwater flow rates which exceeded 1982 rates.

Groundwater entering redds during spawning has a mean TDS of 173 mg/l, a mean Cl concentration of 0.32 mg/l and an average DO of 9.0 mg/l. Based on the available chemical analyses there is no indication of groundwater pollution during spawning.

As the lake stage declined, five sandpoint wells were installed and operated in conjunction with the seepage meters. Water table decline generally follows lake stage drop from mid December to early February. The water table then stablizes with little response to lake stage change until late April when it parallels lake stage rise. Water table profiles for wells YB2A and YB3 are presented in Figures 28 and 29. During incubation, areas of two to four meters in width adjacent to the lake remained wetted within redd depth. At site YB3 during early February and March, a zone of up to seven meters remained wetted within redd depth. However at times late in each of those months areas of less than one meter in width were wetted within redd depth. During emergence in early April a strip less that one meter wide was wetted within 15 cm of the surface. Yellow Bay Creek, which enters the study area, caused up to 2.5 meters of downcutting of the beach materials in its channel this year. However the water table fluctuation records do not appear to reflect the stream action.

Figure 30 presents on-shore apparent velocity data during incubation and emergence. Velocities at well YB2A generally remained stable during both

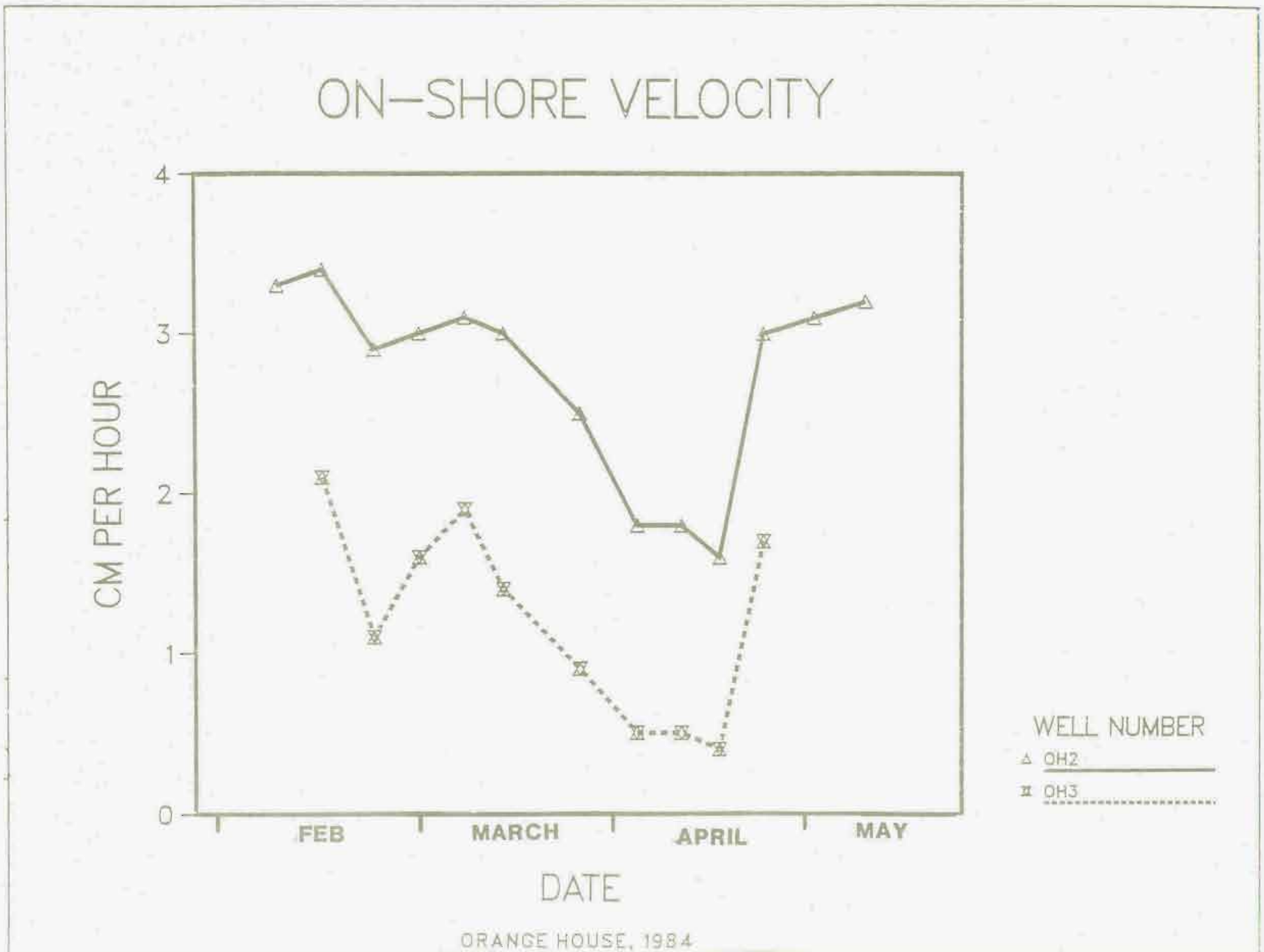

Figure 26: On-shore Velocity vs Date, Orange House

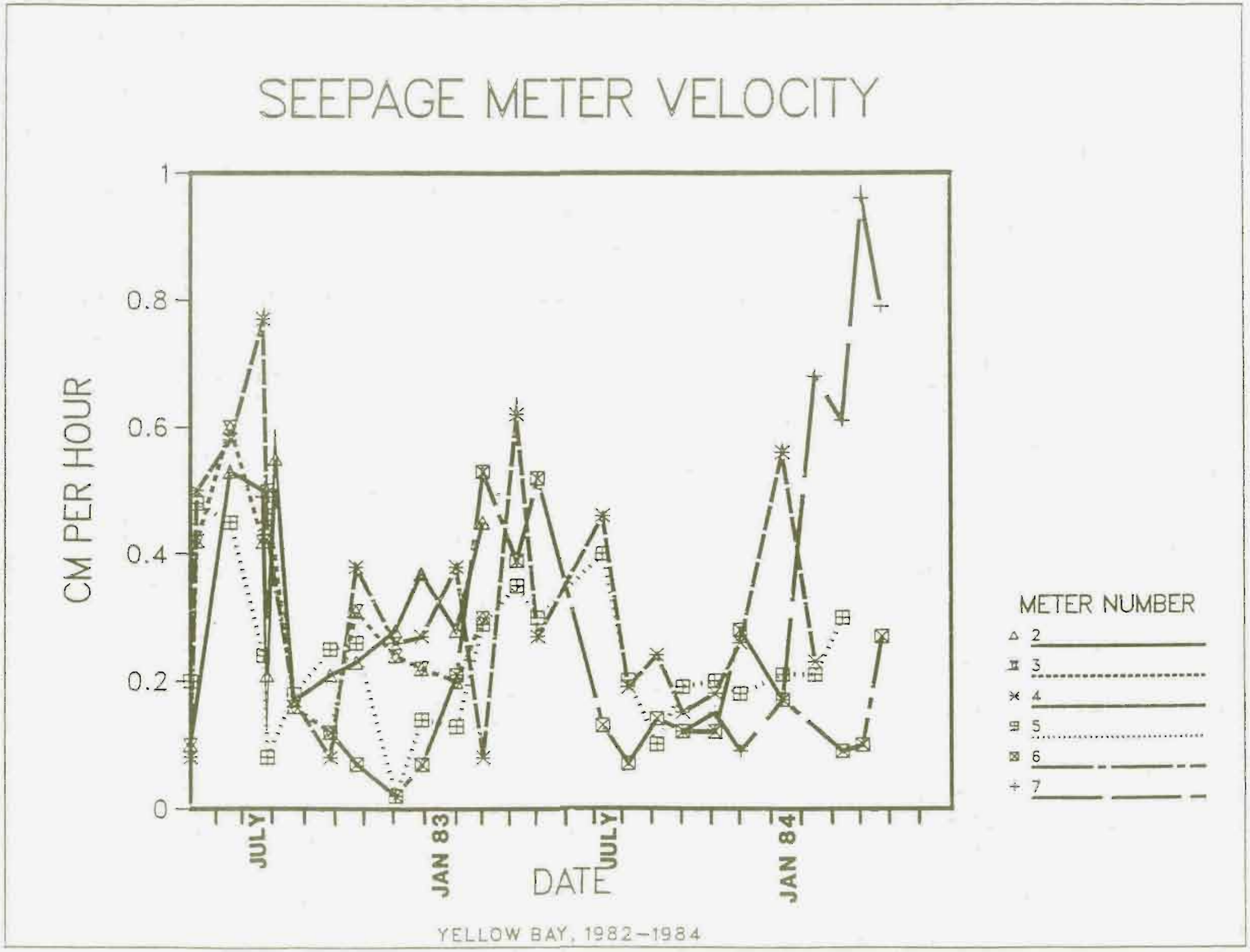

Figure 27: Seepage Meter Velocity vs. Date, Yellow Bay

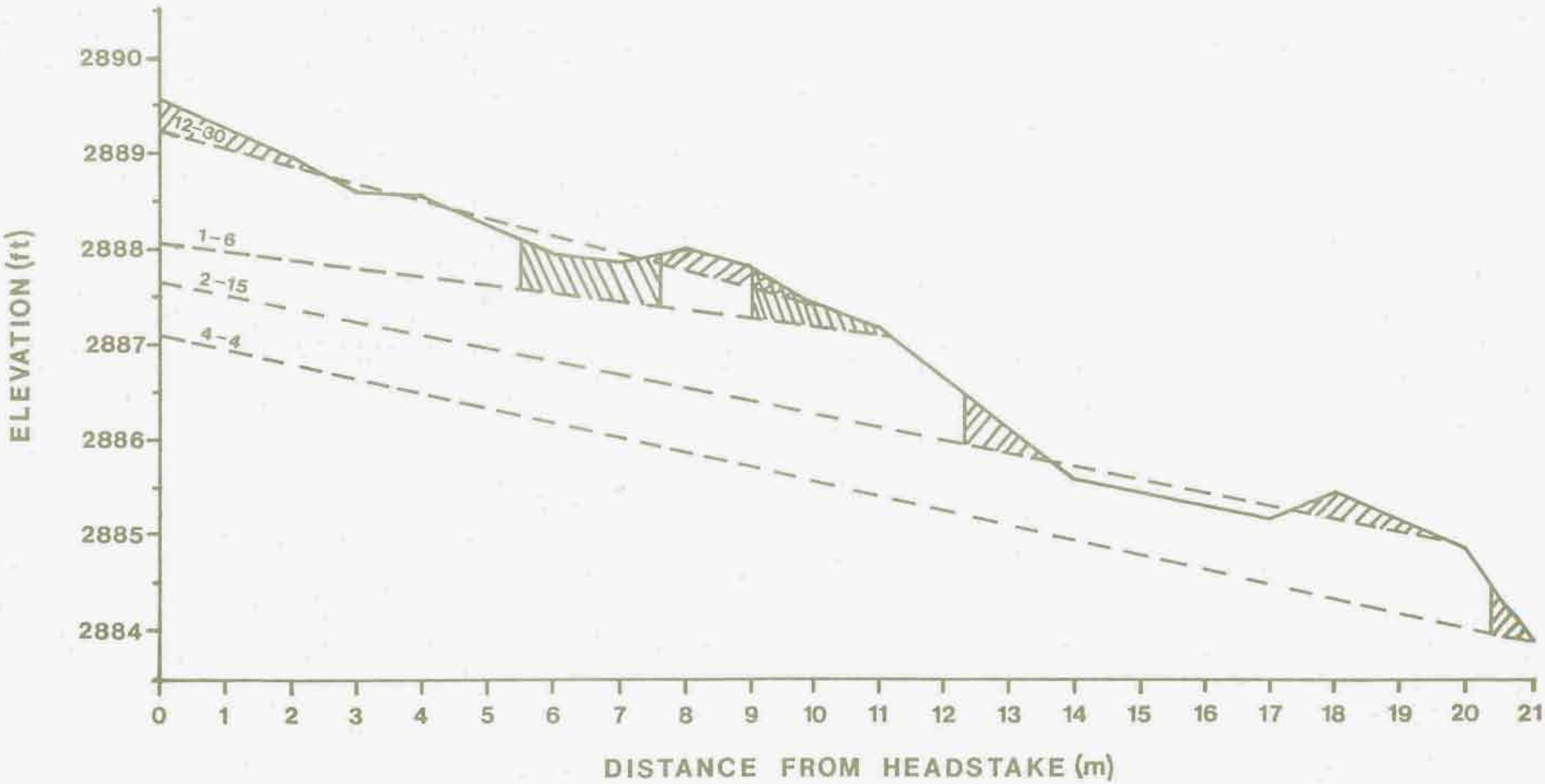

Figure 28: Water table profile, Yellow Bay well 2A

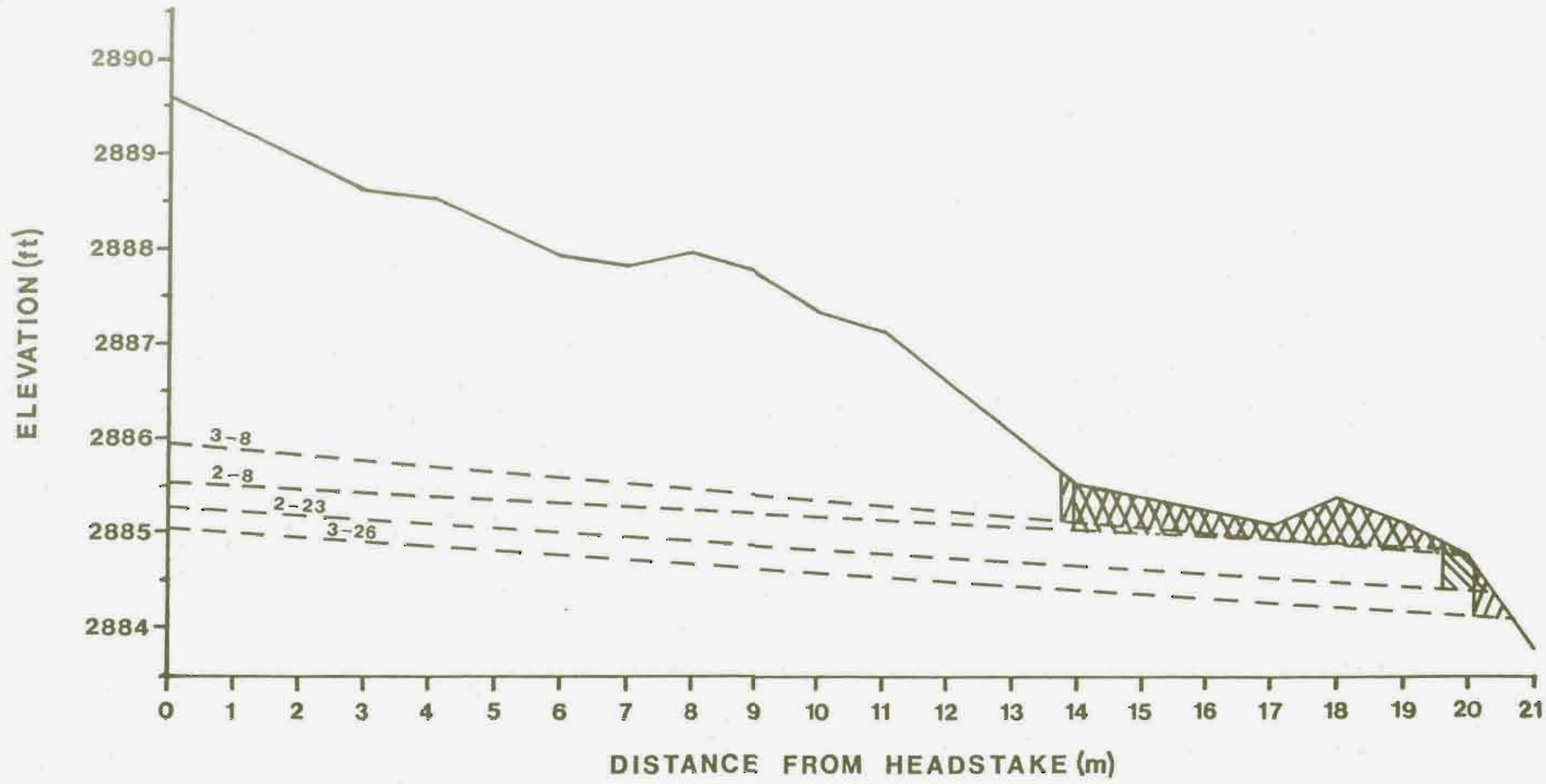

Figure 29: Water table profile, Yellow Bay well 3

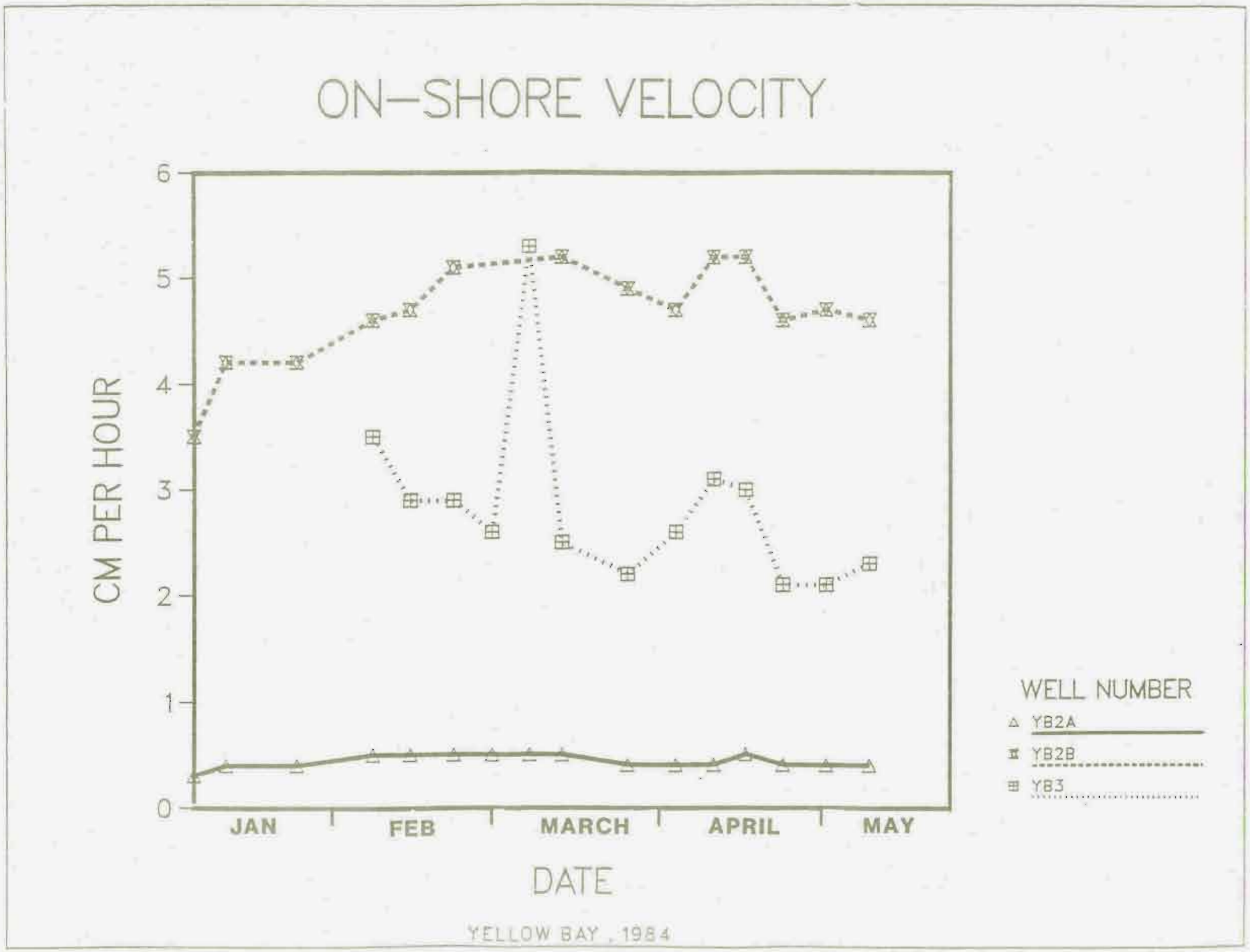

Figure 30: On-shore Veolcity vs. Date, Yellow Bay

periods. At well YB2B the apparent velocity generally increases during incubation. Rates during emergence declined initially and then leveled off. The apparent velocity recorded at well site YB3 which is located closest to the lake generally increased and decreased with lake stage. The apparent velocities decreased during incubation with only a sharp rise and fall in late February and early March. During incubation the velocity increased in early April and then declined until it began to increase in early May in response to lake stage rise. during emergence. Mean values of on-shore apparent velocity during incubation and emergence are 3.9 and 3.7 cm/hr, respectively. Apparent velocity data during incubation and emergence for the deep submerged spawning site is presented in Figure 27. There appears to be a general increase in velocity during incubation and emergence. The trend continues until lake stage stablization in June and then apparent velocities decline until lake stage begins to fall in late October. Mean seepage meter apparent velocities during incubation and emergence are 0.31 cm/hr and 0.29 mg/l, respectively.

Portable seepage meters were installed parallel to shore in August, October and January of this field season and during July, August, October and April of last field season. Results of the 1983-1984 season are presented in Figure 31. Again, as in the study last year, apparent velocity in the spawning area during spawning was not as high as in the area to the west. During incubation the highest velocity recorded was in the redd area. Apparently, the fish are not necessarily keying in to the maximun velocity.

Figure 31 presents the variation in apparent velocity parallel to shore in October, 1982 and 1983. With the exception of Meter 1E, rates mirror each other with the 1982 velocities being the smaller of the two. Higher rates during a more rapid decline in the 1983 lake stage were not realized. Apparently, the groundwater system was responding to slightly less recharge to the system up gradient from the lake.

Groundwater flowing through redds located in the deep spawning area during incubation has a mean TDS of 166 mg/l, a Cl concentration of 0.65 mg/l and a mean DO of 8.9 mg/l. Groundwater flowing through wetted redds in the on-shore area has a mean TDS of 203 mg/l, a mean Cl concentration of 0.86 mg/l and a mean DO of 8.3 mg/l. Only DO data are available to characterize the deep site groundwater quality during emergence. The groundwater has a mean DO of 7.8 mg/l. The emergence groundwater quality for the exposed on-shore site is characterized by a mean TDS of 194 mg/l and a Cl concentration of 0.60 mg/l. DO data are not available. Water quality data did not indicate the presence of groundwater pollution at the on-shore or deep area.

Dr. Richards North (Hochmarks)

Seepage meters were not installed during spawning and apparent velocity and general water quality data were not collected. Groundwater quality is characterized by a mean DO of 10.1 mg/l. As lake stage declined five sandpoint wells were installed. Water level records for the wells show that the water table in the spawning area basically remained unchanged from the observations in mid December through late April. Figures 33 and 34 present water table profiles for wells BH2A and BH3 during egg incubation. A two to four meter wide zone adjacent to the lake remained wetted to redd depth from

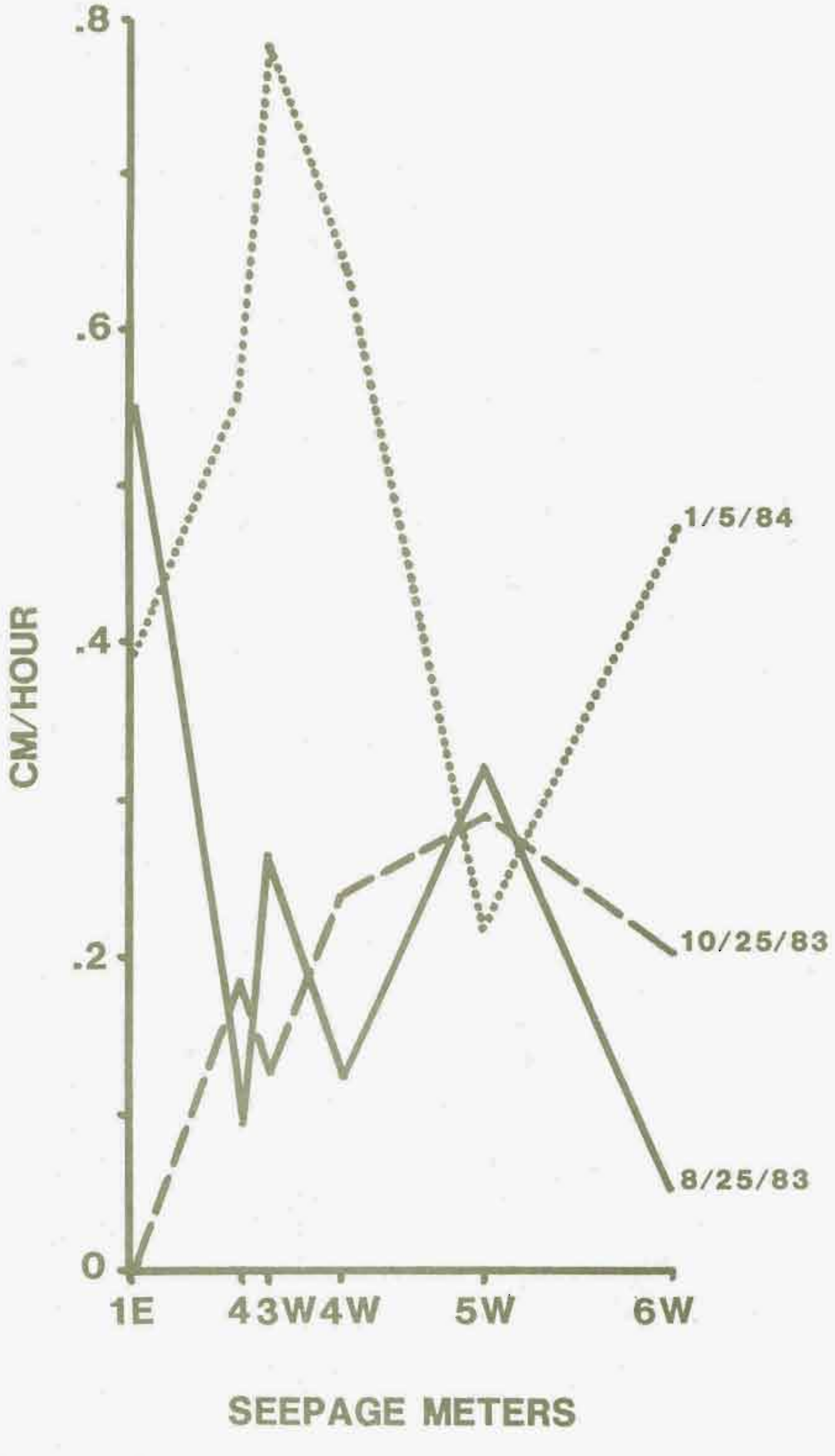

Figure 31: Seepage Variation Parallel to Shore
Yellow Bay

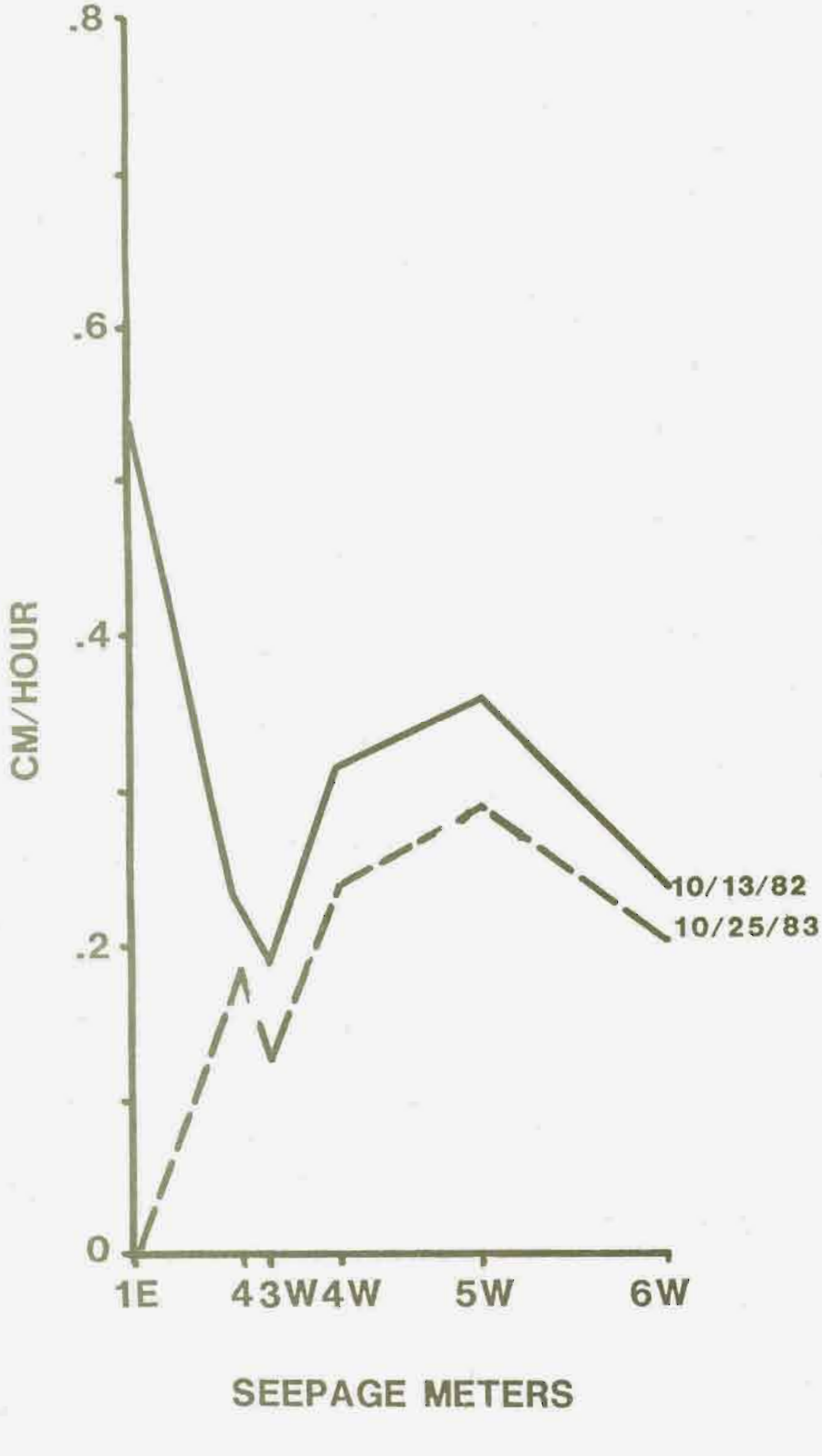

Figure 32: Seepage variation parallel to shore, Yellow Bay, 1982 and 1983 spawning period

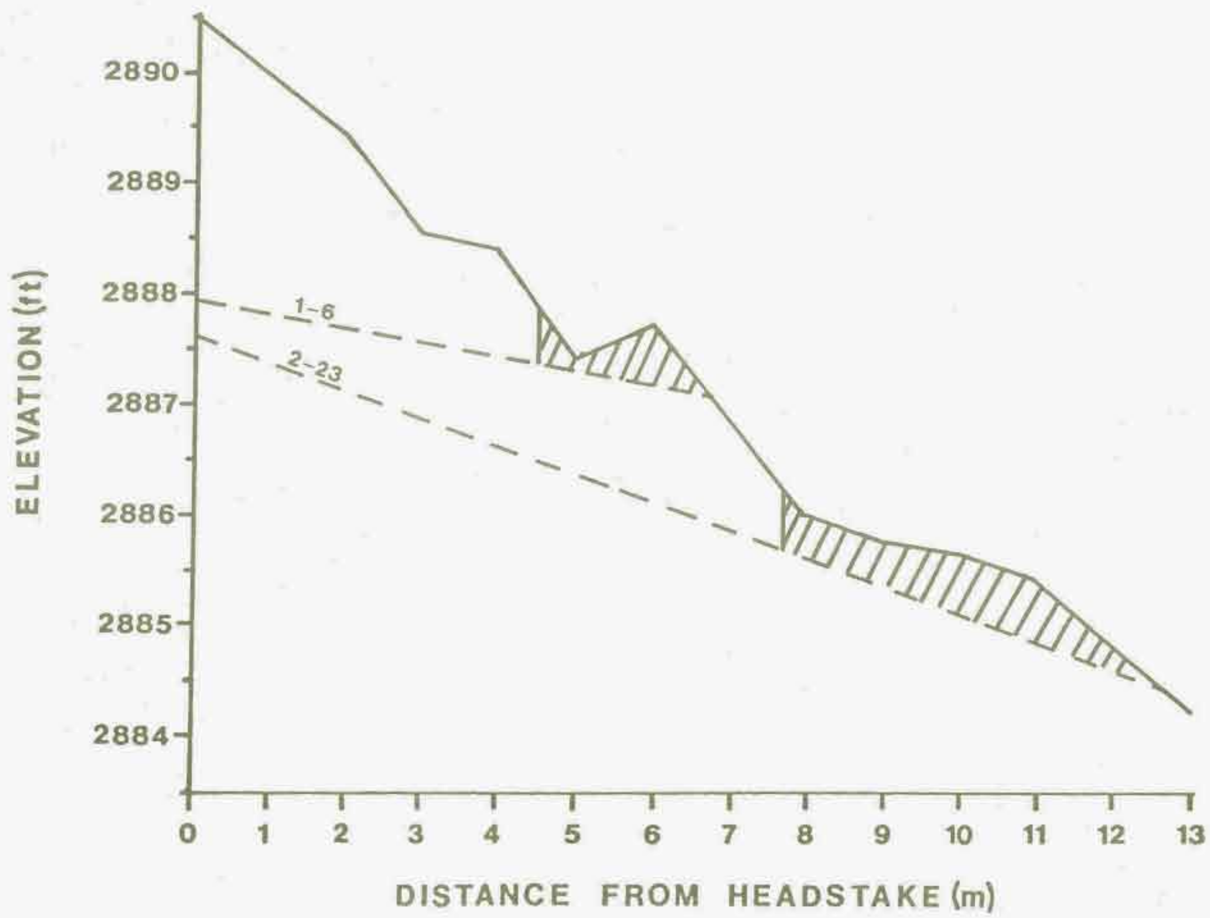

Figure 33: Water table profile, Dr. Richards North well BH2A

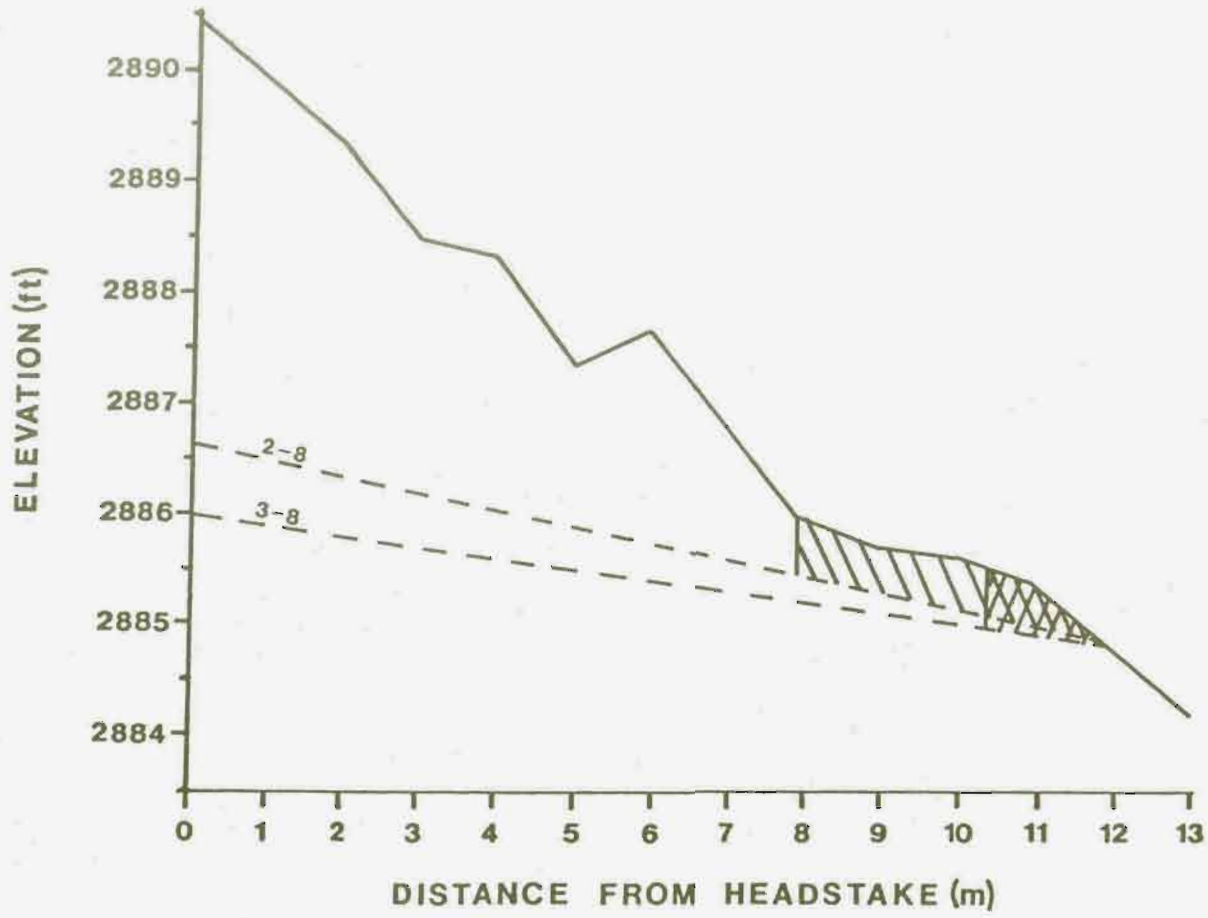

Figure 34: Water table profile, Dr. Richards North well BH3

January through early February. In late February a five and one half meter wide zone was wetted and by early March a two meter zone remained bathed by groundwater. In 1983 a six meter wide zone was wetted to redd depth during incubation and emergence.

On-shore apparent velocity data are presented in Figure 35. Velocities generally increased during incubation and remained stable during emergence. At well BH4, located closest to the lake, the apparent velocity showed the greatest influence of lake stage change. Mean apparent velocity during incubation was 3.8 cm/hr. The mean apparent velocity in redds wetted by groundwater during emergence was also 3.8 cm/hr.

On shore seepage velocity for a sand point installed in February, 1983 is presented in Figure 36. The velocity is similar in magnitude to 1984 data. Generally the velocity increased during incubation in response to lake stage decline and decreased with lake filling. Both 1983 and 1984 data show similar trends.

Groundwater flowing through redds during incubation and emergence has a mean TDS of 138 mg/l. The mean Cl concentration during each period is 0.61 and 0.34 mg/l, respectively. The mean DO values are 10.5 mg/l during incubation and 3.5 mg/l during emergence. Water quality sampling of BH2A in March showed generally low nitrate, chloride and TDS, however, the sulfate was 10.7 mg/l and the pH was 10. A May sample for the same well had a pH of 9.7 and a sulfate concentration of 10.7 mg/l. This is interpeted to indicate groundwater pollution during March and May, 1984 at well BH2A. Other wells sampled over the last two years show no evidence of pollution.

Gallaghers

Seepage meters were not operated at this site and apparent velocity and general chemistry data to characterize the spawning period are not available. The mean DO of the groundwater flowing through redd areas is 10.1 mg/l.

As the lake stage declined, three sandpoint wells were installed. Water level records for the wells show that the water table in the spawning area remained baiscally unchanged after the installation, acting independently of falling lake stage until lake stage rise began in late April. Figure 37 presents water table profile data for well GAL1. During January a zone less than one meter in with adjacent to the lake was wetted to the 15 cm redddepth. By mid February, however, a three meter zone remained wetted by groundwater within redd depth. By emergence in April, the wetted zone had expanded to six meters with a seepage face of about one meter.

Figure 38 presents apparent velocity values calculated at each well site. During incubation all three sites responded differently. However, by mid March the velocities were decreasing at all sites. The lowest values of apparent velocity were recorded in the end of March or early April at the beginning of fry emergence. Velocities generally increase in April as the lake stage began to rise. Mean apparent velocities during incubation and emergence are 1.0 cm/hr and 0.8 cm/hr, respectively.

Groundwater flowing through wetted redds during incubation has an average

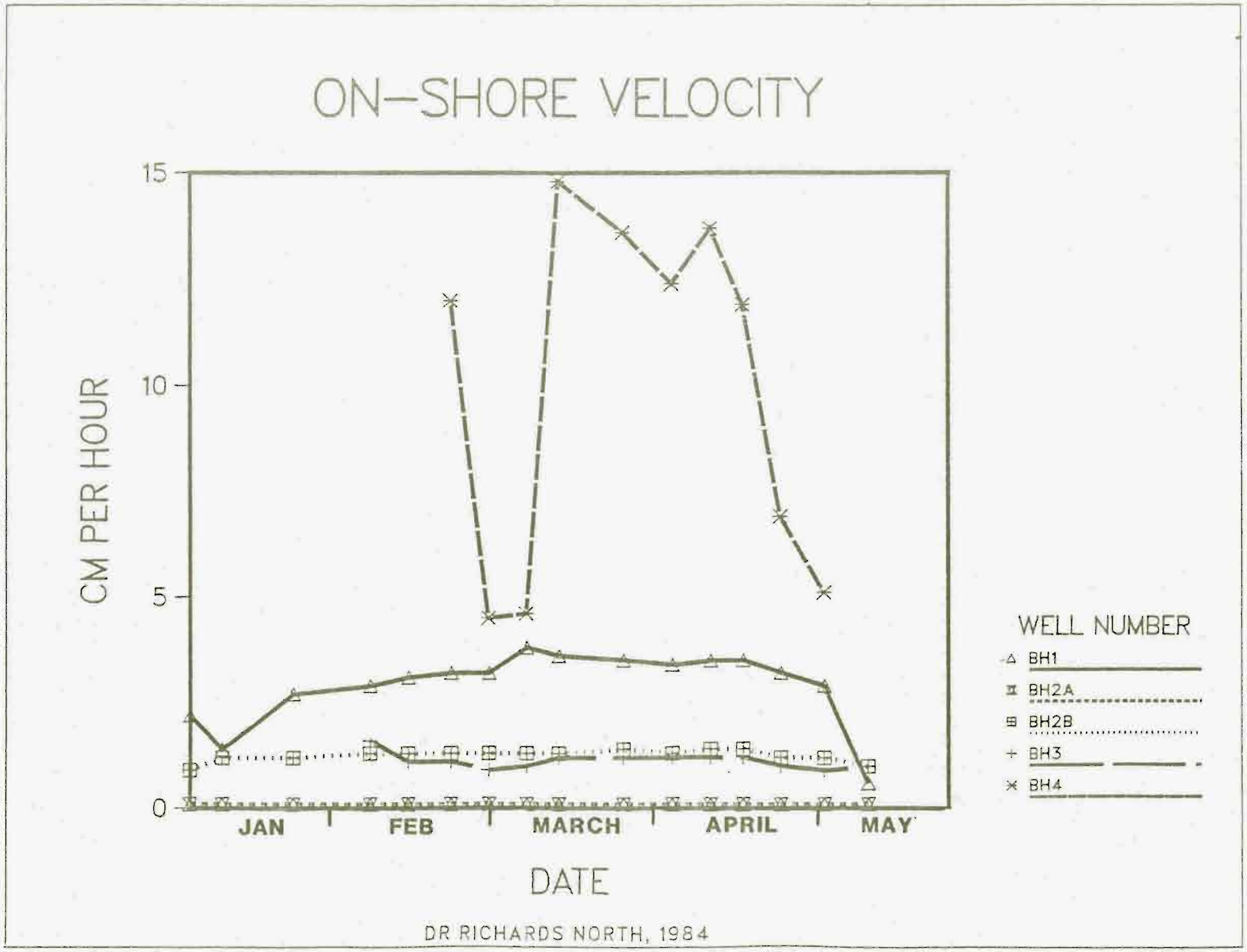

Figure 35: On-shore Velocity vs. Date, Dr. Richards North

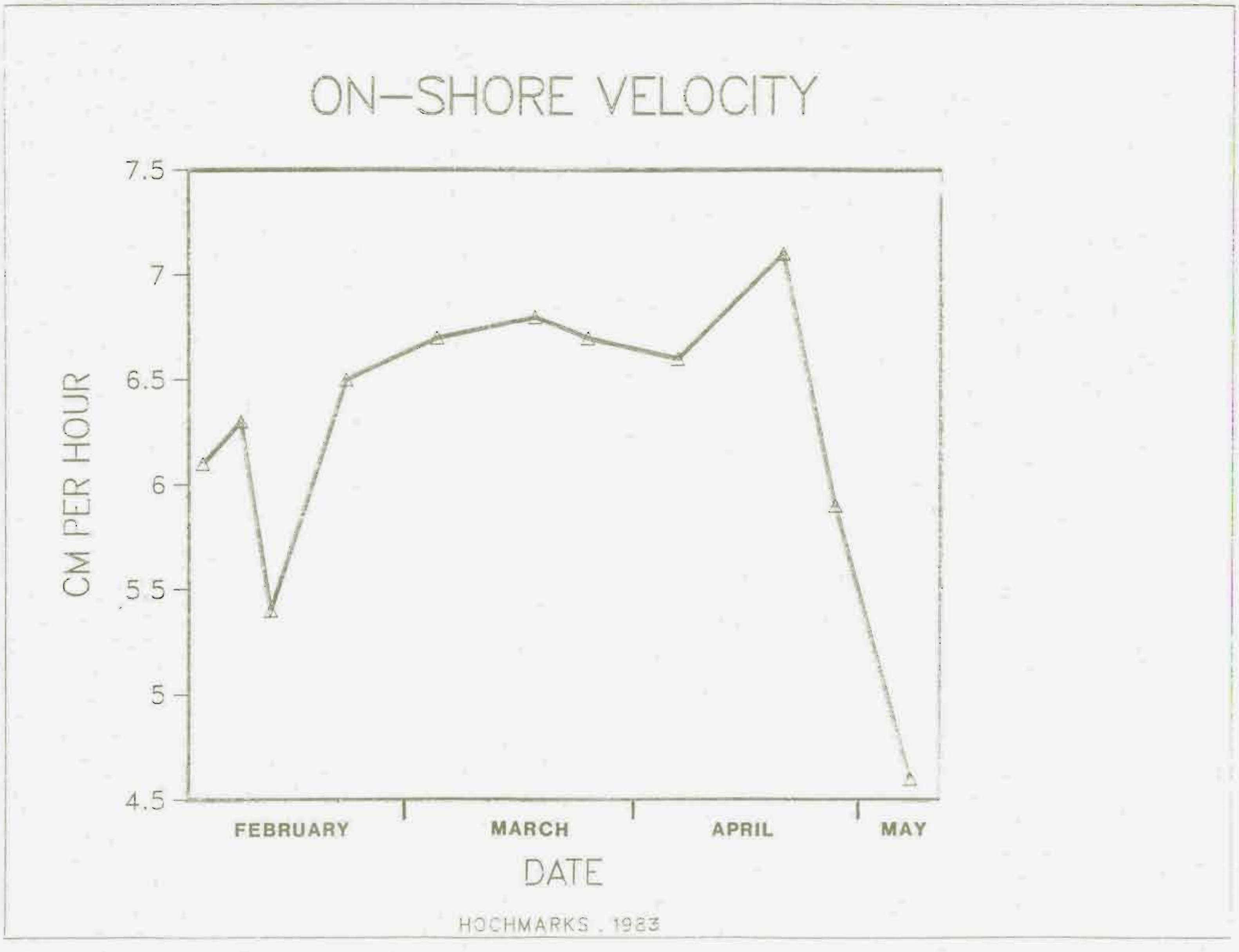

Figure 36: On-shore velocity vs. date, 1983, Dr. Richards Bay North

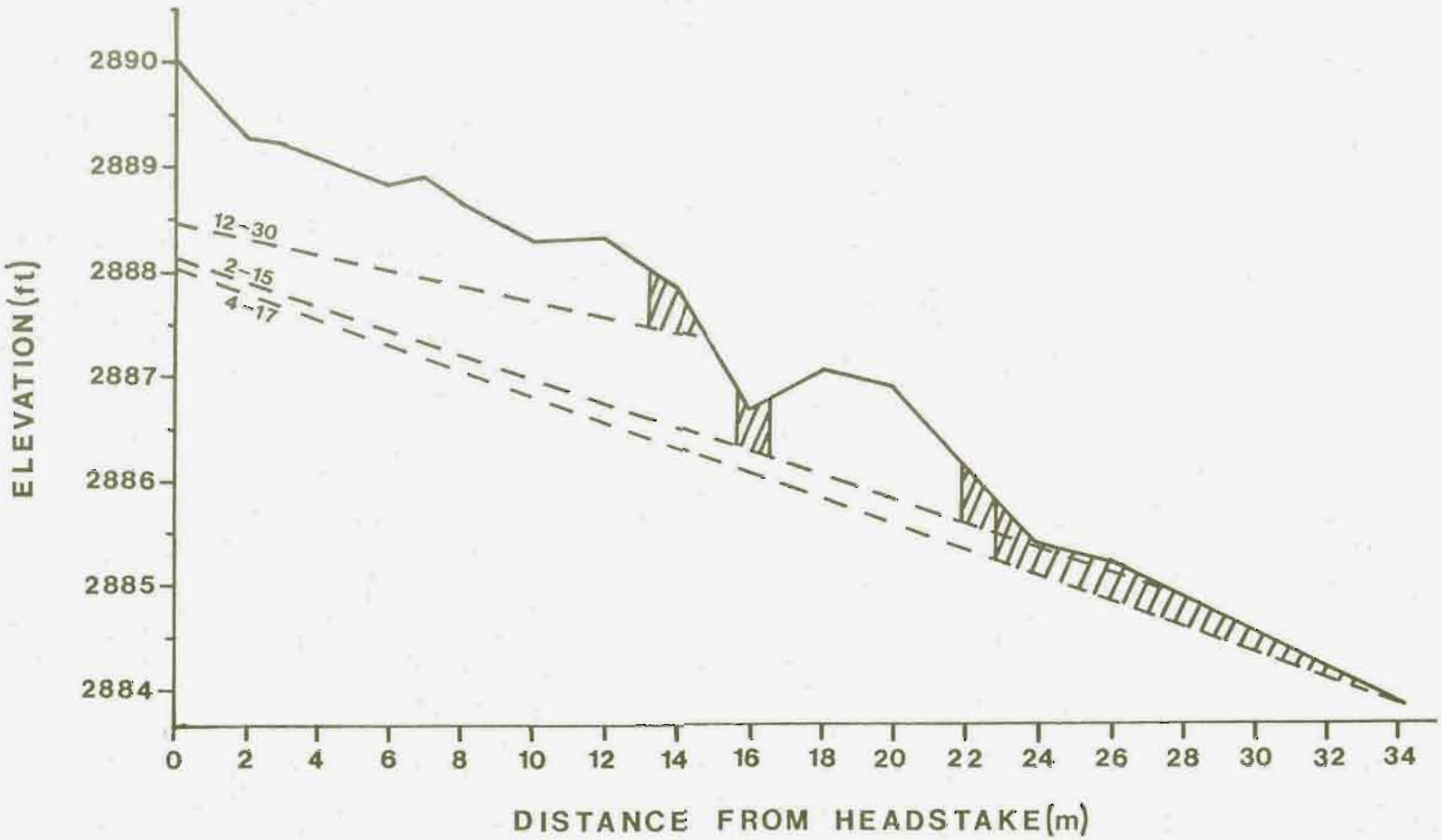

Figure 37: Water table profile, Gallaghers

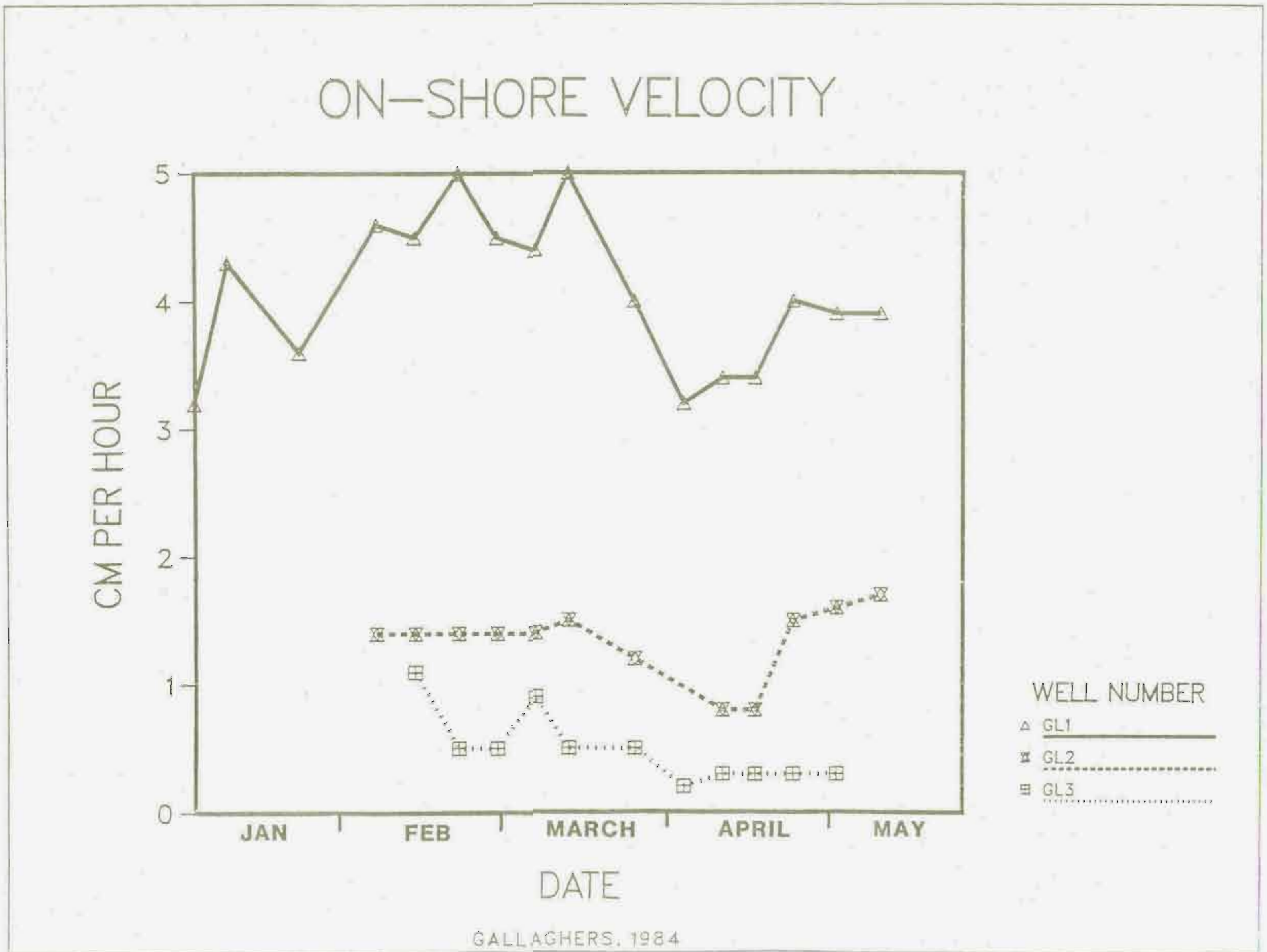

Figure 38: On-shore Velocity vs. Date, Gallaghers

TDS of 290 mg/l, a Cl content of 0.99 mg/l and a meann DO of 4.5 mg/l. Emergence groundwater is similar in quality to incubation groundwater though only one sample is available for analysis. Cl values ranged over 1.0 mg/l though the water does not appear to be polluted.

West Gallaghers

Seepage meters were not operated during spawning and apparent velocity and general water quality data are not available for the spawning period. DO transect data are available and the mean groundwater DO during spawning is 4.8 mg/l. As lake stage declined, three sandpoint wells were installed. Water level records for the wells show that the water table remained constant after installation of the wells in December and February until it rose with the lake stage rise in late April. Figure 39 presents water table profiles for well WGAL1. During incubation, the width of the zone adjacent to the lake that was wetted to redd depth increased from two meters in January to over seven meters by the end of March. By April the zone was up to 12 meters in width.

Figure 40 presents the on-shore apparent velocity data for January through May. The apparent velocity during incubation remained fairly stable through mid February, then declined in late February, rose in response to a brief lake stage rise, then declined in April. During emergence the apparent velocities generally increase while lake stage rose at the end of April. The mean apparent velocity during incubation was 0.64 cm/hr. The mean value during emergence was 0.51 cm/hr.

Groundwater flowing through the redds during incubation has a mean TDS of 275 mg/l, a Cl concentration of 1.01 mg/l and a mean DO of 6.9 mg/l. During emergence the groundwater is characterized by only one sample with a TDS of 270 mg/l, a Cl content of 0.77 mg/l and a DO of 6.9 mg/l. The available chemistry data does not indicate groundwater contamination.

Crescent Bay

Seepage meters were operated at this site intermittently since April, 1982. Apparent velocity data are presented in Figure 41. During the spawning period it appears that the apparent velocity increased as lake stage fell. The mean apparent velocity during spawning is 0.22 cm/hr. The groundwater flowing through the spawning area during this period has a mean TDS of 214 mg/l, a Cl concentration of 0.50 mg/l and a mean DO of 8.9 mg/l.

Apparent velocities during spawning were higher in 1983 than 1982. This may reflect the more rapid decline in lake stage in 1983.

As the lake stage declined, four sandpoint wells were installed. Water level records for the wells show that the water table remained unchanged as the lake stage fell. Figure 42 presents water table profiles for well CRES2. During incubation and emergence a zone of about one meter in width remained wetted to redd depth. In 1983 a strip of shore area adjacent to the lake about 0.8 meters wide remained wetted to a depth of 15 cm by the water table until late February when an area of up to 7.8 meters remained wetted through incubation.

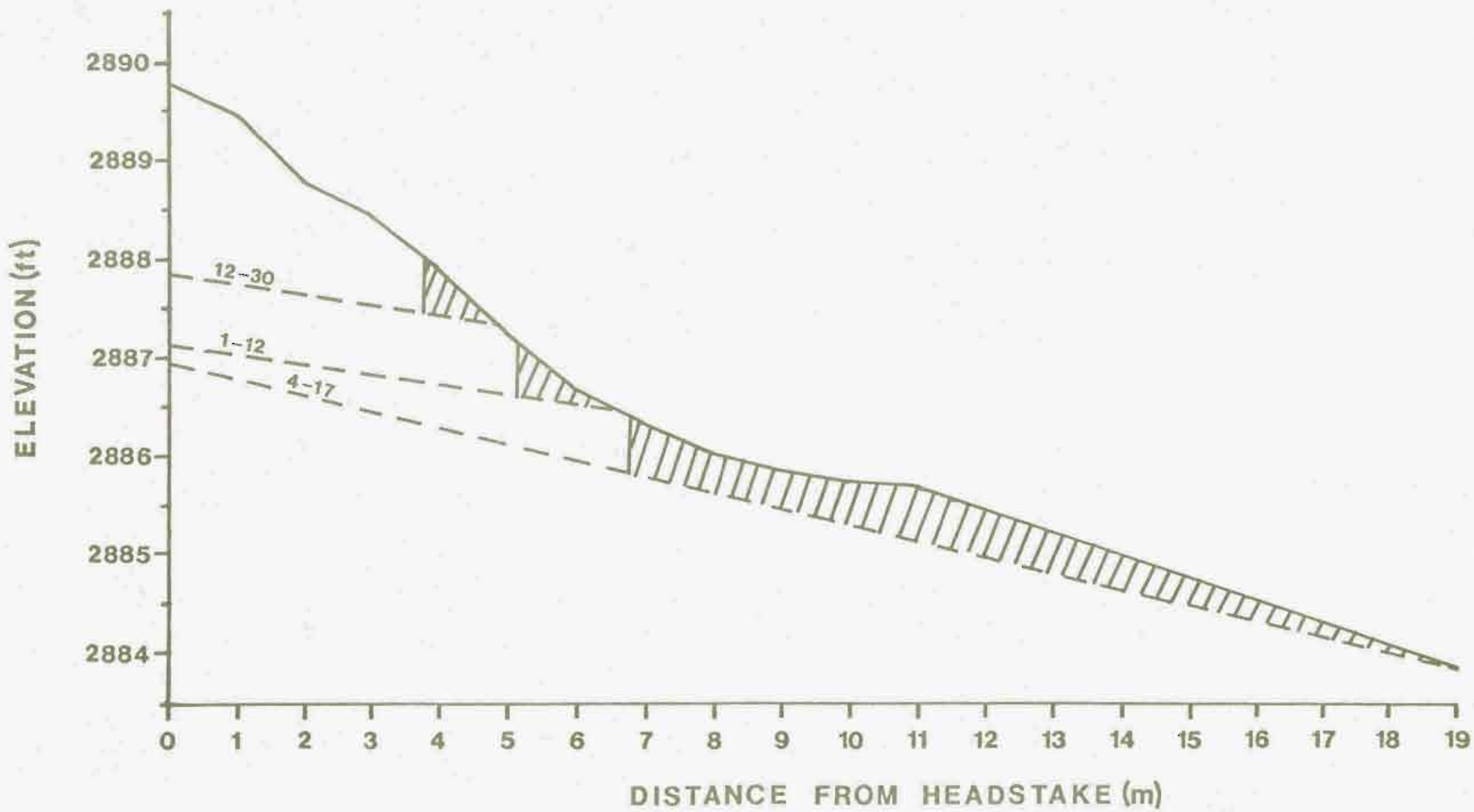

Figure 39: Water table profile, West Gallaghers

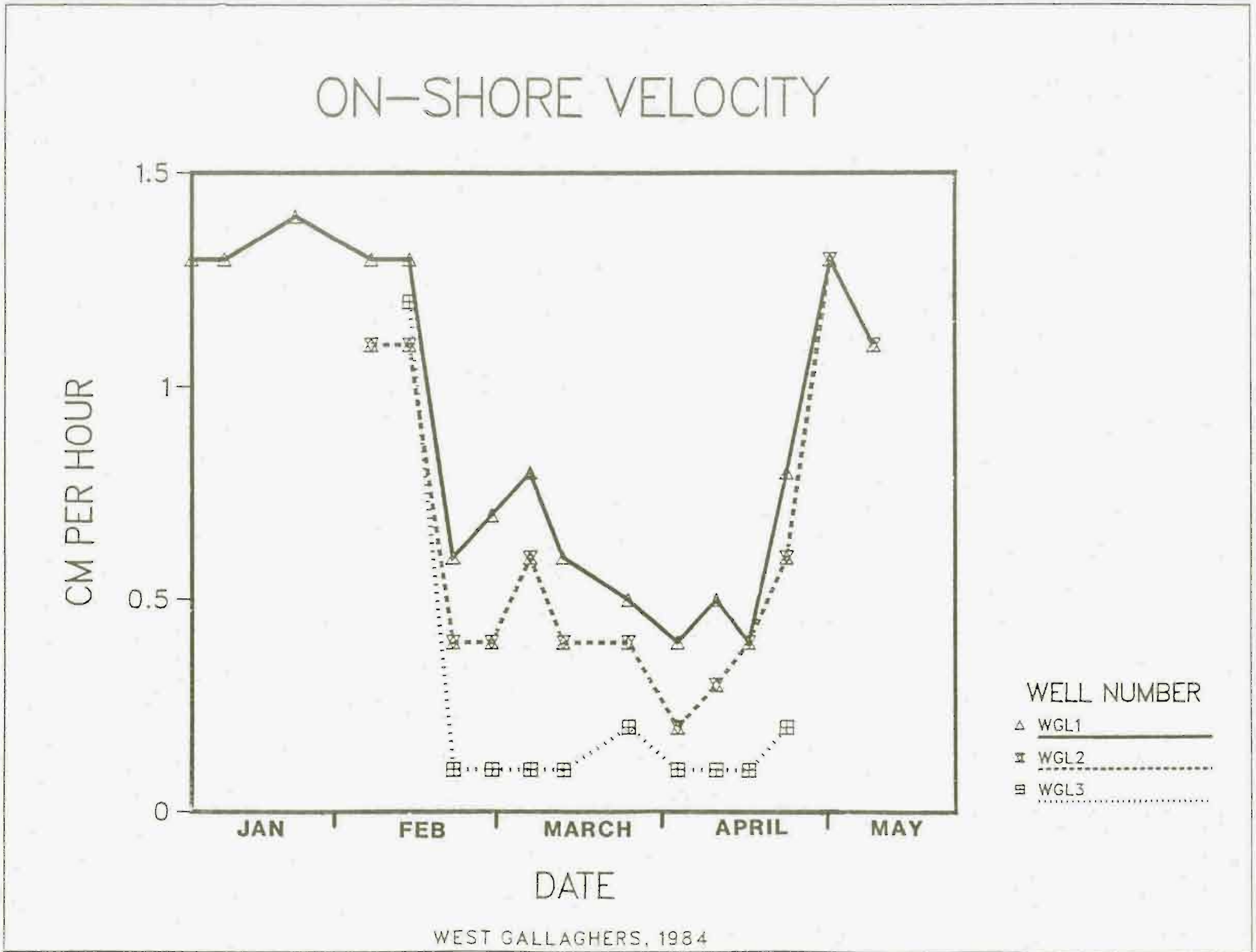

Figure 40: On-shore Velocity vs. Date, West Gallaghers

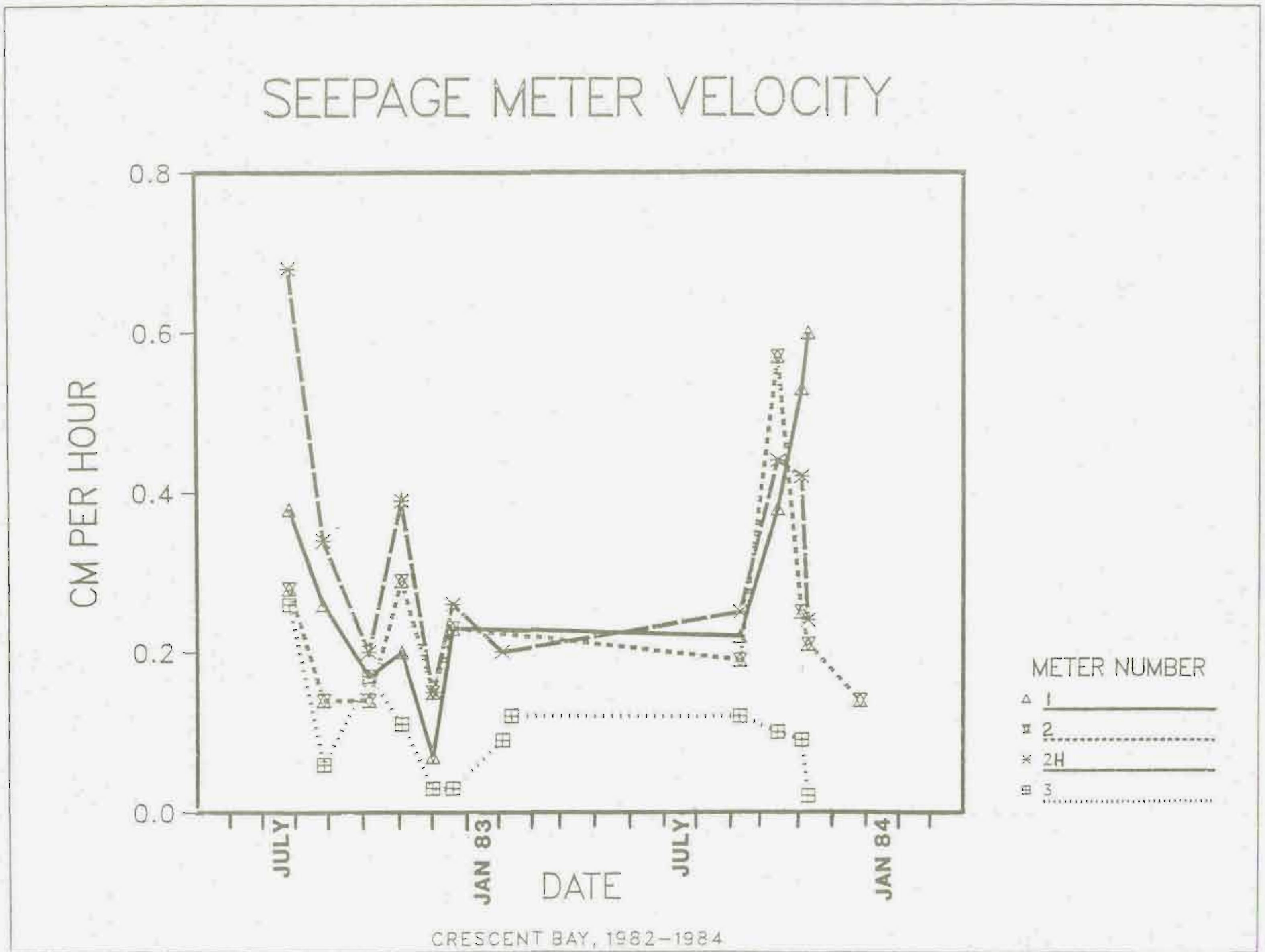

Figure 41: Seepage Meter Velocity vs. Date, Crescent Bay

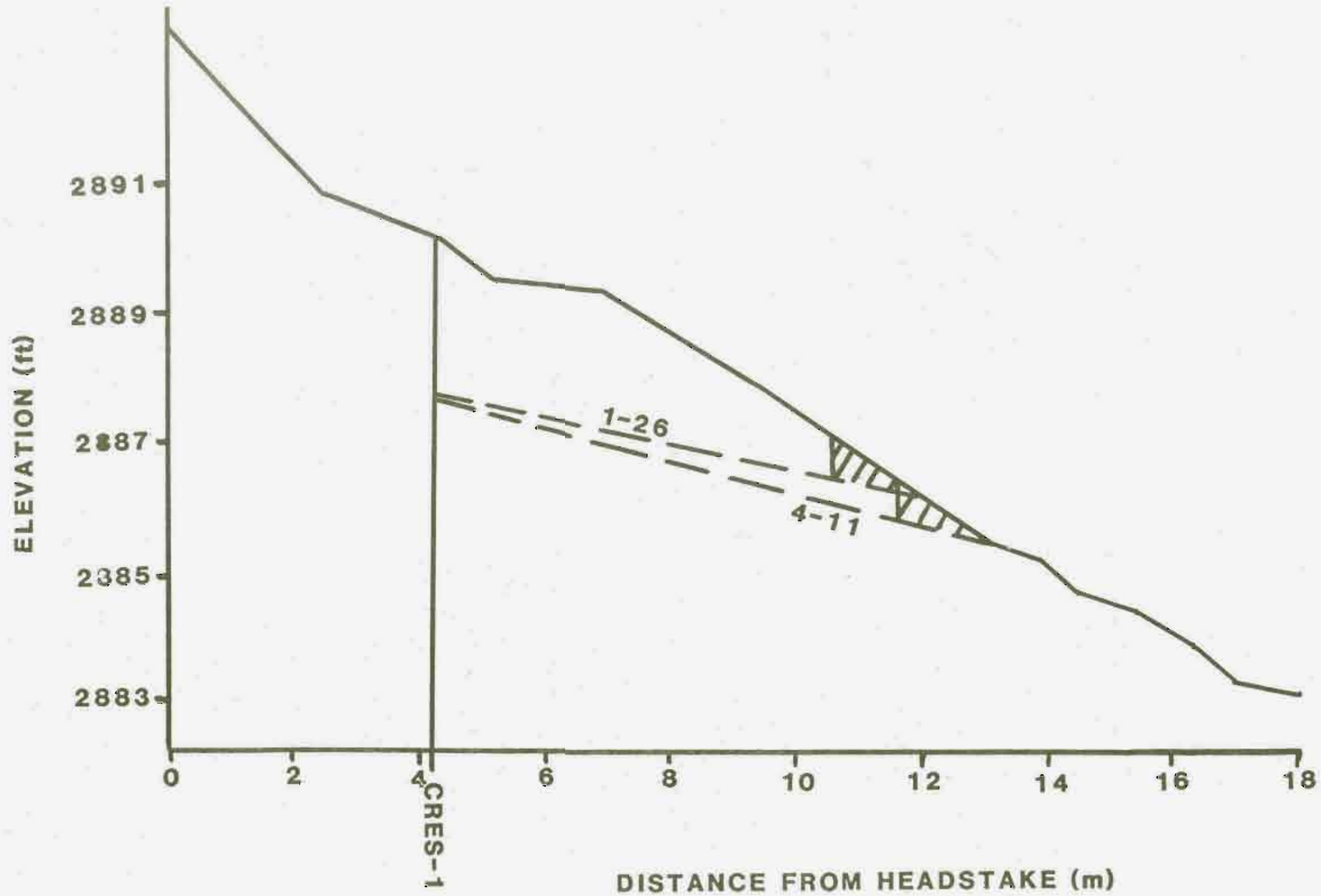

Figure 42: Water table profile, Crescent Bay

Figure 43 presents calculations of on-shore velocities at well sites.Velocities during incubation remained fairly stable until late February when they increased as the lake stage rose then either remained higher than before, as at HR1B, or declined. During emergence in early April, rates generally declined and increased as the lake stage rose in late April. The mean apparent velocity during incubation was 2.6 cm/hr and 2.9 cm/hr during emergence.

Figure 44 presents on shore velocities at one sandpoint location in 1983. The two orders of magnitude difference in velocity is a function of a large hydraulic conductivity value which is suspect. However, the velocity trend will remain the same. The on shore velocity increased during incubation in February then declined with lake stage and leveled off in March. Velocities then declined during emergence as lake stage rose. Trends in 1983 and 1984 generally appear to mirror lake stage during incubation and the reverse and stage rises during emergence.

Portable seepage meters were placed parallel to shore both this season and last season. The distribution of apparent velocities is shown for this season in Figure 45. These data are representive of the spawning period and are similar to the last seasons results. It appears that spawning did not occur in the area of maximun apparent velocity. The higher velocities are to the north of the spawning site. Figure 46 presents a comparison of 1982 and 1983 seepage velocities parallel to shore. 1983 values were generally greater. This may reflect the more rapid decline in stage during spawning in 1983.

Groundwater flowing through the spawning sites during incubation has a mean TDS of 324 mg/l, a mean Cl of 1.53 mg/l and a mean DO of 6.6 mg/l. The quality during emergence is characterized by a mean TDS of 348 mg/l, an average Cl concentration of 1.8 mg/l and a mean DO of 5.8 mg/l. The groundwater quality typically contains levels of Cl in the one to two milligrams per liter range at the site. The water quality of the two creeks entering the beach area is of similar quality. It does not appear that the groundwater is contaminated.

Deep Bay

This site was instrumented with seepage meters from late August through November, 1983. Spawning was not observed at this site. Figure 47 presents the apparent velocity values calculated from seepage meter data. The velocity in the mini meter increased as lake stage began to decline in late October. Little change was noted in the deep meter. The mean apparent velocity during the spawning period is 0.11 cm/hr. The groundwater quality at the time of spawning is characterized by a mean TDS of 146 mg/l, a mean Cl of 0.23 mg/l and a mean DO of 8.4 mg/l. Only two samples were available for evaluation. No additional data were collected for incubation or emergence.

Table Bay

Seepage meters were operated at this site from late August through

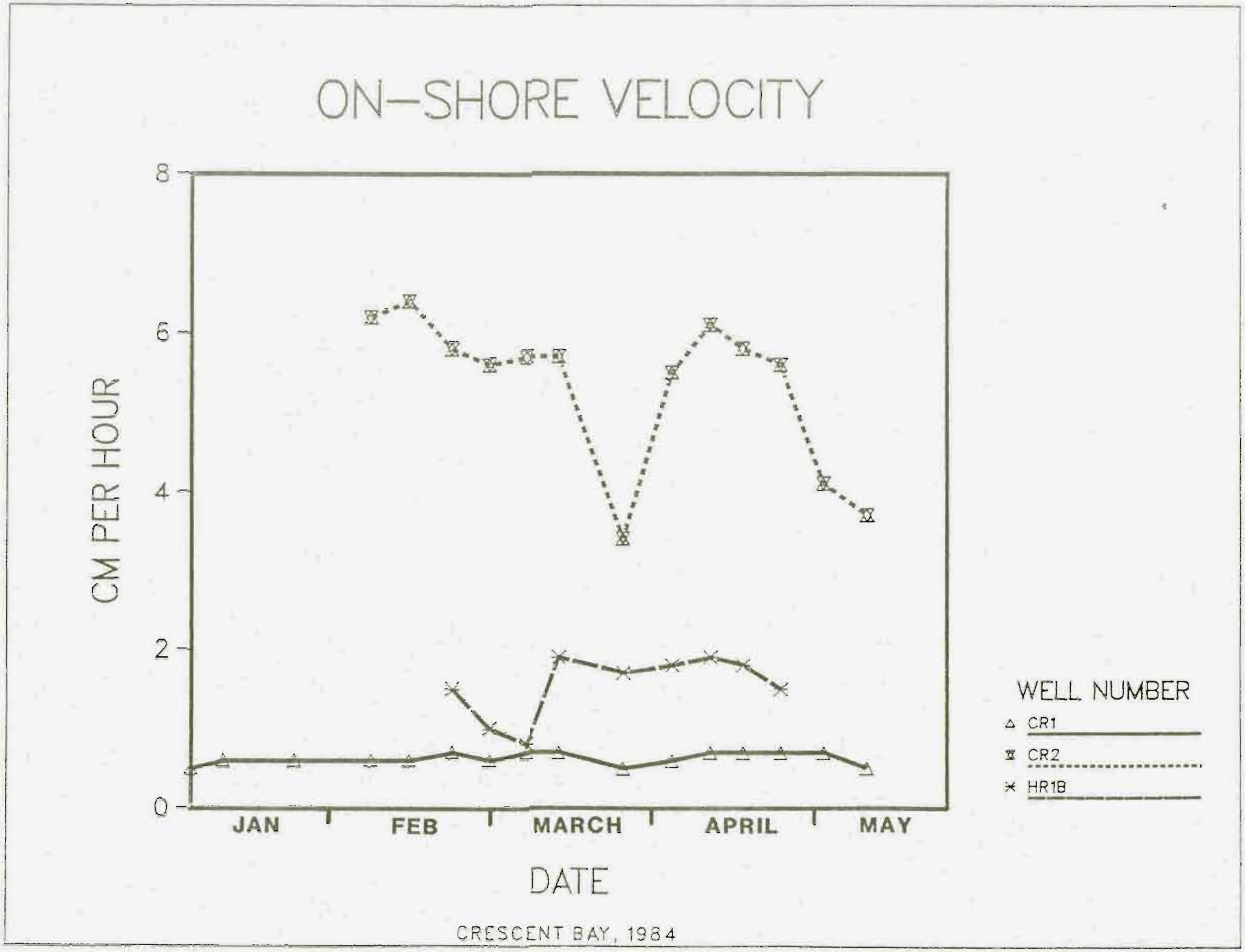

Figure 43: On-shore Velocity vs. Date, Crescent Bay

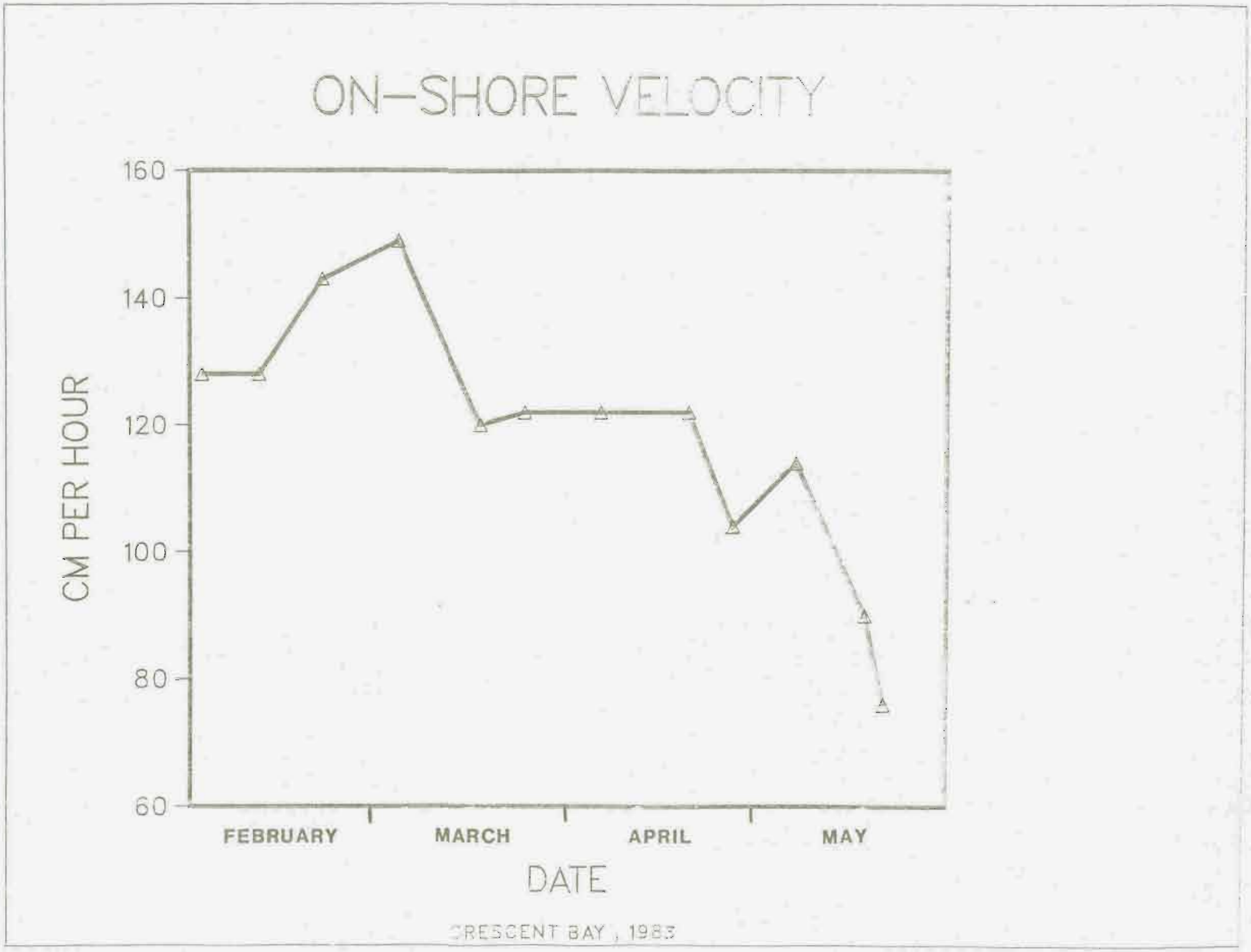

Figure 44: On-shore velocity vs. date, 1983, Crescent Bay

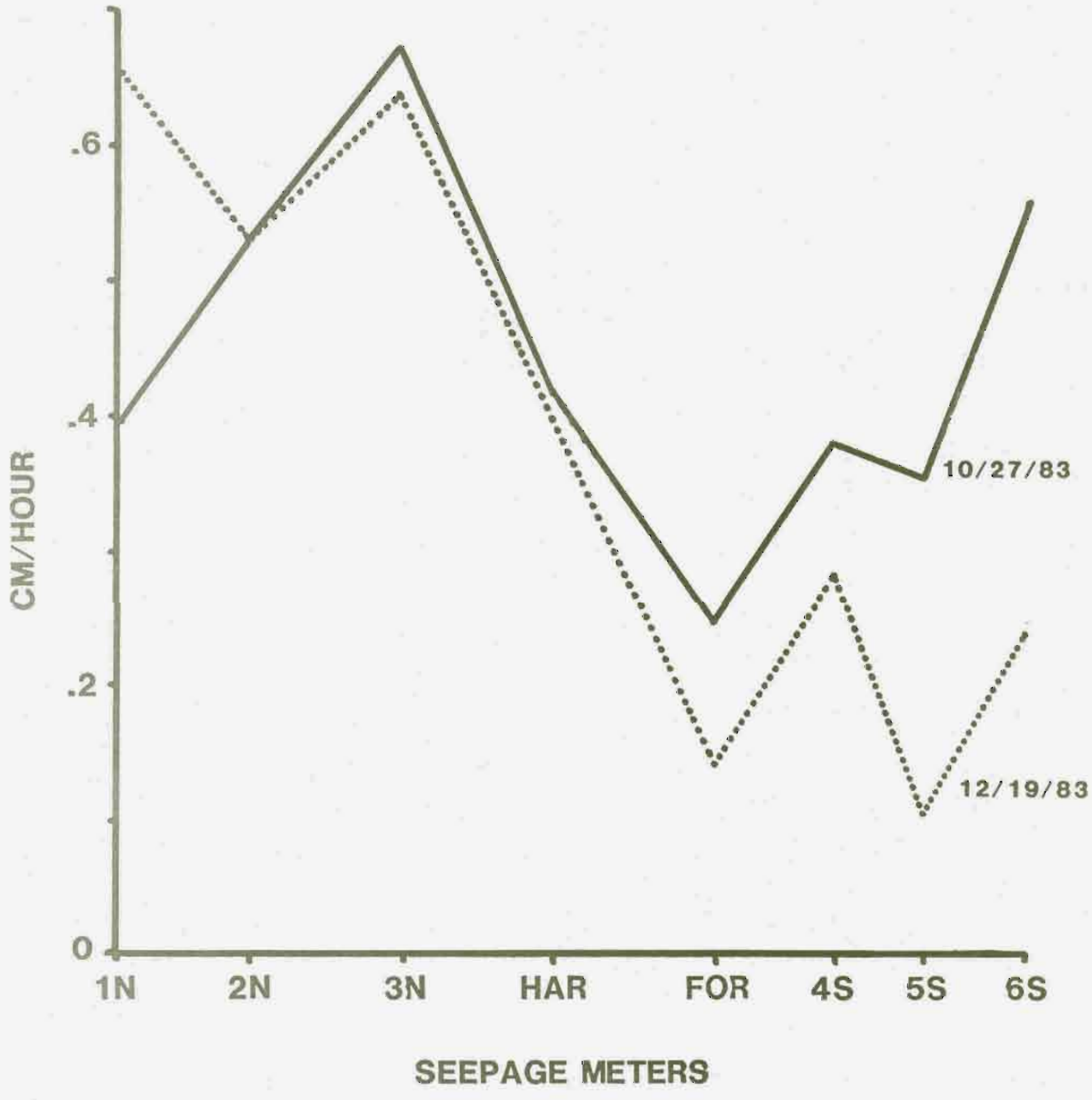

Figure 45: Seepage Variation Parallel to Shore
Crescent Bay

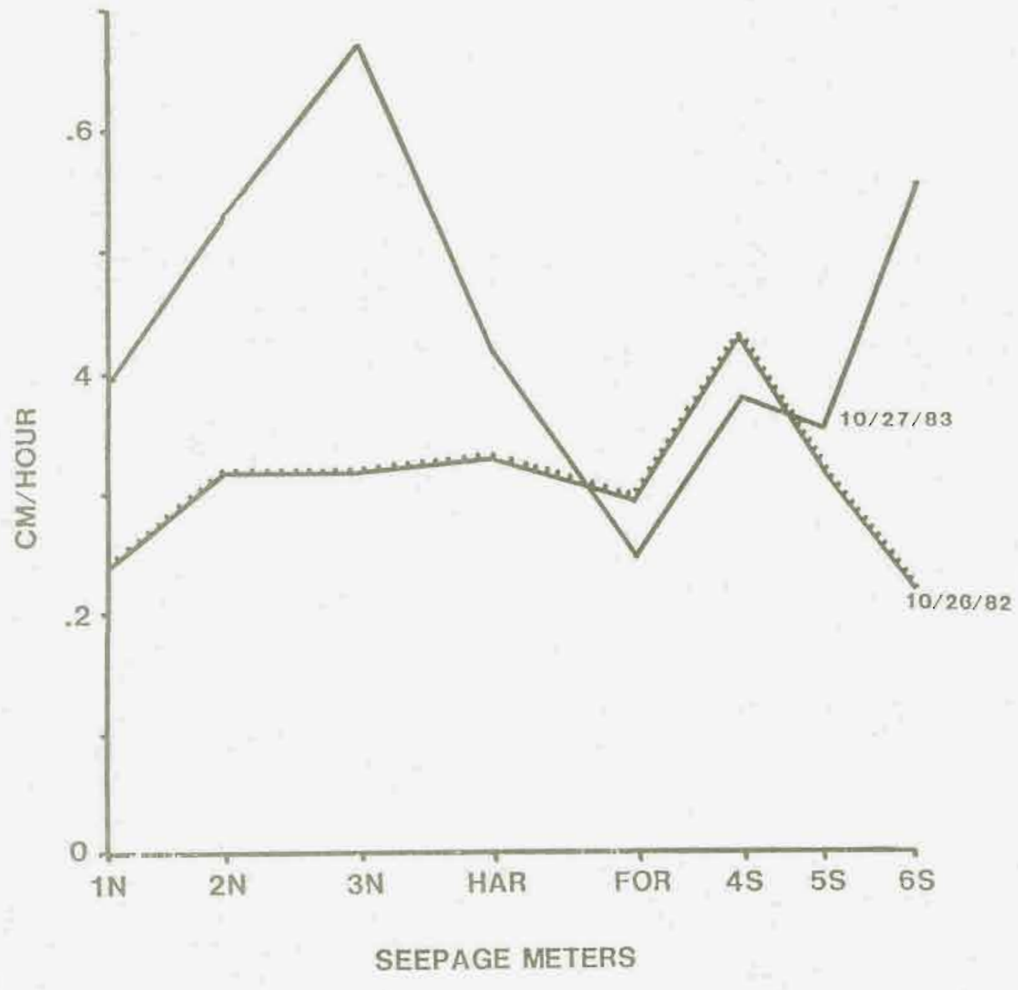

Figure 46: Seepage variation parallel to shore, Crescent Bay, 1982 and 1983 spawning period

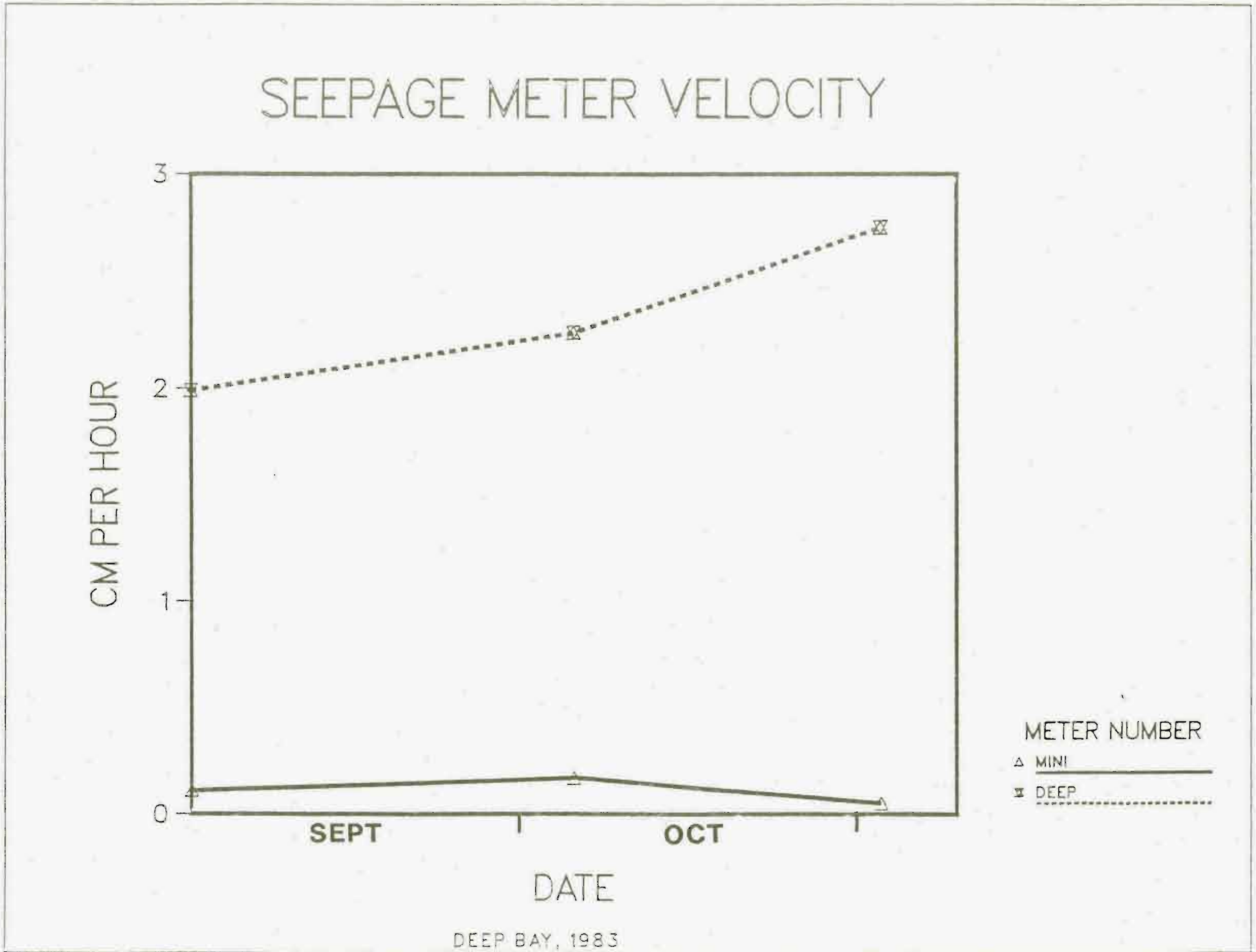

Figure 47: Seepage Meter Velocity vs. Date, Deep Bay

November, 1983. No spawning was recorded at this site. Apparent velocity values calculated from the seepage meter data are presented in Figure 48. During the spawning period from October to November, the apparent velocity declined with lake stage decline. The mean apparent velocity for the spawning period is 0.18 cm/hr. The chemistry of the groundwater discharging in the spawning area is represented by a mean TDS of 137 mg/l, a mean Cl of 0.24 mg/l and an average DO of 10.0 mg/l. The water quality results do not appear to indicate groundwater pollution. No other data are available to describe the incubation and emergence period for this site.

Woods Bay

Seepage meters were installed in Woods Bay during the spring, summer and fall of 1983. Apparent velocity data for the summer and fall are presented in Figure 49. Apparent velocities generally declined through the summer and into October. They increased as the lake stage declined in late October until mid December when the apparent velocities began to decline. The mean velocity during the spawning period is 0.23 cm/hr. Only DO transect data are available to characterize the groundwater quality during spawning. The mean DO is 10.2 mg/l. Seepage meter data collected during emergence has a mean apparent velocity of 0.18 mg/l. Groundwater DO during this period has a mean value of 6.3 mg/l. No data are available to characterize the groundwater conditions during incubation.

DATA DISCUSSION AND TRENDS

The Site Characterization section of this report describes apparent velocities and water chemistry data measured at study sites during the spawning, egg incubation and fry emergence periods. That section also includes lake shore profiles which show the position of the water table during egg incubation and fry emergence. In this section, we discuss the data within a framework provided by FWP. They requested that we evaluate the data to determine: 1) Hydrogeologic similarities among sites, 2) effects of lake stage variation on groundwater dissolved oxygen concentrations and apparent velocities associated with data groupings or specific sites, 3) water chemistry trends during spawning, egg incubation and fry emergence, 4) apparent velocity relationships for exposed spawning sites versus deep spawning sites, 5) relationships between apparent velocity distribution parallel to shore and spawning site selection, 6) the effect of the 1982-1983 and 1983-1984 operation of Kerr dam on apparent velocity .

Before we present our discussion of the data, it is important to realize that the data base is incomplete. Apparent velocity and water quality data are not available for all sites during the same periods. Analysis of the field data is further complicated by the fact that apparent velocity is a dependent variable. The value derived at any one site at a specific time is a function of a number of factors including: 1) the variation in the permeability of the gravel, 2) the annual variation in recharge to the

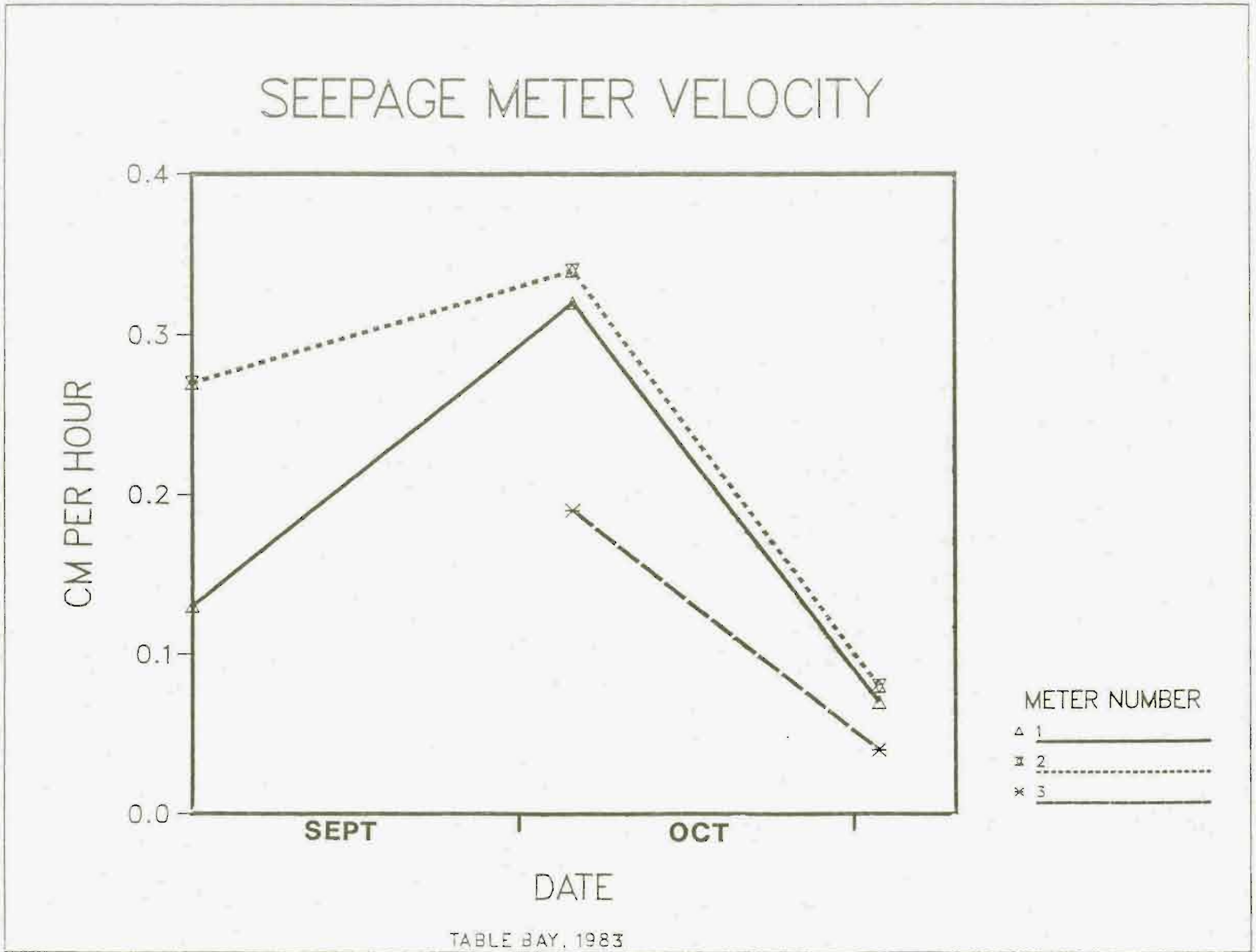

Figure 48: Seepage Meter Velocity vs. Date, Table Bay

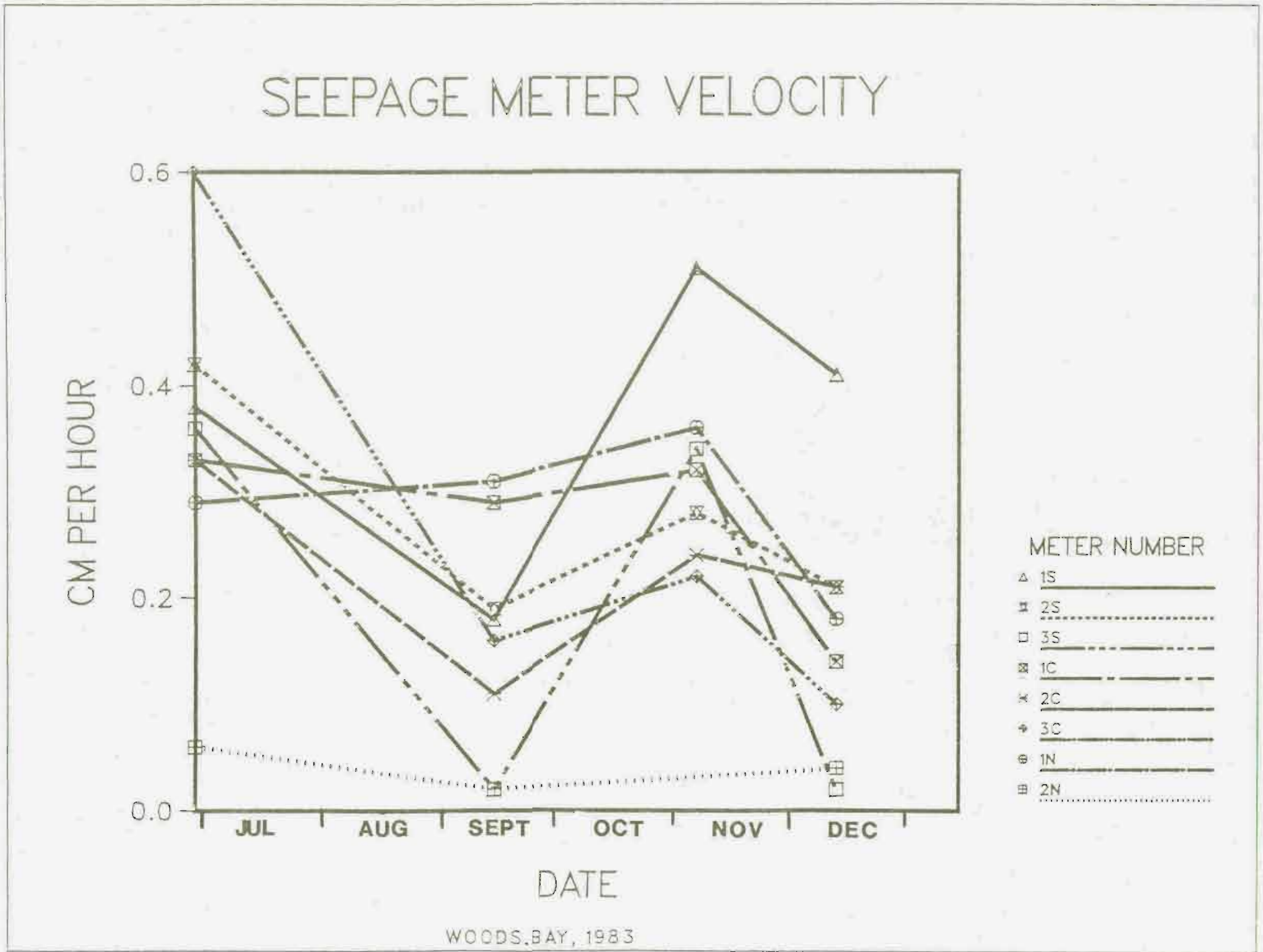

Figure 49: Seepage Meter Velocity vs. Date, Woods Bay

groundwater system, 3) the changes in the local groundwater gradient which result from falling and rising lake stages, 4) the rate of lake stage change, 5) the position of the sampling device in the groundwater system. A further discussion of these factors is found in Appendix D.

Grouping of Sites by Water Table Response

Our approach is to first categorize the sites by response of the water table to lake level fluctuation. Sites at which the water table rose and fell in a similar manner in response to lake stage change have similar hydrogeologic parameters. Three groups of sites are apparent: 1) Group I, the water table immediately follows changes in lake level, 2) Group II, the water table lags behind changes in the level of the lake, 3) Group III, changes in the water table appear to be independent of lake stage fluctuations. Six sites are included in Group I, three in Group II and four in Group III (Tables 2, 3, and 4). We will discuss the general characteristics of these groups in the context of periods of spawning, incubation and emergence.

Spawning

Apparent velocity and water chemistry are very similar between the three groups of sites during spawning. All groups have mean apparent velocities between 0.18 and 0.22 cm/hr. The TDS of the groundwater flowing through the spawning areas is generally slightly higher than the 140 mg/l typical of lake water. Means of average DO values in the spawning area groundwater are 9.4 mg/l, 6.2 mg/l and 8.0 mg/l, respectively.

Incubation

During egg incubation, seepage meter data were only available at a single Group I site, Gravel Bay, and one Group II site, Yellow Bay. At both of these submerged sites, groundwater flow through the redds increases slightly. At the remaining sites, the winter decline in lake stage results in the exposure of many spawning sites. Apparent velocity values for on-shore groundwater are typically an order of magnitude or more greater than the values recorded at the submerged sites. The on-shore values represent the flux of groundwater through lower portions of the redds which have remained saturated during incubation. The average values are weighted by the high on-shore velocities. Means of group velocity averages, excluding Somers Bay at which there was no spawning, are 5.9 cm/hr, 4.6 cm/hr and 2.0 cm/hr, respectively. We believe Group I sites have higher on-shore velocities because the hydraulic conductivity (324 cm/hr) and the lower hydraulic gradients result in faster draining of the sediments. Group III sites have the lowest apparent velocities during incubation. This is most likely related to lower hydraulic conductivities (averaging 31 cm/hr) which permits replacement of water from up gradient at the same rate as water flows to the lake. During egg incubation at exposed sites, the amount of the spawning area in which the water table is closer than 15 cm from the surface is critical. Generally, Group III sites have more shore area with a high water table. The TDS of the groundwater during incubation to on the is slightly higher than during spawning. Group TDS trends are not discernable. Means of average DO values for the three groups are 8.1 mg/l, 8.0 mg/l and 6.6 mg/l. The mean DO value of Group III may reflect a slower rate of groundwater flow which results in the depletion of oxygen in the groundwater system as it travels to the lake.

Emergence

Sites which are still submerged in April, when fry emergence begins, do not show consistent trends. At the Group I Gravel Bay site, apparent velocity decreases during emergence. At Yellow Bay (GroupII) the velocity increases. Yellow Bay Creek runoff may have contributed to local groundwater recharge and the increase in apparent velocity. The mean apparent velocities for exposed sites reported on Table 4 are 5.9 cm/hr, 3.0 cm/hr and 2.0 cm/hr, respectively. These values are similar to the incubation values. Instead of reducing the on-shore gradients, which would result in lower apparent velocities, the rising lake stage effects were overpowered by spring recharge effects. The recharge maintained the hydraulic gradient at sites included in Group I and II. The lowest velocity seen in Group III is related to a lower hydraulic conductivity allowing for a slower relay of the effects of lake fluctuation. Plots of on-shore apparent velocities show that most Group III sites show no immediate response to the rising lake stage in late April when the other sites do respond. TDS concentrations of the groundwater are similar to those measured during incubation. Means of average DO values for the three groups are 6.6 mg/l, 6.4 mg/l and 5.1 mg/l. Trends between groups are difficult to identify with this data. However, it is interesting to note that DO levels are generally lowest in all groups during April-May emergence.

Parameter Correlations

As the hydrogeologic data are discussed by groupings, sites and periods, general observations can be made about the relationship of lake stage to various parameters. In an attempt to determine if those general trends are statistically identifiable we assessed the data using the SPSSX software available for the DEC 2060. To date, we have only attempted to examine the presence or absence of linear correlations. Correlations are significant if the correlation coefficient is greater that 0.6 and the significance value is less than 0.05. For each analysis, only one seepage meter or well per site was chosen to represent the site except where noted otherwise. This is necessary because differences in magnitude between well or seepage meter data at a single site would obscure the correlation, even if the trends are the same.

Lake Stage with Seepage Meter Apparent Velocity

We evaluated seepage meter data for Skidoo Bay, Gravel Bay, Yellow Bay, Crescent Bay and Woods Bay. Initially, we evaluated seepage meter data for all meters at each site. There are no correlations. Next, we examined values for one meter at each site. Only Skidoo Bay data correlates with lake stage. The correlation coefficient is -0.64 (n=16). This indicates that as the lake stage declines, the velocity at meter 1C increases and vice versa. The statistical analysis shows that this relationship is linear at the one meter at Skidoo Bay and nonlinear at the other sites.

Lake Stage with On-Shore Apparent Velocity

We evaluated on-shore velocity data for all sites shown on Table 2 except Woods Bay, Table Bay and Deep Bay. Using one well at each site for comparison with lake stage, wells OH2 (coef.=0.95, n=13), WGAL2 (coef.= 0.81, n= 16), PG2 (coef.= 0.69, n= 13), BH1 (coef.=-0.62, n= 16) and HR1B (coef.= - with positive correlations, velocity tends to be highest at the same time that lake stage is high. The reverse is true at the wells with negative correlation coefficients. This seems problematical at first, but it is important to note that the two negative correlations occur at sites with streams. Stream discharge probably plays a role in determining the velocity at these two sites and may therefore be masking an attempt at simply comparing lake stage with velocity.

DO with Seepage Meter Apparent Velocity

We evaluated apprent velocity values for one meter at Skidoo Bay, Gravel Bay and Crescent Bay. We tested values for four meters, both together and individually, at Yellow Bay and three at Woods Bay. Only Yellow Bay meters YB6 (coef.= 0.70, n=6) and YB7 (coef.= -0.93, n=6) show a correlation with dissolved oxygen. The two meters show opposite types of correlation, which is confusing. In general, six data points are probably not enough values from which to draw conclusions.

DO with On-Shore Apparent Velocity

We used data from one well for all sites with wells except Somers Bay, Woods Bay and Gravel Bay. Unfortunately only three to six data points are available at each site. Well SK2 has a coefficient of 0.63 (n=5) but in lieu of the lack of data, this represents a poor correlation. We rejected the analysis.

We conclude from the statistical analyses that few, if any, data trends follow linear relationships. At best, there is a weak correlation between lake stage and on-shore apparent velocity at a few sites. We had hoped that statistical analysis would yield an uncomplicated method to assess effects of various lake operation scenarios on the groundwater system, but this is not the case.

Summary of Water Quality Data

The following description of the gross chemistry of water moving through the redds is organized by time period and by site. Stiff diagrams present this data graphically (Figures 50, 51, 52, 53 and 54).

The groundwater discharging at the shoreline of Flathead Lake is a calcium bicarbonate type. The TDS ranges from 100 to 422 mg/l. Seepage meter samples were lower in TDS during spawning than during incubation and emergence. This generalization is based on too few data points to be conclusive, however. A comparison of samples between incubation and emergence

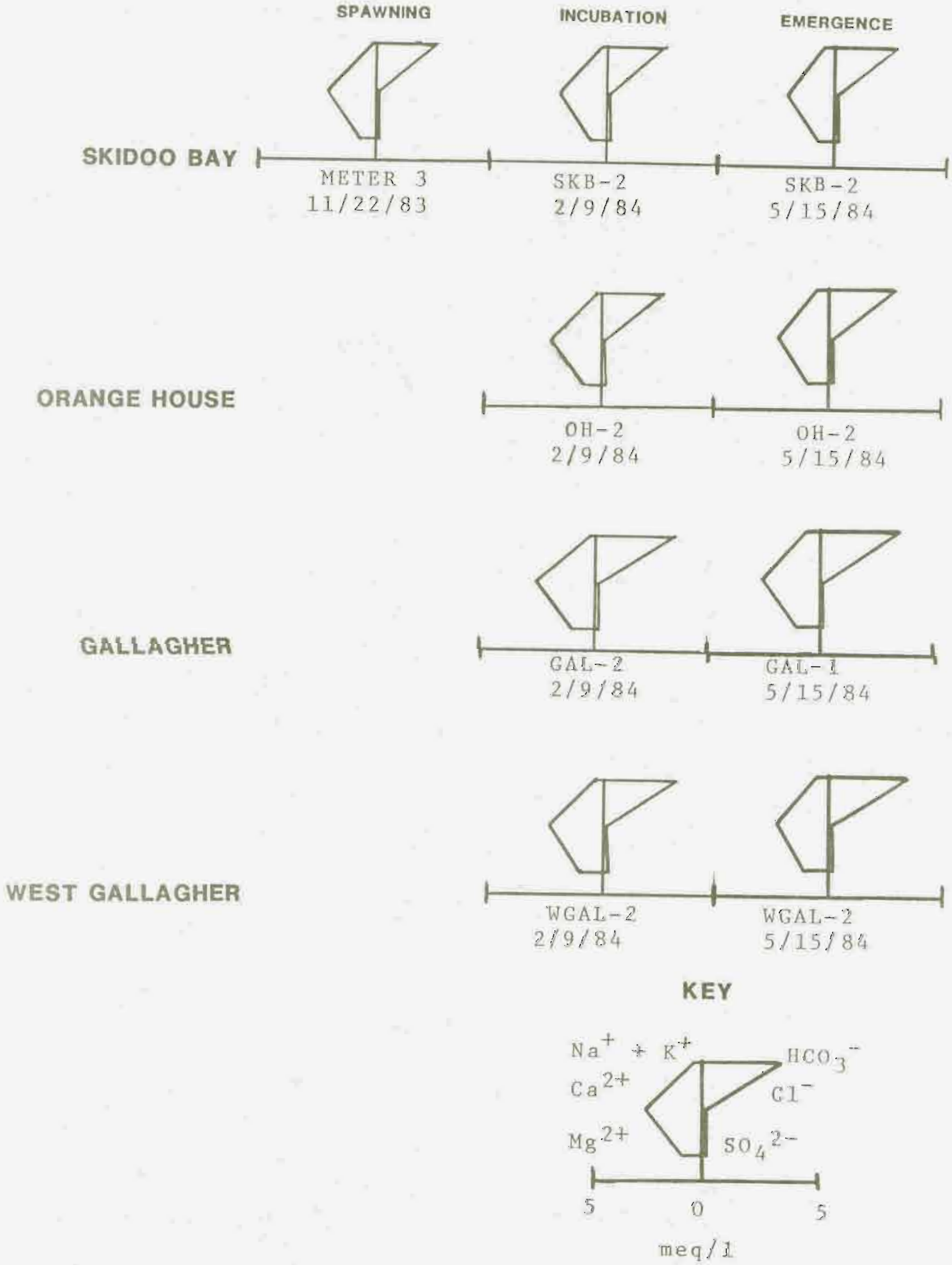

Figure 50: Stiff diagrams for Skidoo Bay, Orange House, Gallaghers and West Gallaghers

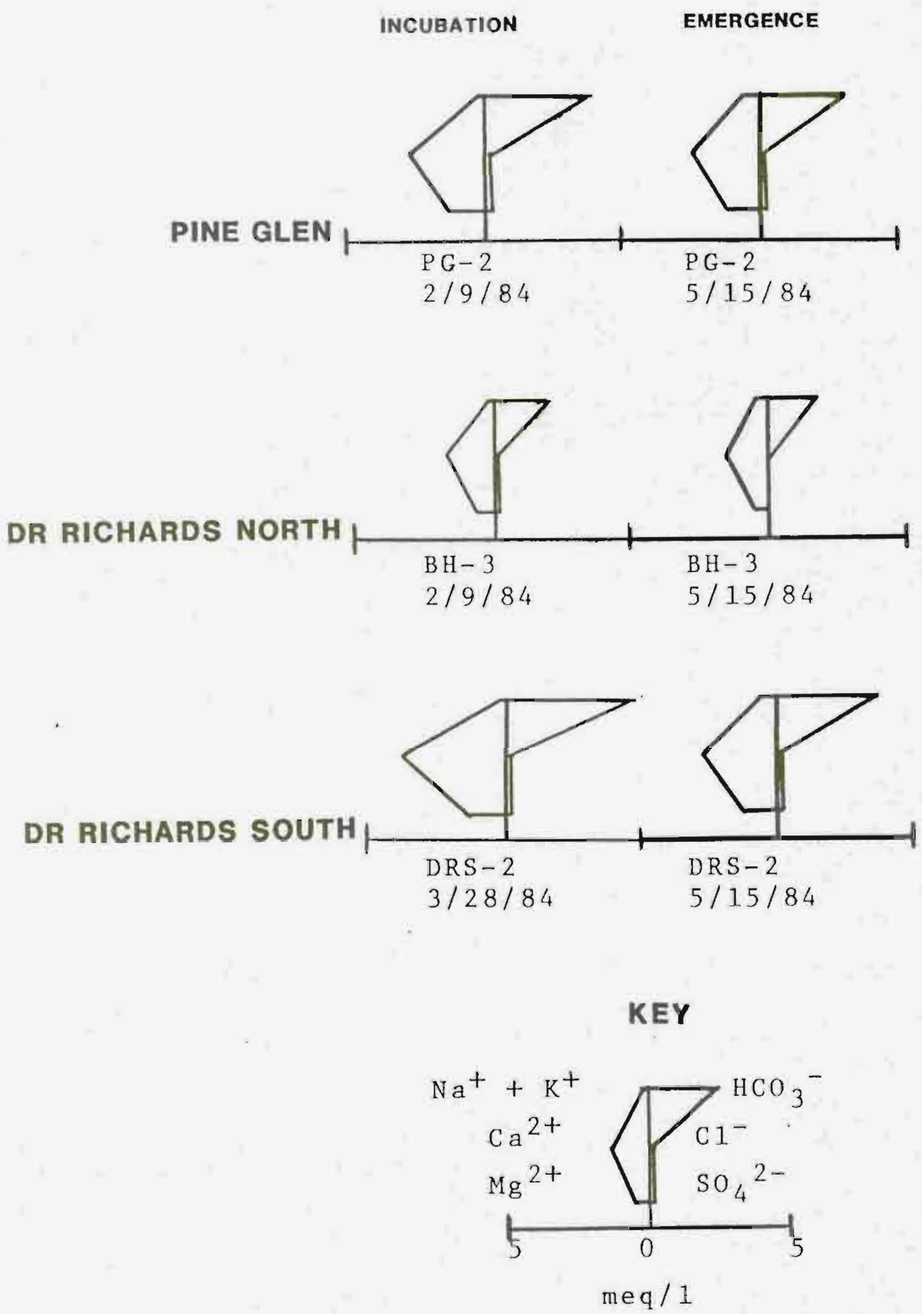

Figure 51: Stiff diagrams for Pine Glen, Dr. Richards North and Dr. Richards South

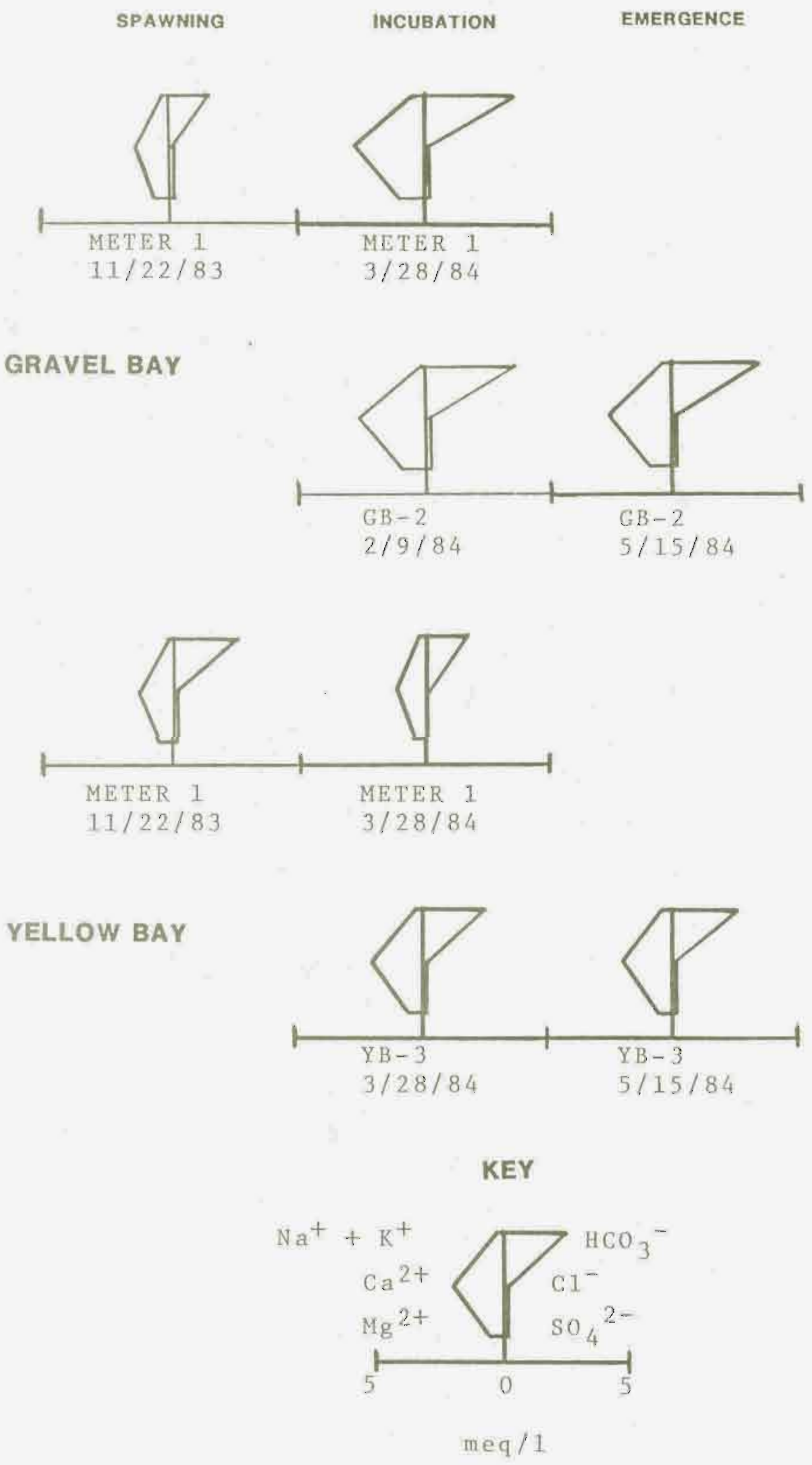

Figure 52: Stiff diagrams for Gravel Bay and Yellow Bay

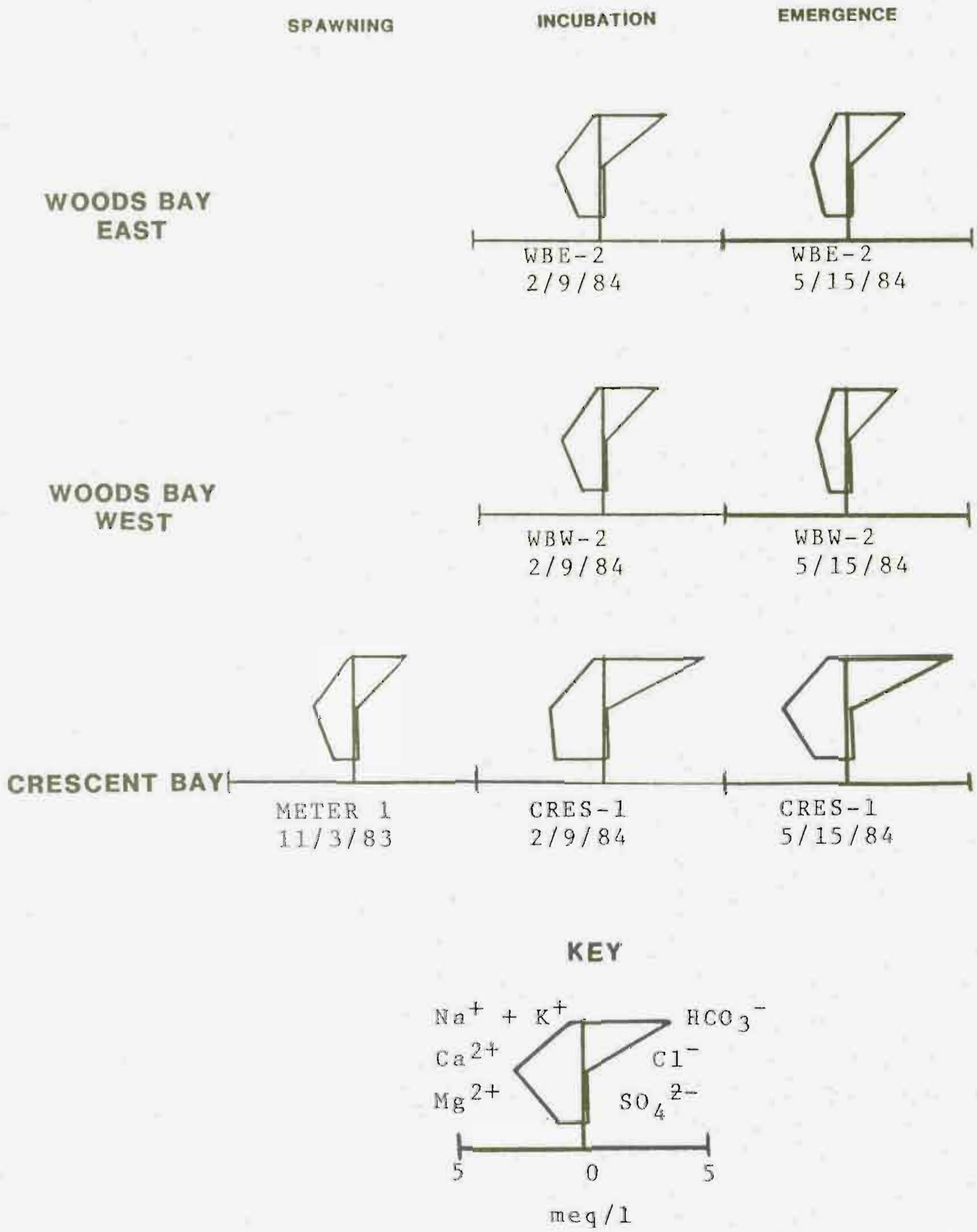

Figure 53: Stiff diagrams for Woods Bay East, Woods Bay West and Crescent Bay

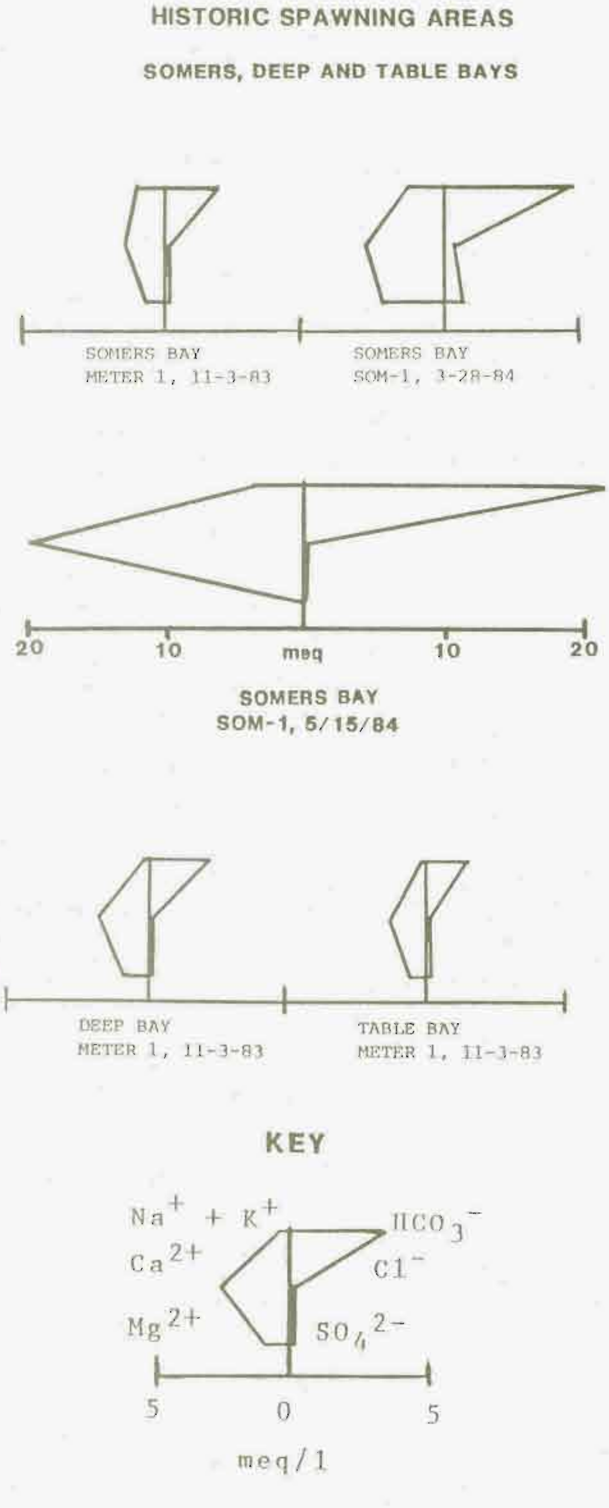

Figure 54: Stiff diagrams for historic spawning areas, Somers, Deep and Table Bays

shows very little change in water quality at most of the sites.

Groundwater is considered contaminated if TDS, chlorides and nitrates exceed background levels in the general area. Typical TDS levels vary from 100 mg/l to 350 mg/l. Background is determined by combining values for closely assoicated sites. Higher than background concentrations of chlorides and nitrates could result from sewage associated with on-shore development. Background levels are typically in the 0.1 to 2 mg/l range for Cl and 0.01 to 0.5 mg/l range for NO_3. The data show a slight increase in major ions at Pine Glen and Dr. Richards South during the incubation period and this may or may not be man-induced contamination. Levels of major constituents are slightly elevated at Pine Glen, Dr. Richards South and Crescent Bay. Chloride and nitrate concentrations at Dr.Richards South and Woods Bay West exceed background. At these sites groundwater may be affected by on-shore waste disposal.

Stiff diagrams of samples from the historic spawning sites are shown in Figure 54. Deep Bay and Table Bay have good quality groundwater during spawning. The groundwater at Somers Bay is generally good during spawning but has more sodium than the water at other sites. As the Stiff diagrams show, the water deteriorates significantly in quality during incubation and emergence. The source of the contamination is not clear but as mentioned previously, may result from septic system leakage or purging.

Deep Spawning Sites compared with Exposed Spawning Sites

Conditions at Gravel Bay and Yellow Bay allowed us to collect data during all three periods at both the deep submerged spawning sites and the exposed shore sites during incubation and emergence. The submerged sites have fairly consistent apparent velocity rates in the 0.10 to 0.35 cm/hr range. In contrast, on-shore sites commonly have velocities which fall in a 1.0 to 36.0 cm/hr range. The water quality at on-shore and at deep sites is very similar and does not appear to vary significantly. We would anticipate similar conditions exist at all sites studied. When fish select deeper spawning sites, redds are insulated from large changes in apparent velocity and water chemistry.

The Distribution of Apparent Velocity Parallel to Shore

We placed seepage meters parallel to shore at Skidoo Bay, Yellow Bay, Gravel Bay and Crecsent Bay. We found that at each of these sites, there are areas of higher groundwater discharge next to the sites actually selected for spawning. Though the data base is limited, when the substrate is similar in size, the spawning salmon don't necessarily select areas with the maximum apparent velocity values.

The Effects of Dam Operation on Apparent Velocity

A comparison of the rates of fall and rise of the lake between the two years of study reveals that small differences in the lake level control have little effect of apparent veolcity. We noticed minor effects at Cresent Bay where apparent velocity increases with the more rapid rate of stage decline in 1983-1984. However, at Gravel Bay, we observered the opposite situation. Generally, the variation in operation from 1982-1983 to 1983-1984 was either not significantly different and/ or was over-shadowed by natural variations in the hydrogeologic system.

PREDICTION OF HYDROGEOLOGIC CONDITIONS

Thus far, we have described and characterized the hydrogeologic parameters of the spawning sites identified by FWP. The next step is to attempt to predict the apparent velocities and water table position with pre-dam lake stage fluctuation patterns or with any other pattern of lake level change. In order to do this, detailed hydrogeologic data have been collected at a number of sites. We had hoped that the regression analyses would provide relatively simple means of predicting lake stage effects of the groundwater system. Our initial efforts did not yield equations which could be used to predict the consequences of stage change on the beach hydrologic system. The next approach is to select a site with both seepage meter data and piezometer information for development of a site-specific numerical model. Once we construct a model we will attempt to reproduce the groundwater response to lake stage change over the last two years. If this can be successfully accomplished, the other lake fluctuation scenarios can be addressed. We have initiated work with a Prickett-Lonnquist numerical model, however, we are not at the stage to present results in this report.

The modeling discussed above assumes the physical beach framework has remained unchanged since the closure of Kerr dam. Based on the effects the lake operation has had on the delta at the north end of the lake we would anticipate that the summer high stand of the lake has probably significantly altered the character of the spawning substrate. High lake stage slowly erodes the shore and redistributes the material along shore and into deeper water below wave base. These effects may be masked by the construction of docks and groins on the shore which may redistribute littoral sediments. As the lake stage gradually declines in the fall and winter the lake has a chance to rework and redistribute gravel deposited at high stage. These processes could be causing a gradual change in the size distribution and thickness of available spawning gravel. A thickening of the beach gravel over time by either process, or a combination of the two, could slowly reduce the width of the zone adjacent to the lake which remains wetted to redd depth during low stage. If the gravel zone near the water table thickens, and the basic groundwater flow rate to the lake remains the same, the water table position will remain at the same position in space as the spawning surface rises. Figure 55 illustrates this scenario. This scenario should be evaluated next year by a review of the available aerial photography and by on-site examination of the shoreline beach stratigraphy.

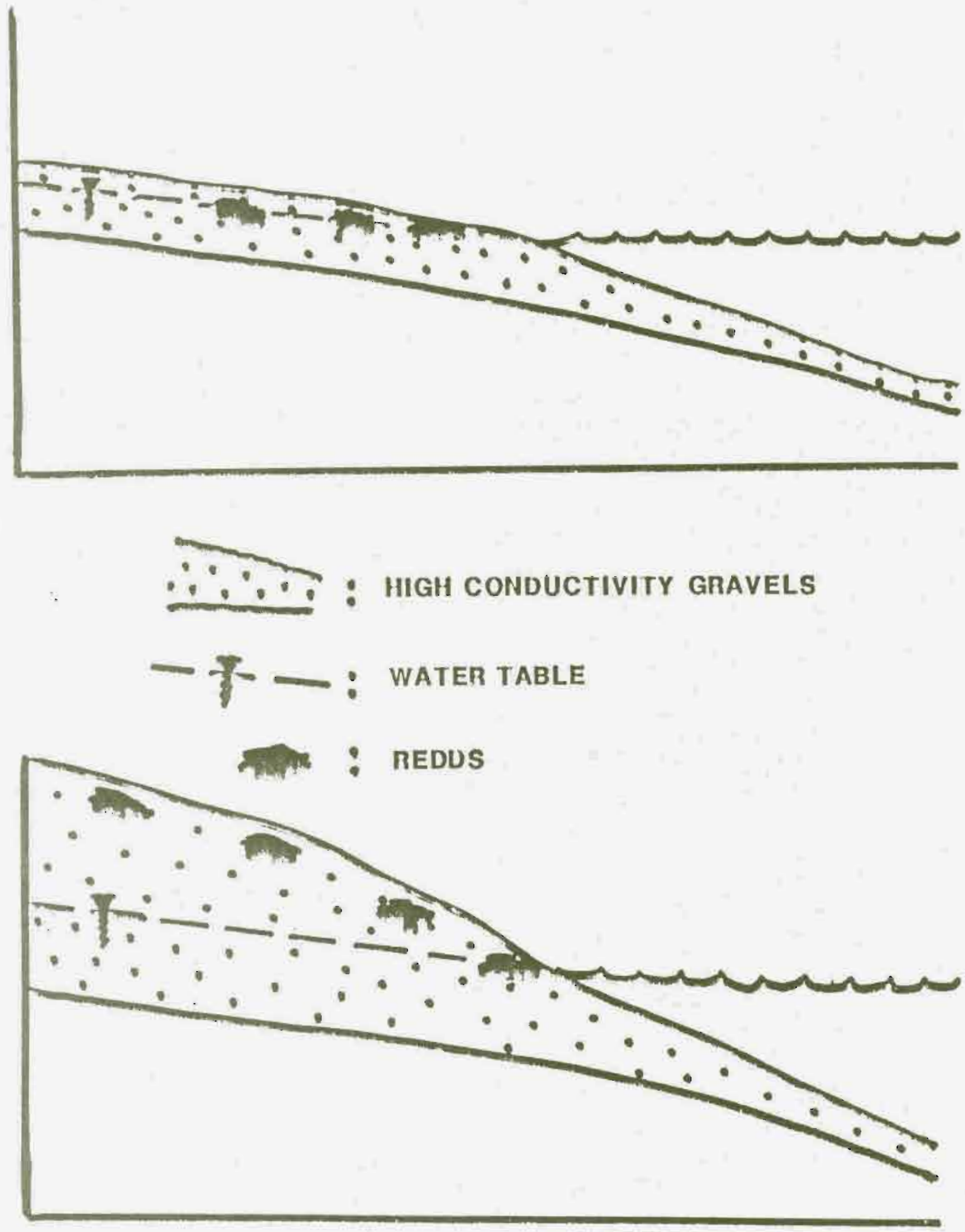

Figure 55: Effect of Thickening Gravels on the Water Table

RECOMMENDATIONS

1. Spawning period data. As can be seen in Table 2, a number of the sites we have been studying for two years have not been instrumented with seepage meters during spawning. Thus we know nothing about the hydrogeologic conditions during spawning at those sites. Additional seepage meter data should be collected during spawning next fall at Dr. Richards South, Woods Bay West, Woods Bay East, Pine Glen, Orange House, Gallaghers and West Gallaghers.

2. Historical Spawning sites. Additional historical spawning sites should be instrumented during all three periods. Two seepage meters should be operated during the spawning period, and water level and hydraulic conductivity data should be collected for at least one sandpoint well during the other two periods.

3. Gravel Stratigraphy. A sediment transport/ beach erosion study should be conducted to determine the effect of man made structures on the transport of material and the operation of Kerr Dam on the stratigraphy of the spawning sites.

4. Modeling efforts. Work should continue on modeling the hydrogeologic systems of the spawning areas, and the historic, present day and future effects of lake stage fluctuations on the shoreline groundwater system.

REFERENCES CITED

Woessner, W.W. and Brick, C.M., 1983, Groundwater investigations related to the location and sucess of Kokanee salmon spawning, Flathead Lake, Montana : Preliminary results, April, 1982-June, 1983. Project Rpt.prepared for Mt. Fish, Wildlife and Parks, University of Montana, unpb.,129pp.

APPENDIX A

SEEPAGE METER AND WELL DATA

Table 1A. Seepage meter apparent velocity data (cm/hr) during spawning October to December 1982 and 1983.

Location	Elevation (ft)	1982		1983		1982-1983	
		Range	Average	Range	Average	Range	Average
Skidoo Bay							
1C	2884.32	0.19-0.49	0.33		0.15	0.15-0.49	0.29
2C	2883.79	0.13-0.18	0.16		0.21	0.13-0.21	0.18
3C	2883.57	0.11-0.17	0.15		0.17	0.11-0.17	0.15
1E	2884.32	0.14-0.18	0.16		0.13	0.13-0.18	0.15
1W	2884.32	0.28-0.30	0.29		0.21	0.21-0.30	0.26
MINI					2.10		
Gravel Bay							
I	2880.21		0.10	0.05-0.14	0.10	0.05-0.14	0.10
2S	2874.97	0.18-0.21	0.20	0.09-0.15	0.12	0.09-0.21	0.16
3	2868.71	0.19-0.15	0.17	0.09-0.37	0.23	0.09-0.37	0.18
4	2863.55	0.19-0.20	0.20	0.10-0.13	0.12	0.10-0.20	0.16
2C	2875.22	0.26-0.31	0.29	0.07-0.24	0.16	0.07-0.31	0.22
2N	2875.18	0.22-0.37	0.30	0.07-0.27	0.17	0.07-0.37	0.23
MINI				3.50-4.00	4.00	3.50-4.40	4.00
Yellow Bay							
1	2883.89	0.18-0.31	0.26			0.18-0.31	0.26
2	2882.50	0.23-0.37	0.29			0.23-0.37	0.29
3	2880.69	0.22-0.31	0.26			0.22-0.31	0.26
4	2877.45	0.26-0.38	0.30	0.18-0.26	0.22	0.18-0.38	0.27
5	2872.45	0.02-0.26	0.14	0.18-0.20	0.19	0.02-0.26	0.16
6	2867.45	0.02-0.07	0.05	0.12-0.28	0.20	0.02-0.28	0.11
7	2868.50			0.09-0.15	0.12	0.09-0.15	0.12
Crescent Bay							
CS1	2889.42	0.07-0.23	0.17	0.38-0.60	0.50	0.07-0.60	0.34
CS2	2887.34	0.15-0.29	0.22	0.14-0.58	0.25	0.14-0.58	0.26
CS3	2883.65	0.03-0.11	0.06	0.02-0.10	0.07	0.02-0.11	0.07
MINI					2.60		2.60
Woods Bay							
S1	2849.47			0.10-0.22	0.16		
S2	2829.97			0.18-0.35	0.27		
S3	2817.97				0.04		
C1	2864.47			0.41-0.51	0.46		
C2	2842.47			0.21-0.29	0.25		
C3	2832.47			0.02-0.34	0.18		
N1	2870.97			0.14-0.32	0.23		
N2	2856.97			0.21-0.24	0.23		
Somers Bay							
1	2888.76			0.24-0.32	0.28		
2	2882.42			0.11-0.17	0.14		
MINI	2890.87			2.50-3.80	3.15		
Table Bay							
1	2886.18			0.07-0.32	0.20		
2	2884.26			0.08-0.34	0.21		
3				0.04-0.19	0.12		
MINI	2889.08			1.10-1.90	1.50		
Deep Bay							
MINI	2890.50			2.30-2.80	2.60		
DEEP	2884.24			0.05-0.17	0.11		

Table 1B. Seepage meter apparent velocity data during incubation January to March 1983 and 1984.

Location	Elevation (ft)	1983		1984		1983-1984	
		Range	Average	Range	Average	Range	Average
Gravel Bay							
1	2880.21	0.22-0.36	0.29	0.08-0.26	0.20	0.08-0.36	0.23
2S	2874.97	0.20-0.60	0.39	0.04-0.30	0.16	0.04-0.60	0.25
3	2868.71	0.23-0.42	0.32	0.07-0.17	0.12	0.07-0.42	0.21
4	2863.55	0.01-0.38	0.19	0.01-0.24	0.10	0.01-0.38	0.14
2C	2875.22	0.21-0.29	0.25	0.03-0.16	0.07	0.03-0.29	0.15
2N	2875.18	0.03-0.45	0.20	0.03-0.15	0.10	0.03-0.45	0.15
Yellow Bay							
2	2882.50	0.28-0.45	0.37			0.28-0.45	0.37
3	2880.69	0.20-0.30	0.25			0.20-0.30	0.25
4	2877.45	0.08-0.62	0.36	0.23-0.56	0.40	0.08-0.62	0.37
5	2872.45	0.13-0.35	0.26	0.21-0.30	0.24	0.13-0.35	0.25
6	2867.45	0.21-0.53	0.38	0.09-0.17	0.12	0.09-0.53	0.19
7	2868.50			0.17-0.96	0.61	0.17-0.96	0.61

Table 1C. Seepage meter apparent velocity data during emergence April to May 1983 and 1984.

Location	Elevation (ft)	1983		1984		1983-84	
		Range	Average	Range	Average	Range	Average
Gravel Bay							
1	2880.21	0.00-0.21	0.11		0.09	0.00-0.21	0.10
2S	2874.97	0.11-0.36	0.24		0.11	0.11-0.36	0.22
3	2868.71	0.19-0.33	0.26		0.06	0.06-0.33	0.19
4	2863.55	0.00-0.09	0.05		0.05	0.00-0.09	0.05
2C	2875.22	0.15-0.33	0.23		0.10	0.10-0.33	0.20
2N	2875.18	0.10-0.22	0.15		0.03	0.03-0.22	0.12
Yellow Bay							
2	2882.50						
3	2880.69						
4	2877.45		0.27				
5	2872.45		0.30				
6	2867.45		0.52		0.27		0.40
7	2868.50				0.79		
Woods Bay							
S1	2849.47		0.11				
S2	2829.97		0.07				
S3	2817.97		0.11				
C1	2864.47		0.24				
C2	2842.47		0.38				
C3	2832.47		0.12				
N1	2870.97		0.12				
N2	2856.97		0.29				

Table 1D. On-shore apparent velocity data (cm/hr) 1984.

Site	Well	Incubation		Emergence	
		Range	Average	Range	Average
Skidoo Bay	SKB-1	1.28- 1.5	1.40	1.00- 1.40	1.19
	SKB-2	2.20- 3.8	3.29	1.30- 3.50	2.30
	SKB-3A	5.10-52.7	20.98	2.30-35.30	10.65
	SKB-3B	1.60-11.0	5.00	0.40-10.30	3.08
Orange House	OH-2	2.50- 3.4	3.03	1.60- 3.00	2.42
	OH-3	0.90- 2.1	1.49	0.40- 1.70	0.78
Gallagher	GAL-1	3.20- 5.0	4.30	3.20- 4.00	3.63
	GAL-2	1.20- 1.5	1.38	0.80- 1.70	1.28
	GAL-3	0.50- 1.1	0.65	0.20- 0.30	0.28
West Gallagher	WGAL-1	0.50- 1.4	0.97	0.40- 1.30	0.75
	WGAL-2	0.40- 1.1	0.63	0.20- 1.30	0.65
	WGAL-3	0.10- 1.2	0.31	0.10- 0.20	0.13
Pine Glen	PG-2	23.20-32.5	27.70	23.70-40.60	29.90
	PG-3	0.60- 2.0	1.26	1.00- 1.50	1.25
Dr. Richards S	DRS-2	0.96- 1.2	1.03	0.50- 2.40	1.08
	DRS-3	0.10- 0.6	0.30	0.04- 0.60	0.27
Dr. Richards N	BH-1	1.30- 3.8	2.96	0.60- 3.50	2.85
	BH-2A	0.07- 0.1	0.08	0.10- 1.40	1.25
	BH-3	0.90- 1.6	1.16	0.90- 1.20	1.08
	BH-4	4.40-14.8	9.89	5.10-13.70	10.00
Gravel Bay	GB-2	3.70-36.2	10.60	5.70-56.80	18.30
	GB-3	1.40- 3.9	2.60	1.40- 8.70	4.00
Yellow Bay	YB-2A	0.30- 0.5	0.44	0.40- 0.50	0.42
	YB-2B	3.50- 5.2	4.60	4.60- 5.20	4.80
	YB-3	2.20- 5.3	3.10	2.10- 3.10	2.50
Woods Bay West	WBW-1	0.60- 3.7	2.30	0.27- 1.00	0.58
	WBW-3	1.20- 3.3	2.10	0.72- 3.50	2.00
Woods Bay East	WBE-1	0.03- 0.6	0.17	0.10- 0.06	0.05
	WBE-3	0.81-18.6	7.80	1.40- 3.30	2.60
Crescent Bay	CR-1	0.40- 0.7	0.60	0.50- 0.70	0.65
	CR-2	3.40- 6.4	5.50	4.10- 5.80	5.10
	HR-1B	0.80- 1.9	1.40	1.50- 1.90	1.80

APPENDIX B

GROUNDWATER QUALITY DATA

Table B1 : Groundwater Quality Data, Dr. Richard's South site.

Location Date	Meter #	DO	pH	NO_3	PO_4	Cl	SO_4	HCO_3	Ca	Mg	Na	K	TDS	SpC umhos	T 'C
				Ion Concentration in mg/l											
Well Data															
DRS-1															
5-23-83			8.1	0.058	0.016	0.23	1.6	73	19.4	2.6	1.4	0.6	100		
DRS-2															
3-30-83			7.6	0.102	0.010	0.37	1.9	108	26.0	5.2	2.1	0.8	145		
Well Date 1984															
DRS 2															
3-28-84			8.3	0.63	0.001	9.9	11.0	280	73.2	15.5	3.9	1.2	400		
5-15-84			8.0	0.51	0.001	3.01	4.0	230	53.2	13.2	4.1	1.4	314		

Table B2 : Groundwater Quality Data, Woods Bay East- Woods Bay West

Location Date	Meter #	DO	pH	NO_3	PO_4	Cl	SO_4	HCO_3	Ca	Mg	Na	K	TDS	SpC umhos	T 'C		
					Ion Concentration in mg/l												
Well Data																	
Woods Bay																	
East																	
WBE-2																	
2-9-84			8.3	0.380	0.002	0.65	2.5	16 0	33.4	10.4	2.6	1.3	213				
5-15-84			8.3	0.38	0.002	0.79	2.3	142	28.7	10.2	2.6	1.3	190				
Woods Bay																	
West																	
WBW-2																	
2-9-84			8.2	0.287	0.002	1.74	6.5	137	31.2	8.7	3.1	1.1	191				
5-15-84			8.8	1.25	0.001	1.40	3.3	122	24.2	8.6	5.4	1.2	172				

Table B4 Groundwater Quality Data, Gravel Bay site.

Location Date	Meter #	DO	pH	NO_3	PO_4	Cl	SO_4	HCO_3	Ca	Mg	Na	K	TDS	SpC umhos	T °C		
				Ion Concentration in mg/l													
GB	1																
1-26-83			7.5	0.011	<0.001	0.23	2.6	90	18.8	6.2	1.2	0.5	119				
3-30-83			7.8	0 033	0.001	0.26	2.9	119	28.4	6.4	1.2	0.6	158				
Shallow																	
9-22-83			8.1	0.003	0.001	0.20	2.6	100	22.8	6.0	1.2	0.3	133				
11-22-83			8.0	0.019	0.001	0.28	2.9	102	24.0	6.2	1.1	0.4	137				
3-28-84			8.5	0.051	0.001	0.84	4.0	218	52.7	11.0	2.7	1.2	290				
Middle																	
2-9-84			7.9	0.014	0.001	0.92	5.1	202	49.9	9.8	2.3	1.1	274				
GB	4																
1-26-83			6.9	0.002	0.004	1.12	<1.0	141	33.9	6.8	1.3	.1.	185				
Deep																	
9-22-83			7.9	0.004	<0.001	1.31	<1	288	68.0	12.1	2.7	3.0	376			Fe in	sample
11-22-83			7.6	0.011	0.001	0.87	<1	211	51.2	9.0	1.6	1.6	275				
3-28-84			8.2	0.047	0.001	0.20	3.2	106	23.7	6.5	1.6	0.4	290				
Wells 1984																	
GBS1																	
2-9-84			8.1	0.033	0.001	0.24	2.7	106	24.0	6.1	1.1	0.5	141				
GB2																	
2-9-84			8.1	0.026	0.003	1.04	2.8	213	51.4	10.4	2.4	1.5	286				
5-15-84			8.0	0.890	0.001	0.57	3.4	209	50.2	10.2	2.5	1.3	277				

Table B5 : Groundwater Quality Data, Pine Glen site.

Location Date	Meter #	DO	pH	NO_3	PO_4	Cl	SO_4	HCO_3	Ca	Mg	Na	K	TDS	SpC umhos	T 'C		
				Ion Concentration in mg/l													
Well Data																	
PG-2A																	
3-30-83		7.6	0.045		0.003	0.60	3.2	226	51.9	12.3	2.8	1.5	298				
Well Data																	
1984																	
PG 2																	
2-9-84			8.0	0.150	0.004	1.74	3.0	238	52.0	14.8	3.3	2.0	315				
3-28-84			8.1	0.38	0.001	1.06	6.6	212	47.7	13.5	2.9	1.6	285				
5-15-84			8.0	0.119	0.001	0.72	3.2	226	48.8	14.2	3.1	1.9	296				

Table B6 : Groundwater Quality Data, Somers Bay

Location Date	Meter #	DO	pH	NO_3	PO_4	Cl	SO_4	HCO_3	Ca	Mg	Na	K	TDS	SpC umhos	T °C	
			Ion Concentration in mg/l													
Shallow																
9-3-83			8.0	1.93	0.001	71.2	13.4	292	67.0	22.1	45.7	2.0	530			
10-6-83			7.9	0.148	0.039	2.9	3.5	116	21.4	7.6	7.9	0.6	154			
11-3-83			8.3	0.010	<0.001	0.80	3.4	121	27.5	7.3	1.9	0.5	162			
Middle																
9-3-83			8.2	0.019	0.001	0.45	2.6	106	23.7	6.4	1.3	0.4	141			
Deep																
9-3-83			8.2	0.004	<0.001	0.43	2.7	107	24.4	6.4	1.4	0.4	143			
11-3-83			8.3	0.010	0.001	0.34	3.0	106	24.1	6.5	1.2	0.4	142			
Well Data																
Somers-1																
3-28-84			8.8	0.013	0.001	18.0	35.3	283	53.6	25.6	24.8	0.5	440			
5-15-84			12.2	0.051	0.001	8.30	6.6	1323	398	0.1	79.0	1.0	1816			

Table B7: Groundwater Quality Data, Skidoo Bay site.

Location Date	Meter #	DO	pH	Ion Concentration in mg/l: NO_3	PO_4	Cl	SO_4	HCO_3	Ca	Mg	Na	K	TDS	SpC umhos	T 'C
Seepage Meter Data															
	1														
9-17-82			7.7	0.122	0.003	0.45	2.4	149	38.4	5.9	1.8	1.0	200	255	17.2
11-24-82			7.7	0.053	<0.001	0.30	2.8	117	27.6	6.1	1.4	0.5	156		
1-26-83			7.7	0.144	0.002	0.45	1.8	142	35.6	6.0	1.9	0.9	189		
9-22-83			8.2	0.005	0.001	0.20	2.9	102	23.7	6.0	1.3	0.3	137		
	2														
5-24-83			11.1												
	3														
9-17-82			7.7	0.005	0.001	0.45	1.8	154	39.1	6.0	1.9	1.2	204		
11-14-82			7.9	0.099	0.001	0.36	2.5	124	30.3	5.9	1.6	0.6	166		
1-26-83			7.8	0.146	0.002	0.47	2.3	140	35.2	6.1	2.0	0.8	188		
5-23-83			8.0	0.175	0.004	0.41	1.8	149	36.8	6.9	2.0	1.0	199		
9-22-83			7.9	0.002	0.002	0.46	1.6	153	36.6	6.7	2.3	1.0	202		
11-22-83			7.8	0.383	0.001	0.90	2.1	166	41.2	7.6	2.2	1.1	220		
	1W														
5-23-83		11.5													
	1E														
5-23-83		4.8													
Well Data															
SKB-1	1														
3-30-83			7.7	0.157	<0.001	0.60	2.5	152	38.4	6.3	2.1	1.1			
5-23-83		7.8	8.3	0.154	0.002	0.47	2.7	152	36.3	7.8	2.1	1.1	204		
SKB-2A	2A														
3-30-83			8.0	0.120	<0.001	0.47	1.4	139	33.1	6.6	2.1	1.1	185		
SKB-3	3														
5-23-83		8.9	8.2	0.473	0.002	0.58	2.2	164	39.6	8.1	2.1	1.1	222		
Well Data															
1984															
SKB 2															
2-9-84			8.2	0.232	0.001	0.78	2.1	160	39.1	7.5	2.3	1.2	217		
3-28-84			8.3	0.68	0.001	1.08	8.2	197	52.2	8.8	2.4	1.1	280		
5-15-84			8.0	0.313	0.001	0.74	2.1	164	40.0	7.8	2.3	1.2	220		
SKB 3B															
3-28-84			8.1	0.163	0.001	0.53	3.6	150	35.8	7.3	2.4	1.0	201		

Table B8: Groundwater Quality Data, West Gallaghers

Location Date	Meter #	DO	pH	NO_3	PO_4	Cl	SO_4	HCO_3	Ca	Mg	Na	K	TDS	SpC umhos	T 'C		
				Ion Concentration in mg/l													
Well Data																	
1984																	
WGAL 2																	
2-9-84			8.1	0.143	0.002	1.01	3.0	204	45.9	11.5	3.6	1.5	273				
3-28-84			8.2	0.168	0.004	0.72	4.1	208	46.3	12.4	3.5	1.3	277				
5-15-84			8.0	0.135	0.002	0.77	2.9	206	44.4	12.7	3.7	1.4	270				

Table B9 : Groundwater Quality Data, Orange House- Skidoo Bay

Location Date	Meter #	DO	pH	NO_3	PO_4	Cl	SO_4	HCO_3	Ca	Mg	Na	K	TDS	SpC umhos	T 'C	
				Ion Concentration in mg/l												
Well Data																
OH-2																
2-9-84			8.3	0.158	0.001	1.23	2.4	171	40.8	8.5	2.6	1.4	229			
3-28-84			8.2	0.161	0.001	0.88	6.4	196	48.2	9.2	2.8	1.2	265			
5-15-84			7.9	0.192	0.001	0.79	2.4	185	43.1	9.0	3.0	1.3	245			

Table B10: Groundwater Quality Data, Gallaghers

Location Date	Meter #	DO	pH	NO_3	PO_4	Cl	SO_4	HCO_3	Ca	Mg	Na	K	TDS	SpC umhos	T 'C		
				Ion Concentration in mg/l													
Well Data																	
1984																	
Gal 2																	
2-9-84			8.2	0.124	0.001	1.24	2.9	215	49.0	11.7	3.8	1.7	289				
3-28-84			8.1	0.131	0.004	0.75	5.2	218	48.7	11.8	3.7	1.4	290				
5-15-84			8.1	0.090	0.002	0.89	3.6	213	47.1	12.4	3.8	1.7	279				

Table B11 Groundwater Quality Data, Yellow Bay site.

Location Date	Meter #	DO	pH	NO_3	PO_4	Cl	SO_4	HCO_3	Ca	Mg	Na	K	TDS	SpC umhos	T °C
				Ion Concentration in mg/l											
YB	1														
11-24-82		12.7	7.7	0.028	<0.001	0.26	2.4	107	25.2	6.0	1.1	0.4	142		
1-26-83			7.7	0.086	0.001	0.20	2.9	106	25.2	6.0	1.0	0.4	142		
9-22-83			8.0	0.018	0.001	0.20	2.2	94	21.7	5.2	1.7	0.4	126		
11-22-83			7.8	0.029	0.001	0.23	2.7	101	24.0	5.8	1.3	0.4	136		
3-28-84			7.9	0.085	0.003	0.25	1.6	102	24.3	4.9	2.2	0.6	137		
YB	2														
9-17-82(3")			7.9	0.022	<0.001	0.17	2.6	108	25.9	5.6	1.2	0.4	144	160	17.2
11-24-82			7.7	0.011	<0.001	0.20	2.5	112	26.8	6.0	1.1	0.4	151		
1-26-83			7.8	0.024	<0.002	0.22	2.6	105	25.1	5.8	1.2	0.6	141		
9-17-82(14")			7.8	0.012	0.002	0.19	2.5	112	27.0	5.6	1.2	0.4	149		
**															
YB	5														
9-17-82		8.8	7.9	0.025	0.002	0.18	2.4	102	24.7	5.3	1.1	0.4	136	150	16.7
11-24-82			7.9	0.053	0.001	0.23	2.3	115	28.4	5.9	1.2	0.4	157		
1-26-83			7.0	0.001	0.003	0.65	<1.0	207	51.4	8.4	2.1	1.0	270		
9-22-83			8.2	0.003	0.002	0.52	1	216	51.8	9.0	2.8	1.4	282		
11-22-83			8.0	0.021	0.001	0.69	1	214	51.6	8.9	2.5	1.3	279		
YB	6														
11-24-82		0.0	7.8	0.004	0.016	0.87	1.0	234	58.4	9.1	1.9	1.1	305		
3-30-83			7.5	0.010	<0.001	0.46	2.9	152	37.2	6.6	2.2	1.0	203		
Comparison Data Yellow Bay Creek															
9-17-82		12.2	7.9	0.031	0.004	0.14	2.1	104	25.8	4.1	2.0	0.6	138	160	10.6
11-24-82		13.8	7.9	0.002	0.004	0.16	1.7	102	24.8	4.2	2.0	0.6	134		3.3
3-30-83			7.9	0.037	0.005	0.16	1.5	101	24.4	4.2	2.1	0.7	135		
Jack Rabbit Pump at #5															
9-17-82		6.7	7.7	0.003	0.014	0.22	2.0	112	26.8	5.5	1.1	0.5	148	200	15.6
11-24-82		6.1	7.0	0.035	0.005	0.34	2.1	160	40.5	6.9	1.4	0.7	212		
1-26-83			7.3	0.002	0.014	0.40	<1.0	204	51.3	8.7	1.9	0.8	267		
**YB	4														
3-30-83			7.8	0.052	.0006	0.21	1.9	107	26.0	4.6	2.0	0.7	142		

Table B12 Groundwater Quality Data, Wells Yellow Bay

Location Date	Meter #	DO	pH	NO_3	PO_4	Cl	SO_4	HCO_3	Ca	Mg	Na	K	TDS	SpC umhos	T °C		
				Ion Concentration in mg/l													
YB 2A																	
2-9-84			7.9	0.086	0.006	0.36	2.0	134	34.0	5.3	2.2	0.7	181				
3-28-84			7.9	0.111	0.009	0.86	3.7	157	40.0	6.6	2.3	1.0	213				
5-15-84			7.9	0.049	0.015	0.66	1.9	157	38.4	6.9	2.4	1.0	210				
YB 3																	
2-9-84			8.0	0.073	0.001	0.72	2.1	156	38.8	6.6	2.4	1.1	211				
3-28-84			8.1	0.051	0.006	0.76	2.8	156	39.6	6.5	2.2	0.8	210				
5-15-84			7.8	0.037	0.001	0.83	2.1	156	37.9	6.5	2.5	1.2	207				
Water Level Rec. Well																	
9-22-83			7.9	0.039	0.009	0.20	1.6	103	24.5	4.4	2.2	0.6	136				

Table B13 Groundwater Quality Data, Hochmark's site.

Location Date	Meter #	DO	pH	NO_3	PO_4	Cl	SO_4	HCO_3	Ca	Mg	Na	K	TDS	SpC umhos	T °C		
				Ion Concentration in mg/l													
Well Data																	
BH-1																	
3-30-83			7.2	0.019	<0.001	0.38	2.5	105	24.8	4.5	2.1	0.9	112				
5-23-83			7.9	0.025	0.001	0.24	1.9	118	29.4	4.8	1.8	0.8	157				
Station Creek Data																	
5-23-83			8.3	0.72	.0006	2.0	3.6	291	58.4	23.0	4.3	1.8	390				
Well data																	
1984																	
BH 2A																	
3-28-84			10.0	0.007	0.001	0.43	10.7	67	13.9	3.5	3.4	1.5	102				
5-15-84			9.7	0.007	0.001	0.43	10.7	69	13.9	3.5	3.4	1.5	102				
BH 3																	
2-9-84			8.5	0.040	0.003	1.20	2.8	133	32.1	6.4	2.4	1.2	181				
3-28-84			8.3	0.040	0.001	0.41	3.8	115	27.8	5.7	2.1	0.9	158				
5-15-84			8.0	0.001	0.001	0.36	2.1	114	27.3	5.4	2.1	0.8	156				

Table B14 Groundwater Quality Data, Crescent Bay site.

Location Date	Meter #	DO	pH	NO_3	PO_4	Cl	SO_4	HCO_3	Ca	Mg	Na	K	TDS	SpC umhos	T °C		
						Ion Concentration in mg/l											
Shallow	1																
9-26-82		9.6															
11-24-82			8.0	0.129	0.001	0.46	3.1	139	31.8	8.1	1.8	0.7	186				
9-3-83			8.2	0.006	0.001	0.21	2.6	104	23.3	6.3	1.2	0.5	139				
10-6-83			8.0	0.083	0.001	0.64	2.9	175	37.9	11.2	2.7	1.0	232				
11-3-83			8.3	0.010	0.001	0.69	3.3	181	38.4	12.0	2.8	1.0	242				
9-3-83			8.2	0.169	0.001	0.60	2.2	184	38.1	12.3	3.2	1.2	246.				
11-3-83			8.2	0.056	0.002	0.38	3.1	131	29.1	8.3	1.6	0.6	174				
CBFD	2																
9-26-82		9.6												200			
11-24-82			7.9	0.013	<0.001	0.33	2.1	146	34.5	7.5	1.3	0.7	192				
1-26-83			7.6	0.007	<0.001	0.42	2.5	157	35.5	8.9	1.6	0.8	206				
9-3-83			8.0	0.094	0.001	0.39	1.9	153	33.4	9.4	2.0	0.9	201				
10-6-83			8.0	0.004	0.003	0.57	1.0	200	44.7	11.3	2.1	1.3	267				
9-3-83			8.0	0.015	0.004	0.52	1.0	222	46.7	12.8	2.3	1.5	286.6				
Old #2 CBH																	
9-26-82		7.6															
11-24-82			7.9	0.039	<0.001	0.25	2.6	109	25.3	6.3	1.2	0.4	145				
1-26-83			7.9	0.073	0.001	0.35	3.2	119	27.6	7.2	1.3	0.6	159				
9-3-83	H		8.2	0.030	0.001	0.24	2.1	109	24.3	6.8	1.8	0.5	114				

Table B15 Groundwater Quality Data, Crescent Bay Wells

Location Date	Meter #	DO	pH	NO_3	PO_4	Cl	SO_4	HCO_3	Ca	Mg	Na	K	TDS	SpC umhos	T °C		
				Ion Concentration in mg/l													
Well Data																	
AR-1A																	
5-23-83			8.3	0.005	<0.001	2.8	4.0	320	62.1	25.2	5.7	2.3	422				
AR-1B																	
5-23-83			8.2	0.403	0.011	1.1	3.1	258	52.4	17.6	4.3	1.9	342				
AR-3																	
5-23-83			8.2	0.955	0.005	1.9	4.5	326	67.2	22.2	5.7	2.5	438				
AR-4																	
5-23-83			9.9	0.019	<0.001	1.58	<1.0	116	15.8	20.6	6.7	3.1	194				
AR-5																	
3-30-83			8.0	0.407	0.008	1.29	3.2	281	60.0	17.9	5.1	2.2	373				
Well Data																	
Cres 1																	
2-9-84			8.5	0.070	0.001	1.84	3.6	246	41.8	20.9	6.0	2.5	323				
3-28-84			9.1	0.095	0.001	1.22	4.6	247	41.8	20.9	6.2	2.5	324				
5-15-84			8.4	0.48	0.002	1.62	4.9	260	52.8	18.2	5.1	2.0	343				
HAR 1A																	
3-28-84			10.7	0.028	0.001	0.94	8.7	103	12.1	11.2	6.7	2.7	144				
Big Lodge Creek, Surface water																	
5-23-83			8.3	0.388	0.012	1.1	2.9	258	52.6	16.8	5.4	1.7	342				
Ephermeral stream near Harvey's																	
5-23-83			8.3	0.720	0.006	2.0	3.6	291	58.4	23.0	4.3	1.8	390				

Table B16 Groundwater Quality Data, Deep Bay

Location Date	Meter #	DO	pH	NO_3	PO_4	Cl	SO_4	HCO_3	Ca	Mg	Na	K	TDS	SpC umhos	T °C	
				Ion Concentration in mg/l												
Shallow																
9-3-83			8.2	0.005	<0.001	0.25	3.8	103	23.8	7.3	1.2	0.8	140			
11-3-83			8.2	0.011	<0.001	0.23	2.9	144	33.2	8.1	1.1	0.6	190			
10-6-83			8.0	0.006	0.001	0.23	0.19	167	38.2	9.2	1.3	0.7	218			
Deep																
9-3-83			8.1	0.004	<0.001	0.23	2.4	135	31.0	7.6	1.2	0.6	175			
11-3-83			8.2	0.011	<0.001	0.25	2.7	110	25.8	6.3	1.1	0.4	147			
10-6-83			8.0	0...3	0.001	0.21	2.8	108	25.3	6.2	1.1	0.4	144			

Table B17: Groundwater Quality Data, Table Bay

Location Date	Meter #	DO	pH	NO_3	PO_4	Cl	SO_4	HCO_3	Ca	Mg	Na	K	TDS	SpC umhos	T °C	
				Ion Concentration in mg/l												
Shallow																
9-3-83			8.2	0.009	0.001	0.15	2.2	96	22.2	5.5	1.1	0.4	128			
10-6-83			8.0	0.008	0.001	0.22	3.5	102	23.6	6.1	1.1	0.5	137			
11-3-83			8.3	0.008	0.001	0.24	2.9	104	23.7	6.2	1.1	0.4	138			
Middle																
9-3-83			8.1	0.156	0.001	0.75	2.9	156	32.8	10.2	3.1	0.6	207			
Deep																
9-3-83			8.2	0.002	0.001	0.15	2.4	98	22.4	5.5	1.1	0.4	130			
10-6-83			8.1	0.004	0.001	0.19	2.8	102	23.5	6.1	1.1	0.4	136			
11-3-83			8.3	0.022	0.002	0.33	3.4	103	23.6	6.0	1.4	0.5	138			

APPENDIX C

DISSOLVED OXYGEN TRANSECTS

Table C1: Dissolved Oxygen Transects, Woods' Bay site, Woods Bay East Woods Bay West

Transect Location	Elev. (m)	Dist. Shore (m)	Date 4-7-83	Date 5-18-83	Date 12-9-83	3-27-84					
Line #1	870.2	0	1.7			South transect					
	868.5	4	4.7								
	866.2	8	2.8								
	864.4	12	3.0								
	862.6	16	3.4								
	860.7	20	6.4								
	858.9	27	6.6								
Line #2	879.1	0	10.9	9.4		Center transect					
	877.6	4	6.8	5.0							
	876.8	8	6.3	4.2							
	874.9	12	5.8	9.0							
	872.0	16	7.0	10.1							
	870.7	20	6.8	9.6							
	868.7	24	5.6	6.2							
	866.7	28	6.3	6.9							
	864.7	32	7.8	7.0							
Line #3	878.8	0	11.7			North transect					
	877.0	4	8.3								
	875.0	8	9.0								
	872.9	12	7.3								
	870.8	16	3.4								
	870.2	17	7.2								
Woods Bay East											
	880.46				11.1	dry		2887.9 ft			
	880.36				11.6	''					
	880.30				10.0	''					
	880.18				11.4						
	880.16				dry	''					
	879.98				10.0	''					
	879.98				9.4	''		2886.35 ft			
					12-12-83						
Woods Bay West											
	880.10				9.7	dry		2886.73 ft			
	880.10				8.5	''					
	879.72				dry	''					
	879.53				10.4	''					
	879.45				8.1	''					
	879.41				8.1	''					
	879.30				9.8	''		2884.10 ft			

Table C2: Dissolved Oxygen Transects, Dr. Richard's South site.

Transect Location	Elev. (m)	Dist. Shore (m)	Date 3-15-83	Date	Date						
Line #1		0	-			Black and white house, north					
		4	-								
		8	-								
		12	8.9								
		16	11.1								
		20	11.1								
		24	11.0								
Line #2	880.6	0	-			Black and white house, south					
	879.7	4	-								
	879.7	8	8.7								
	879.2	12	11.2								
	879.1	16	10.0								

Table C3: Dissolved Oxygen Transects, Gravel Bay site.

Transect Location	Elev. (m)	Dist. Shore (m)	Date 11-30-83	Date 3-14-83	Date 6-7-83	12-20-83	3-8-84
* Line #1	878.6	0	9.0	11.4		9.1	11.6
	877.1	4	8.0	11.0			12.1
	876.3	8	5.6	8.5			12.1
	875.4	12	3.1	0.0			dry
** Line #2	879.0	0	5.8	10.8			11.9
	878.2	4	11.5	10.9			
	876.8	8	-	10.4		9.8	12.0
	875.7	12	7.4	8.3		9.5	11.3
	874.8	16	7.1	9.1			
	874.3	20	1.0	8.9			3.3
*** Line #3	878.9	0	5.5	11.3	1.5		10.6
	877.9	4	9.8	11.4	10.1		
	876.3	8	8.7	9.3	9.2		10.6
	875.1	12	9.0	10.8	4.8		
	873.9	16	7.6	-	7.0		dry
	873.0	20	7.0	8.7	7.2		
	872.4	24	5.0	0.2	0.0		6.8

* 25.9 meters east of west stake, out of spawning area, Dist 0 meters the rest are in the spawning area

** 44.2 meters east of west stake, dist 0 meters out of spawning area, the rest are in the spawning area

*** 57.9 meters east of west stake, dist 0 and 4 meters are out of spawning area, the rest are in the spawning area

Table C4: DO Transect Data, Pine Glen site.

Transect Location	Elev. (m)	Dist. Shore (m)	Date 12-9-82	Date 3-16-83	Date						
Random data points	880.3		7.5	-							
	879.9		8.4	-							
	879.7		9.5	9.5							
	879.4		10.2	9.0							
	879.1		9.3	9.5							
	879.0		9.5	9.5							
	879.3		8.7	8.5		In front of north corner of new pilings					
	879.4		9.5	9.5		North edge of spawning area					
	879.6		8.8	9.2		South edge of spawning area					

Table C5 : DO Transect Data, Somers Bay

Transect Location	Elev. (m)	Dist. Shore (m)	Date 12-9-83	Date 3-27-84	Date						
	880.55		dry	dry			2888.20 ft				
	880.53		''	''							
	880.41		10.1	''							
	880.33		dry	''							
	880.33		11.0	''							
	880.30		12.1	''							
	880.19		dry	''							
	880.16		dry	dry			2886.94 ft				

Table 06 : DO Transect Data, Skidoo Bay site

Transect Location	Elev. (m)	Dist. Shore (m)	Date 12-19-82	Date 3-15-83	Date 12-9-84	3-27-84	
Line #1	881.2	0	-	-		1.5 meters from west stake	
	880.6	4	12.8	-			
	800.0	8	11.2	7.1			
	879.4	12	8.9	7.4			
	879.2	16	9.1	6.1			
Line #2	881.3	0	-	-		13.7 meters from west stake	
	880.8	4	11.0	-			
	880.1	8	9.6	7.9			
	879.5	12	9.7	8.6			
	879.1	16	-	8.4			
Line #3	881.3	0	-	-		25.9 meters from west stake	
	880.8	4	9.2	-			
	880.2	8	9.4	7.0			
	879.5	12	9.5	7.4			
	879.2	16	8.5	9.1			
Line #4	881.4	0	-	-		38.1 meters from west stake	
	880.8	4	9.5	-			
	880.2	8	10.1	8.9			
	879.5	12	9.2	8.9			
	879.2	16	5.5	8.6			
East							
	880.23				9.4	dry	2887.21 ft
	880.32				9.0	''	
	879.91				8.6	''	
	879.88				9.2	''	
	879.65				8.5	20.2?	
	879.52				8.3	9.8	2884.84 ft
West							
	880.94				8.6	dry	2889.46
	880.61				8.9	''	
	880.39				8.3	''	
	880.13				5.4	9.7	
	879.83				7.9	8.7	
	879.72				8.8	9.2	2885.49 ft

Table C7 : Dissolved Oxygen Transects, Yellow Bay site.

Transect Location	Elev. (m)	Dist. Shore (m)	Date 12-1-83	Date 4-4-83	Date 6-6-83	9/83	12/83	3/84
* Line #1	879.5	0	1.8	-	8.2	1.1	7.0	8.6
	879.2	4	1.6	8.7	99.0	4.8	7.0	9.3
	879.0	8	1.0	9.4	6.7	7.4	9.1	10.7
	878.3	12	5.7	7.1	4.7	8.1	9.6	10.8
	876.7	16	3.6	5.2	0.6	2.9	.35	4.4
	875.8	19	0.3	4.0		0.8	.45	dry
** Line #2	879.7	0	3.4	10.9	2.5	dry	1.1	11.8
	879.5	4	8.8	10.5	5.6	3.6	1.1	11.7
	879.4	8	1.6	10.8	8.3	9.1	8.1	11.8
	878.8	12	2.8	10.5	8.5	7.6	8.2	11.7
	877.7	16	1.2	10.8	9.0	8.8	2.0	?
	875.9	20	3.1	6.5	7.8	7.8	3.1	?
	874.4	24	1.8	6.1	5.3	4.8	dry	dry
	873.8	26	-	0.6	-	0.0		
*** Line #3	878.3	0	0.7	4.2	1.5	1.5	.3	0.4
	877.2	4	1.9	9.3	5.1	0.4	.35	7.7
	875.5	8	7.6	9.6	4.4	0.8	1.2	8.9
	874.3	12	6.6	7.7	3.8	3.2	2.5	8.0
	873.3	15	-	-	1.9	0.0	dry	dry

* 15.2 meters west of east stake and 7.6 meters east of Yellow Bay Creek, all in spawning area

** 33 meters west of east stake and 7.6 meters west of Yellow Bay Creek

*** 45.7 meters west of east stake and 22.9 meters west of Yellow Bay Creek.

Table C8: Dissolved Oxygen Transects, Hochmark's site.

Transect Location	Elev. (m)	Dist. Shore (m)	Date 3-15-83	Date 12-9-83	Date 3-27-84						
Line #1	880.6	0	10.0								
	880.3	4	9.1								
	879.7	8	12.3								
	879.2	12	11.7								
	878.8	16	8.5								
	878.6	20	11.2								
	880.88			11.5	11.1			2889.29 ft			
	880.70			10.9	11.3						
	880.53			11.0	9.5						
	880.51			dry	?						
	880.35			10.7	10.6						
	880.24			8.4	?						
	880.23			7.8	10.2			2887.18 ft			

Table C9 : DO Transect Data, Gallaghers

Transect Location	Elev. (m)	Dist. Shore (m)	Date 12-8-83	Date 3-27-84	Date						
	880.79		6.4	dry				2888.99 ft			
	880.70		6.2	''							
	880.61		3.8	''							
	880.56		4.5	''							
	880.45		3.7	''							
	880.34		4.3	''				2887.51 ft			

Table C10 : DO Transect Data, West Gallaghers

Transect Location	Elev. (m)	Dist. Shore (m)	Date 12-8-83	Date 3-27-84	Date						
	880.72		9.8	dry			2888.75 ft				
	880.72		11.4	"							
	880.56		8.5	8.8							
	880.30		8.0	dry							
	880.18		6.5	8.1							
	880.01		6.1	dry			2886.43 ft				

Table C1F DO Transect Data, Crescent Bay site.

Transect Location	Elev. (m)	Dist. Shore (m)	Date 1-28-83	Date 3-17-83	Date 6-6-83	3-5-84
Line #1	881.8	0	-	-	2.6	Forman's
	881.1	4	-	9.7	0.7	
	880.7	8	-	10.5	8.1	
	880.1	12	9.9	10.6	4.8	
	879.6	16	8.2	10.7	7.7	
	879.0	20	1.2	5.5	9.7	
	878.7	24	0.2	0.5	-	
Line #2	880.6	0	9.9			Harvey's
	880.1	4	10.3			
	879.6	8	10.2			
	879.3	12	9.2			
	878.6	16	7.3			
	878.5	20	0.0			
						11.5
						10.0
						11.6
						10.4
						8.0
						7.2

APPENDIX D

Apparent Velocity and the Lake--Groundwater System

This appendix presents the variables which effect the apparent velocity data used in this or any study. Apparent velocity measurements are functions of the composition of the earth material through which the groundwater passes, the annual variation in recharge to the groundwater system, the location of the measuring point in the shore-lake groundwater system, the seasonal variation of lake stage and the rates of rise and fall of the lake stage. Because the analysis of data is limited by these factors we will describe each factor and discuss the limitations it imposes on the data.

Groundwater theory dictates that the rate of flow of the water in the lake and beach sediments is directly proportional to the hydraulic conductivity and the slope of the water table and inversely proportional to the distance travelled in the sediments. In the beach area the water table is steep, and the flow path of water near the water table is basically parallel to that slope (Figure D1). Consistant with theoretical expectations, we observed the fastest ground-water flow or apparent velocity near the water table in the beach area. The rate of flow through the lake -bottom sediments decreases exponentially with distance from the shoreline. This exponential change in apparent velocity is due to groundwater below the water table moving along a longer flow path, past the lakeshore, to points further out from shore. With the other controls on flow held constant, the effect of lengthening the flow path reduces the apparent velocity at points off-shore. Examples of the distribution of apparent velocity perpendicular to shore during spawning are presented in Figure D2. Apparent velocities on-shore are consistantly an order of magnitude higher than seepage meter velocities. This means that the apparent velocity during spawning, when the site is submerged, will always be lower than during incubation when the site is exposed.

A second factor which affects the measurement of apparent velocity at individual sites in a spawning area is natural variation in the hydraulic conductivity, the gross ability of sediment to transmit water. Hydraulic conductivity is a function of the quantity and size of interconnected pore spaces in the beach and lake sediments, assuming a constant groundwater temperature. Natural variations in the size, sorting and packing of the sediments results in variations of hydraulic conductivity. This sometimes results in a difference of an order of magnitude in the apparent velocity at a spawning site. Sediment hydraluic conductivity decreases perpendicular to shore as fines are moved from the wave zone into deeper water below wave base.

Seasonal and annual variations of groundwater recharge will also affect both on-shore and off-shore apparent velocity. A year with above-normal precipitation will result in a regional rise in the water table which will increase the water table slope and thus the groundwater apparent velocity. The differences between on-shore and off-shore measurements should, however, remain proportional.

Dam operation results in a lowering of the lake stage from October though March to early April. The lake is then raised rapidly in April and May and is held constant for the summer months. Based on the hydrogeologic system

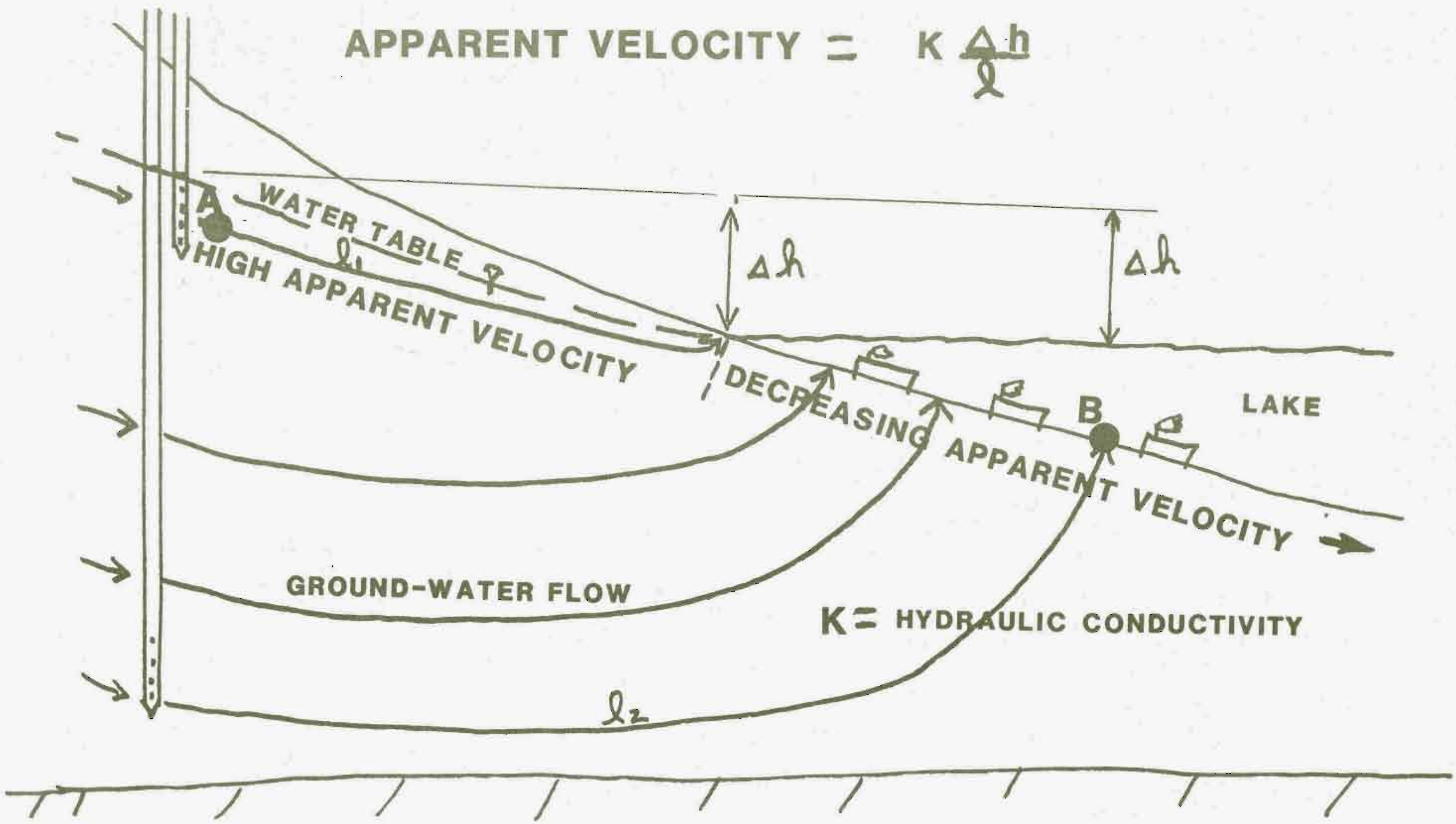

Figure D1: Schematic of beach area. The apparent velocity at A is greater than at B.

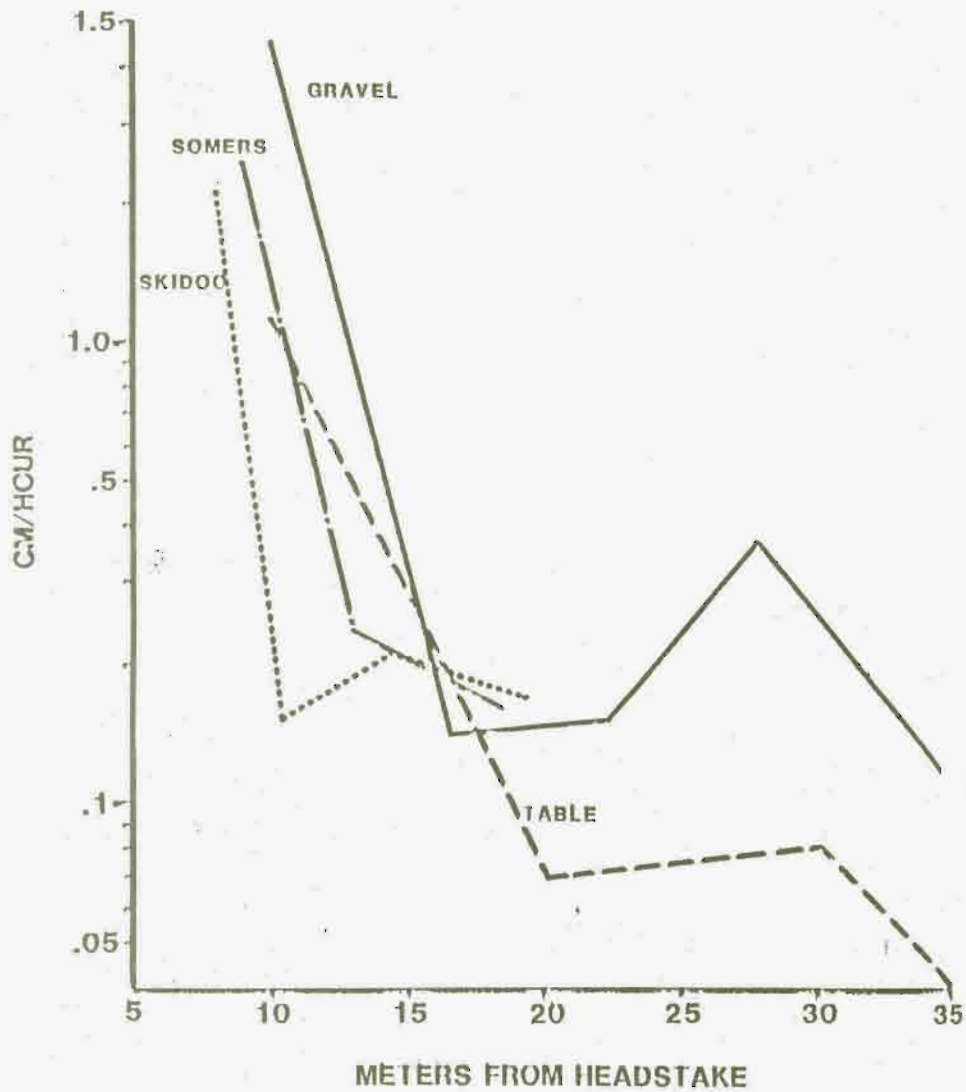

Figure D2: Apparent Velocity Profile October-November 1983 described above, the apparent velocity at seepage meters should increase with the drop in lake stage because the shoreline moves closer to the meters and the water table steepens. A review of the data presented in Appendix A shows that at Gravel and Yellow Bays the apparent velocities did increase during lake stage decline. The lake rise in April and May results in the movement of the shoreline away from the meters. This results in a reduction in the apparent velocity at the metered sites.

Finally, the timing and rates of lake stage change could also affect the apparent velocity values measured for the same period of time in different years.