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ELF Communications System
Terminal Grounds Seasonal Variation Pilot Study -- May 1987 to November 1988

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J. R. Gauger
R. G. Drexler

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A pilot study was conducted to determine the nature and magnitude of seasonal variations in ELF Communications System ground terminal safety parameters and to identify the most appropriate methodology for ground terminal seasonal monitoring. This study was conducted at the Navy's ELF Communications System's Wisconsin Transmitter Facility in northwestern Wisconsin over a seventeen month period from May 1987 to November 1988. Measurements of ground terminal step voltages and body currents at twelve test locations encompassing the principle terrain and soil types of the area were taken using several measurement methodologies. This report documents the pilot study and measurements, presents an analysis of the nature and magnitude of seasonal ground terminal variations, identifies the measurement methodology of choice for all-season monitoring, and makes recommendations for future monitoring of the ELF terminal grounds.

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FOREWORD

This report documents the results of a pilot study of the seasonal variations in ELF Communications System ground terminal safety parameters. Measurements using various methodologies were conducted at 12 test points over a 17 month period from May 1987 to November 1988. This work was funded by the Space and Naval Warfare Systems Command, Submarine Communications Project Office. Work was performed by IIT Research Insitute (IITRI) under Contract Number N00039-88-C-0065. IITRI technical personnel for the effort were Messrs. R. G. Drexler, J. R. Gauger, W. F. Lancaster, T. A. Olson, J. A. Rubino, and M. W. Zankl.

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TERMINAL GROUNDS SEASONAL VARIATION PILOT STUDY
MAY 1987 TO NOVEMBER 1988

1. BACKGROUND

SPAWAR interest in seasonally-induced variations of ELF ground terminal safety parameters dates to 1977 and the publishing of the National Academy of Sciences (NAS) report "Biologic Effects of Electric and Magnetic Fields Associated with Proposed Project Seafarer." In this report the NAS expressed concern for assuring the safety of ELF ground terminals under all conditions. To meet the NAS concerns, SPAWAR adopted a conservative ground terminal safety specification and established a grounds monitoring program.

The "ELF Project Plan For Electrical Safety Monitoring of System Ground Terminals" was drafted for SPAWAR by IITRI in February 1984. It stated that monitoring tests "... must be performed periodically, for a variety of seasonal conditions, and during the life of the ELF system.", and that monitoring "... will support statistical studies of the variables and their dependence on weather conditions, surface contact resistance, and measurement location." The monitoring tests called for in the Plan included an annual safety measurement survey similar in nature to acceptance tests, as well as considerations for seasonal monitoring at special sites. Monitoring at special sites were envisioned to encompass a variety of seasonal and weather conditions, measurements with both rod and pad-type earth contacts, and a variety of soils and soil surface conditions.

The 1984 Plan did not, however, address the specifics or extent of the seasonal monitoring tests because several questions about the nature of grounds seasonal variations remained unanswered. These questions were:

- When and how often must seasonal measurements be taken in order to assure that the ground terminals are safe all year?
- What kind of probe is best for all-season measurement?
- Do the parameters that affect ground terminal safety have enough seasonal variation to necessitate long-term seasonal monitoring in the first place?

Therefore, a pilot study was formulated with the objectives of performing preliminary tests to study seasonal variations in ground terminal safety performance and accumulating a seasonal data base over a year's time. On the basis of the preliminary tests, the above questions could then hopefully be answered sufficiently well to allow development of a rational grounds seasonal monitoring plan. The proposed Grounds Seasonal Variation (GSV) Pilot Study was presented to the ELF Environmental Review Committee on 20 April 1987, and implemented soon thereafter. The study and its results are discussed in the following text.

2. PILOT STUDY DESIGN AND IMPLEMENTATION

2.1 Study Design and Layout

The GSV Pilot Study was designed to observe and measure the variability of ground terminal step voltages (SV) and body currents (BC) with respect to several parameters, as follows:

- Determine SV and BC variations as a function of seasonal climate.
- Determine SV and BC variation as a function of terrain type.
- Determine SV and BC day-to-day variations as a function of rainfall.
- Determine SV and BC measurement variation as a function of probe type and measurement technique.
- Determine the difference in BC variation in high BC areas compared with low BC areas.
- Determine the effectiveness of gravel fill in reducing BC's for all weather conditions.

Twelve test points were established for the study along the ground terminal rights-of-way of the Wisconsin Transmitter Facility (WTF) by IITRI personnel the week of 27-30 May 1987. The test points were chosen carefully to insure integrity of the study while minimizing manpower requirements. Considerations for site selection included:

- Site accessibility needed throughout the year.
- Test points needed at several ground terminals.
- Ground terminal study areas should have a variety of terrain types within walking distance of each other.

- Multiple samples (replicates) needed for each terrain type.
- At least one high and one low BC test point needed for each terrain type.

Twelve test points selected included three test points for each of the four major terrain types:

1 - Loamy soil with vegetation cover
2 - Sandy soil with little or no vegetation
3 - Bog with standing water
4 - Gravel fill (over bog or solid ground)

The test points were distributed among three of the WTF ground terminals. Table 1 lists the test points by terrain type, and gives the ground terminal location and site number. Figure 1 shows the WTF antenna and ground terminals with relative locations of the test points; exact locations along the ground terminal rights-of-way are shown in Figures 2-4.

2.2 Test Probes

A semi-permanent test fixture, illustrated in Figure 5, was installed at each of the twelve test point locations to eliminate measurement positioning errors from visit-to-visit. As shown, the fixture also serves to hold a pair of 7-1/2" long by 1/2" diameter rod electrodes at a fixed spacing of one meter, and has a vertical post to raise a test jack connected to the electrodes above winter snow cover. At the request of the U.S. Forest Service, these fixed probes were flagged and painted to enhance their visibility in the R.O.W. They were also labeled as a scientific study, and posted information on where to direct inquiries.

Design of the fixed electrode probes, as well as the standard rod-type step probe used for grounds safety measurements and the pad-type step probe, is based on the Institute of Electrical and Electronics Engineers (IEEE) Standard 80-1986. This standard models the average adult male body in electrical terms and defines step voltage (SV) and body current (BC) as shown in Figure 6. The human foot is modeled with an eight centimeter radius disk and the human body resistance is set conservatively at 1000 ohms. The standard (rod-type) step probe, shown in Figure 7, uses the same rod electrodes for

Table 1 Grounds Test Points at the WTF

Terrain type	Site no.	Location (Ground terminal)	Monitored by a data logger ??
Loam with vegetation	1	South	Yes
	7	East	No
	12	East	No
Sandy soil with slight vegetation	5	East	No
	8	North	Yes
	9	North	Yes
Bog with standing water	3	South	Yes
	6	East	No
	10	North	Yes
Gravel fill	2	South	Yes
	4	East	No
	11	North	Yes

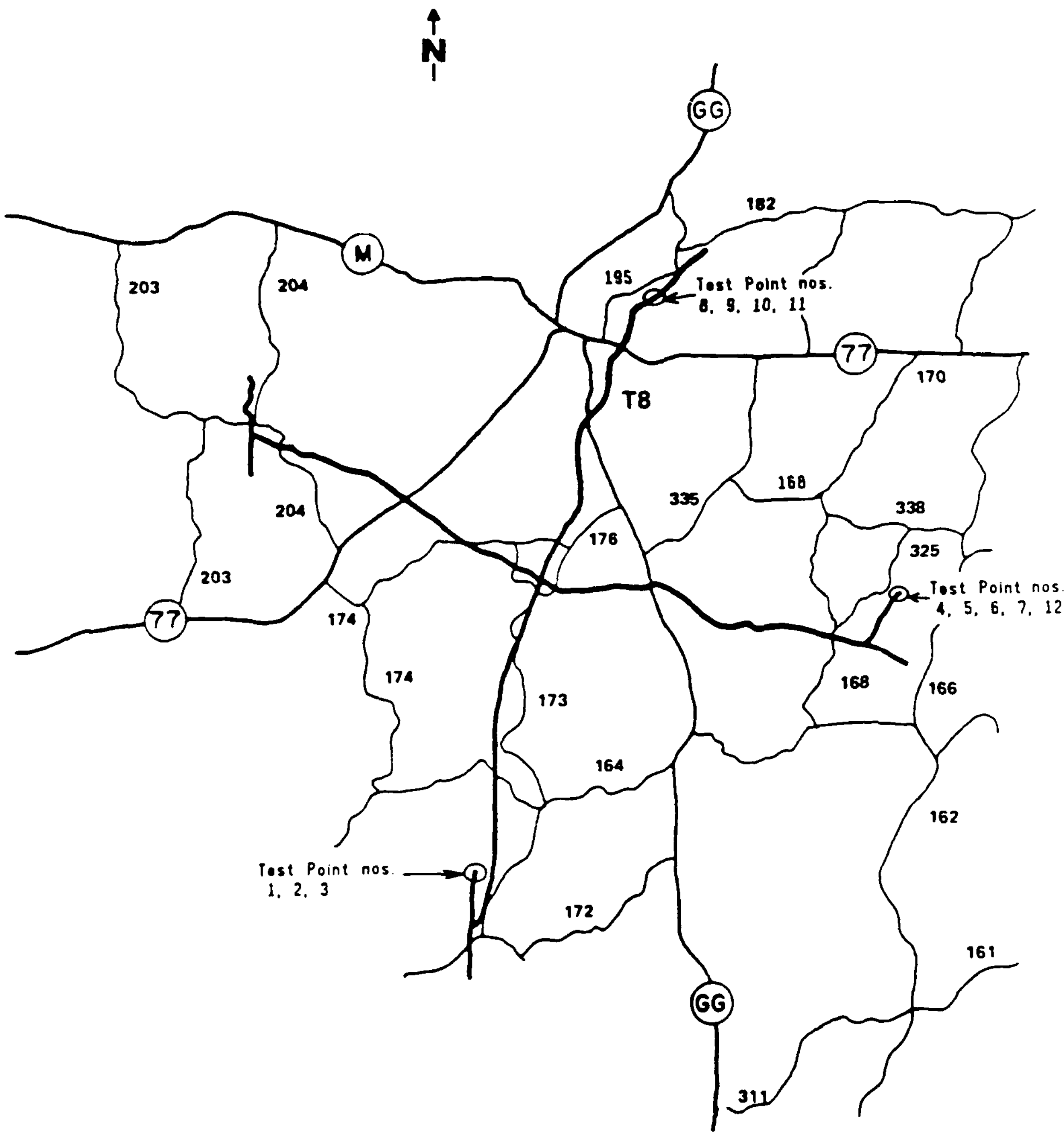


Figure 1. Wisconsin ELF antenna with Grounds Seasonal Variation Pilot Study test point locations.

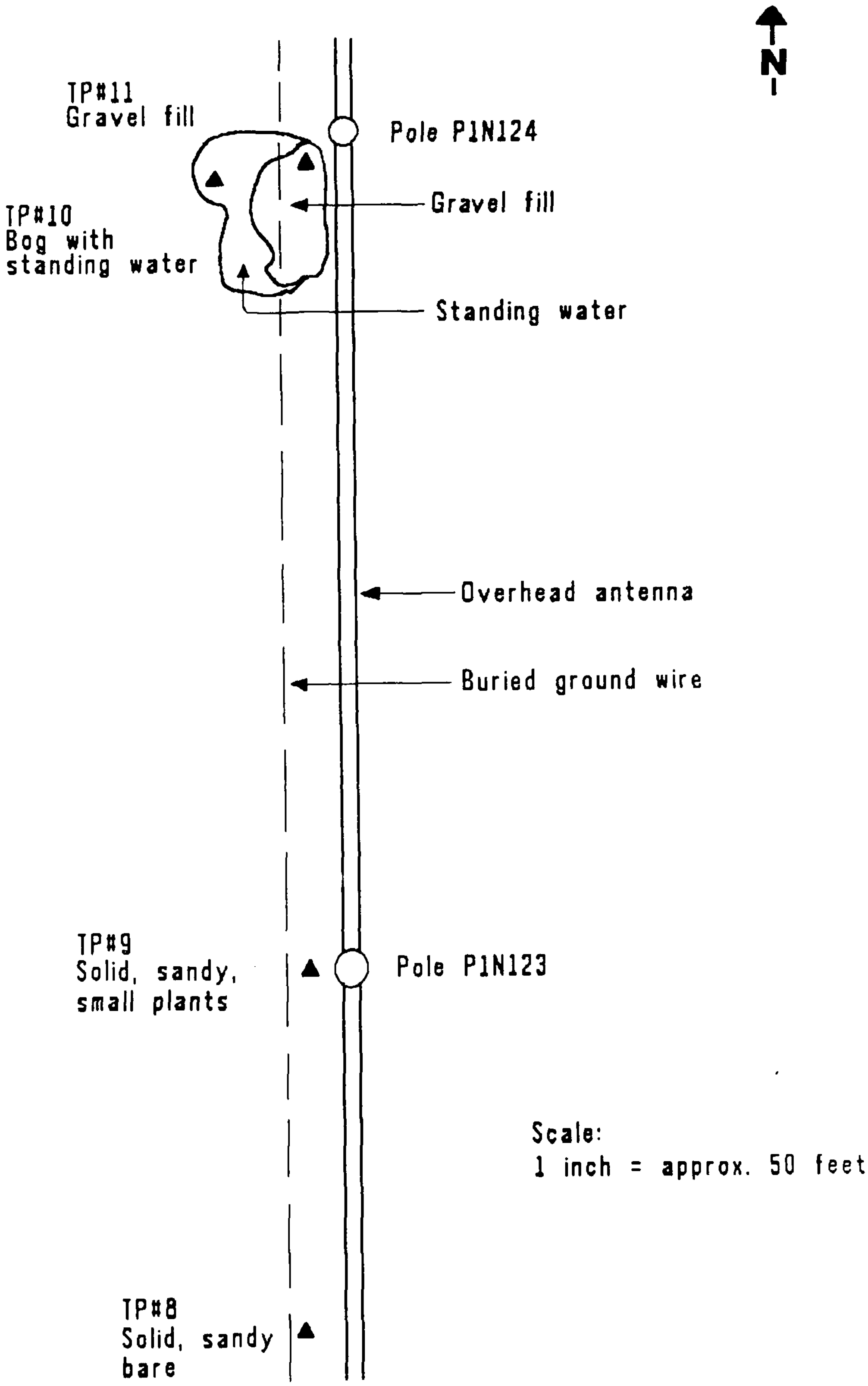


Figure 2. North ground test points

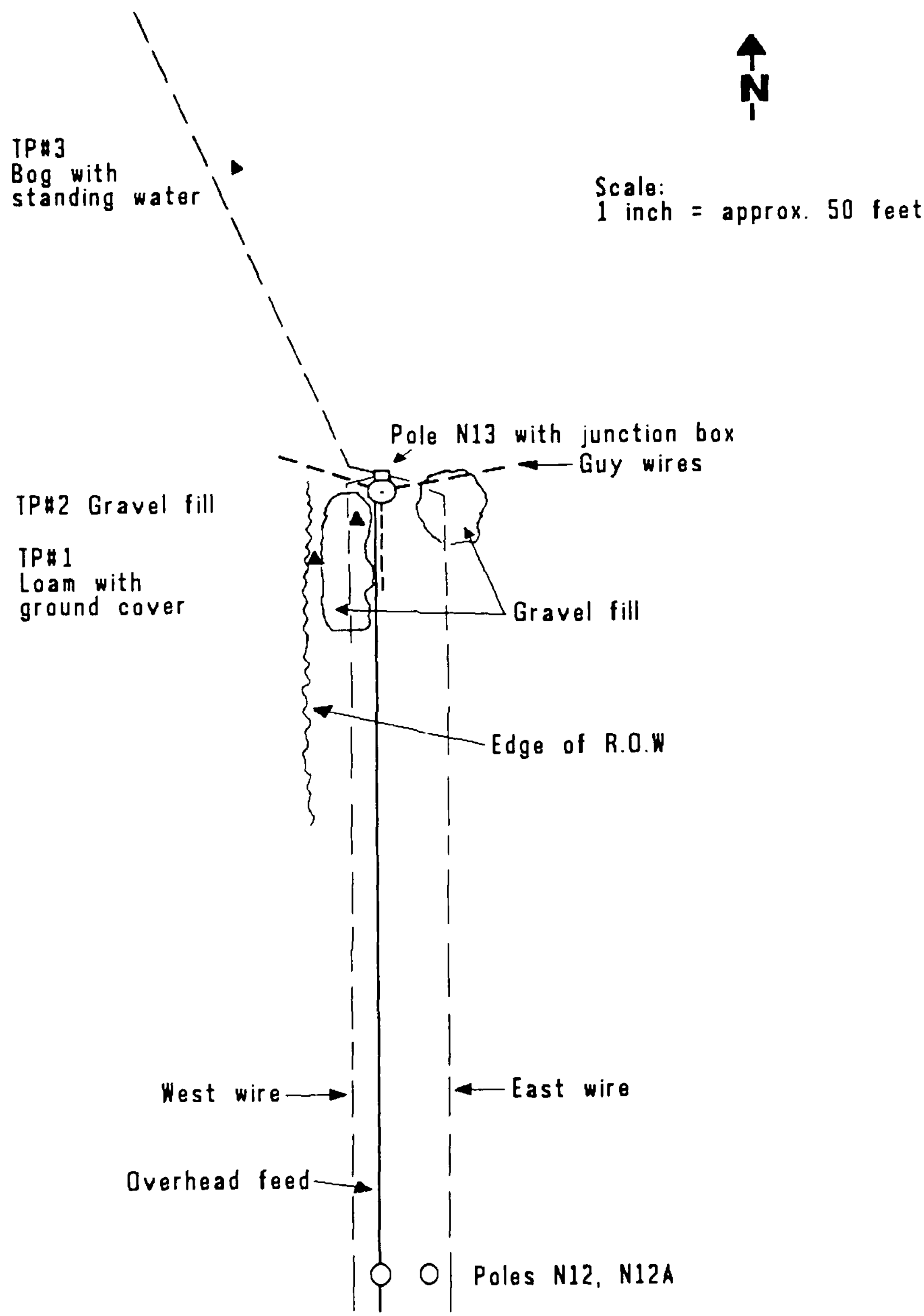


Figure 3. South ground test points

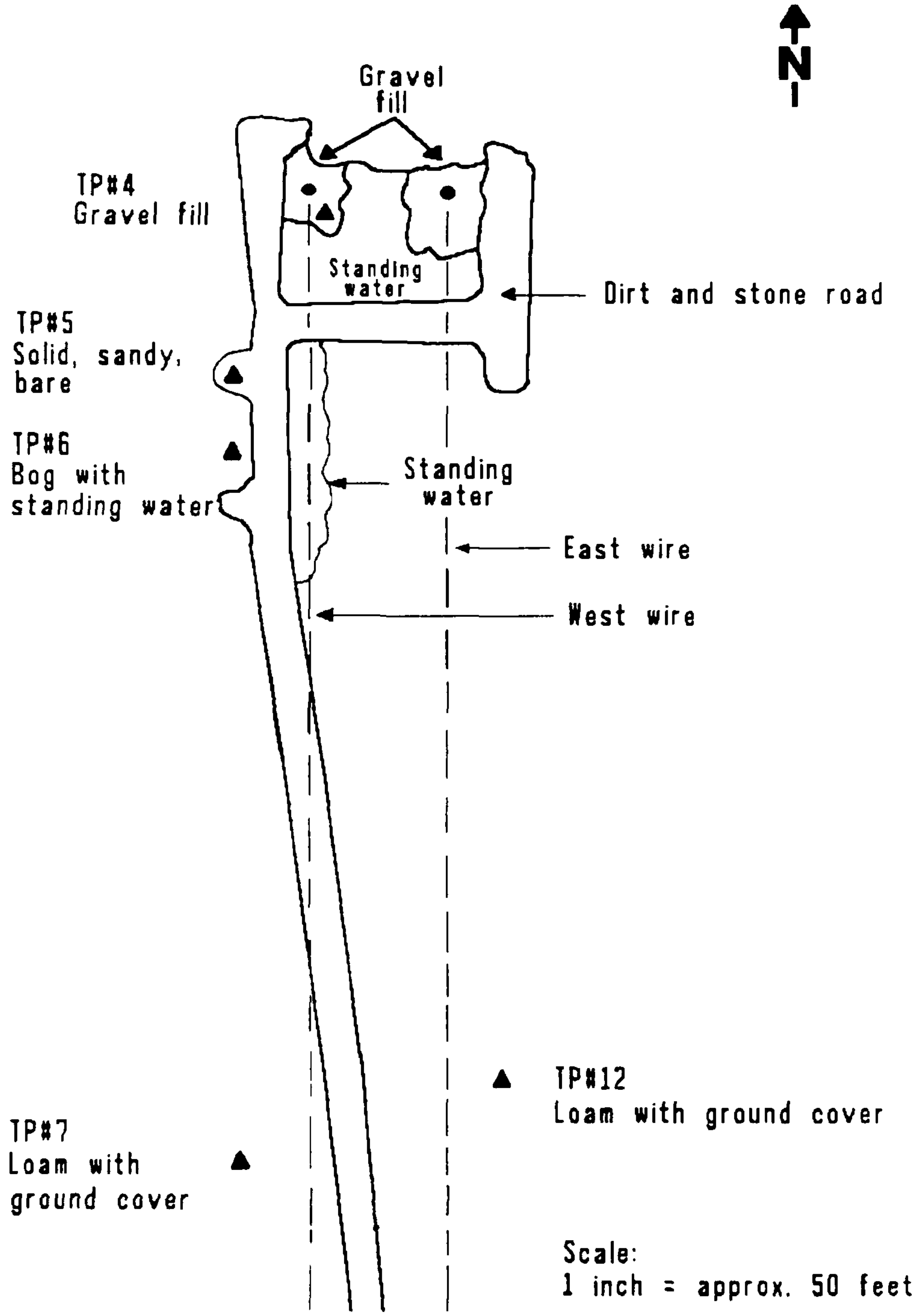


Figure 4. East ground test points

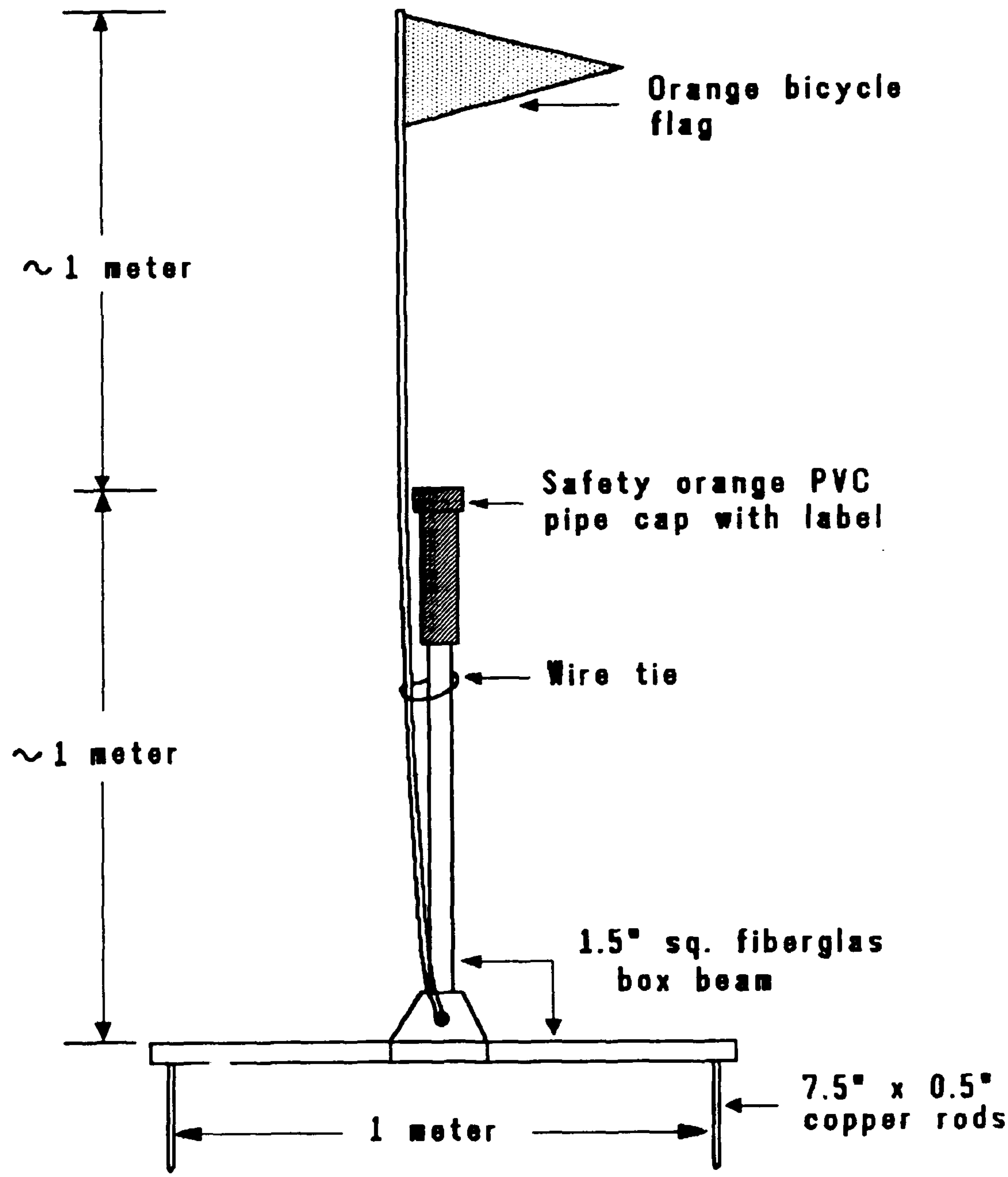
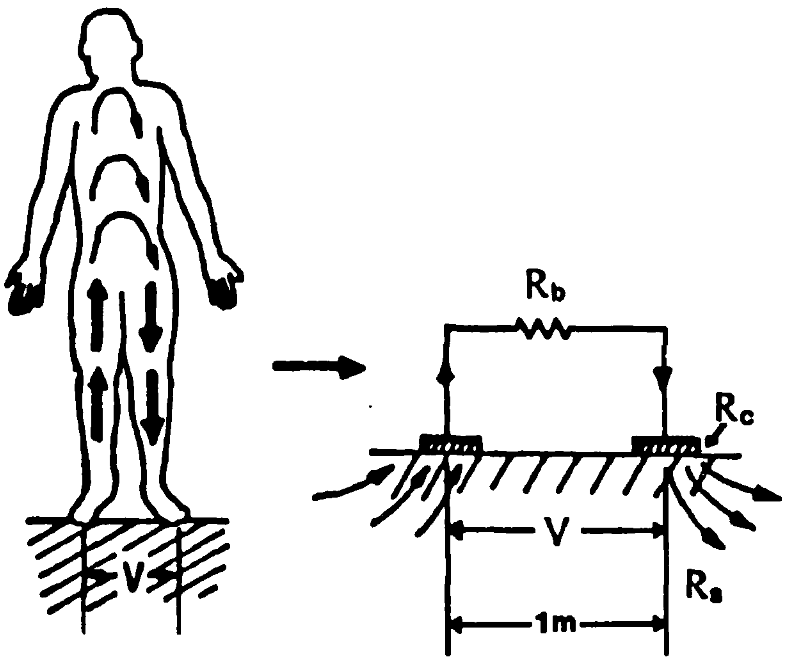


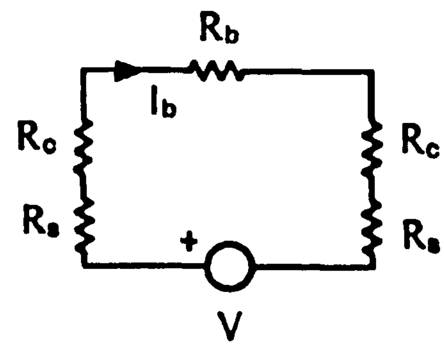
Figure 5. Fixed probe

Step Voltage



Body Current

$$I_b = \frac{V}{R_b + 2R_s + 2R_c}$$



R_c = O (conservative assumption)

$R_s = \frac{1}{4a\sigma} = \frac{3.1}{\sigma}$ (8 cm radius disc)

$R_b = 1000\ \Omega$

Figure 6. IEEE standard 80-1986

Step Voltage Probe

[1m spaced rods equivalent to 8 cm radius disks]

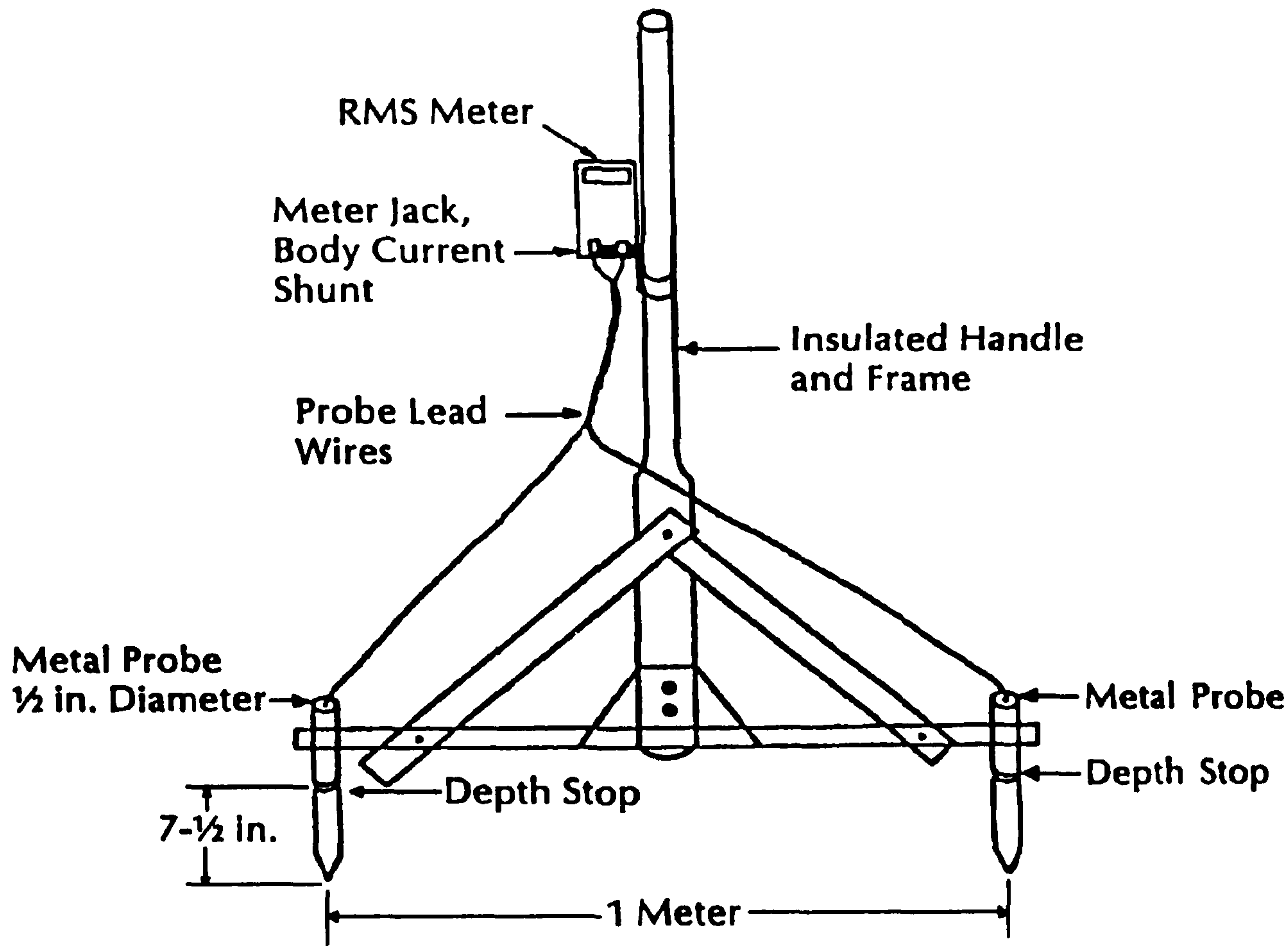


Figure 7. Standard step probe

earth contacts as the fixed probes. These rods, when fully inserted in the earth, have a spreading resistance (R_S) equal to an eight centimeter radius disk contacting the surface. On both probes, the rods are mounted on and are spaced at one meter by a rigid fiberglass frame. The pad (step) probe is identical to the standard step probe except that the rod electrodes are replaced by eight centimeter radius, copper-clad disk electrodes, as called out in the IEEE standard.

2.3 Comparative Measurements

Monthly measurements were conducted by IITRI personnel at each of the twelve test points using all three measurement probe types. A Fluke 8060A true r.m.s. digital multimeter was used as the measurement instrument. A 1000 ohm, one-percent tolerance resistor was placed in shunt with the voltmeter for equivalent body current readings. Step and pad probe measurements were taken with the probes placed parallel with, and about six to eight inches directly north of, the fixed probe locations. The amount of pressure applied on the disks of the pad probe is critical because this affects the contact resistance (R_C in the IEEE model) between the pads and the earth. To insure a consistent and reasonable value for R_C, a man of average weight stood on the bottom crossbeam of the pad probe with one foot near each pad to evenly distribute his weight. The same personnel conducted all pad probe measurements.

2.4 Data Loggers

Special data logger instruments were designed and fabricated to allow collection of data more frequently and cost effectively than would be possible using field personnel. Each data logger contains a programmable, battery-powered onboard computer and special input signal conditioning and control circuitry, and is housed in a weather-proof enclosure. The instruments are able to measure and record data at any user-programmed interval. Measurement data are stored in computer memory, and can easily be retrieved using a portable personal computer and serial communications cable. SV's and BC's could thus be monitored and recorded unattended for extended periods of time in all seasons and weather conditions.

Loggers were deployed and programmed to monitor the fixed electrodes at the seven sites identified in Table 1. Three successive readings of the SV and BC were taken once each hour. The average of the three readings was calculated and its value recorded in memory along with the date and time of measurement. IITRI personnel offloaded the collected data at each data logger when conducting the monthly comparative measurements. All data was reviewed on site to verify data retrieval and proper operation of the logger. The data was then archived on floppy diskettes, as well as hard copy printout, and the loggers were re-initialized for the next measurement period.

2.5 Weather Data

Daily weather summaries were obtained monthly from the State of Wisconsin Department of Natural Resources (WDNR) in Hayward, Wisconsin to allow correlation with collected SV and BC data. These summaries included daily high and low temperatures, daily rain or melted snow amounts, daily snowfall amounts, and total accumulation of snow on the ground.

3. DATA PRESENTATION AND ANALYSIS

3.1 Monthly Comparative Measurements

3.1.1 Data Presentation

The SV and BC measurement data from the monthly comparative measurements using the fixed, step, and pad probes are tabulated and plotted in Tables A1 - A12 and Figures A1 - A12, respectively, which are found in Appendix A. The time period covered is from 28 May 1987 to 8 November 1988. Plots of BC data only, grouped by test points with similar terrain and also by probe type, are presented in Figures A13 - A24 for ease of visual comparison. Statistical summaries of the data in Tables A1 - A12 are given in Tables A13 - A18.

3.1.2 Analysis of Monthly Measurements

The measurement data plotted in the figures in Appendix A illustrate several seasonal trends in the SV's and BC's at the WTF ground terminals. A typical plot of monthly data is presented in Figure 8.

The SV and BC trends which are indicated can be summarized as follows:

- SV's are generally quite constant over all seasons but fixed electrode measurements do exhibit a slight increase over the winter months beginning about mid-November and lasting until about May. (Figures A1 - A12).

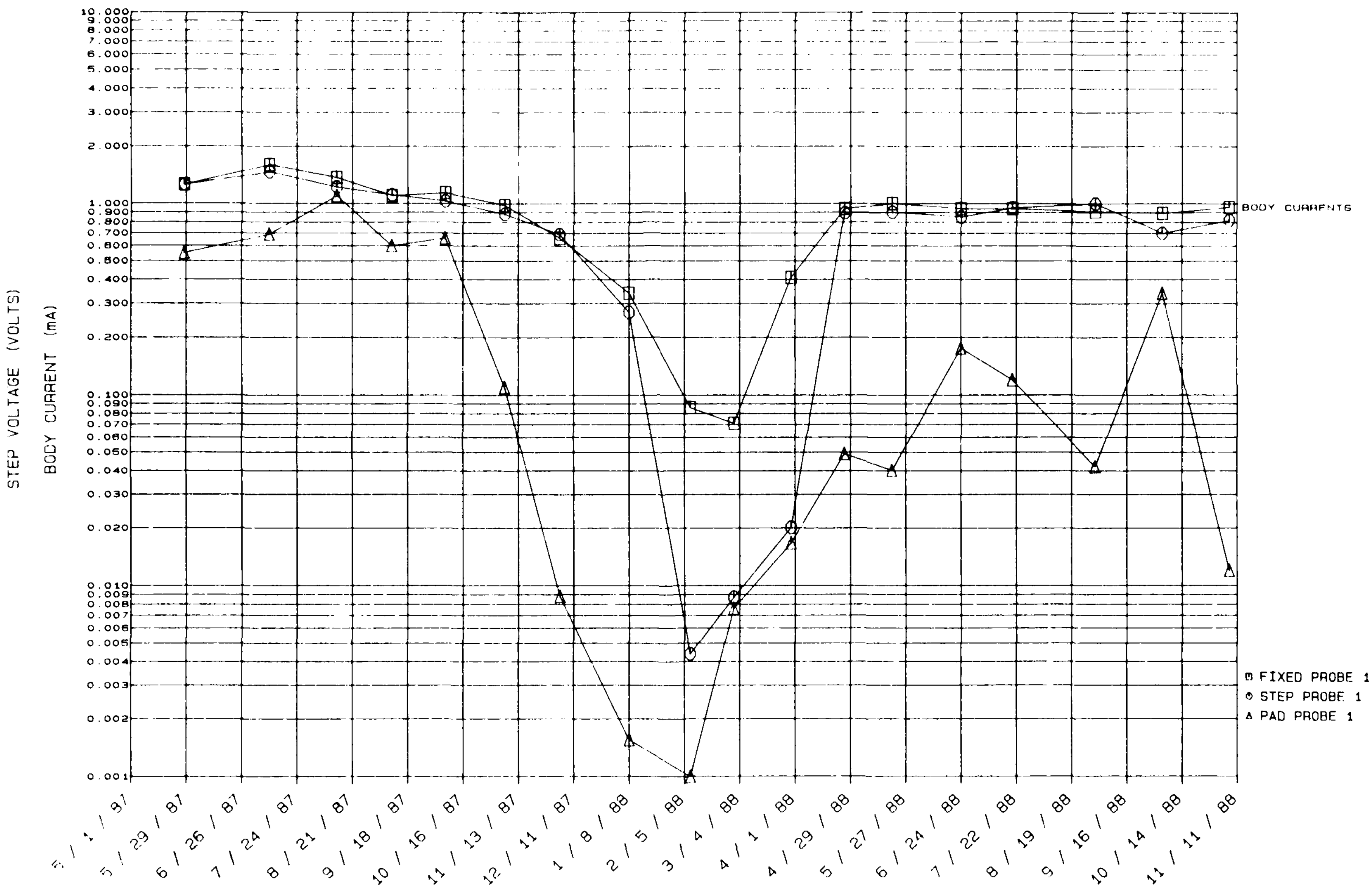


Figure 8. Plot of Monthly Comparative Measurements at Site 1, Loam With Vegetation

- The magnitudes of the SV increases are on the order of a few to several tenths of a volt, and appear to be independent of the magnitude of the SV's themselves. (Figures A1 - A12)

- BC's for all terrains except bogs exhibit a one to three order of magnitude decrease in the winter months, as the soil becomes colder and eventually freezes. (Figures A1, A2, A4, A5, A7-A-9, and A12).

- BC's in bogs are generally quite uniform over the entire year; they decrease only from zero to a factor of three over the winter months for fixed electrodes, probably because the bogs do not freeze to the full depth of the electrodes. (Figures A3, A6, and A10).

- BC's for loamy and sandy soils are generally constant over the warmer months, decrease gradually from fall to winter, and then rebound in the early spring. (Figures A1, A5, A7, A8, A9 and A12).

- BC's for gravel treated areas tend to highly variable in all seasons. (Figures A2, A4, and A11).

- BC's for like terrain types and the same probe type track each other very well. (Figures A13 - A-24).

The monthly comparative measurement data also indicate that a fixed-position probe with rod-electrodes is the choice for all-season measurement of ground terminal safety parameters. The reasons for this choice are as follows:

- Rod electrodes give consistent and repeatable SV and BC measurements on all terrains.

- Fixed rod electrodes consistently provide the most conservative SV and BC Measurements in all seasons.

- Rod-type step probes, while nearly as consistent and conservative as fixed electrodes in warmer weather, cannot be used when the ground is frozen.

- Fixed rod electrodes eliminate variability in the measurement data which would normally be associated with positioning errors of the step probe when taking a new set of measurements

Pad-type step probes were judged unsatisfactory for grounds seasonal measurements. Pad probes provided highly variable and generally unrepeatable BC measurements on all terrains except bogs, and for all seasons. Pad probes were especially poor on gravel, on frozen or snow-covered ground, and under dry surface conditions. BC measurements with pad probes were typically 2 to 10,000 times lower than fixed or step probe measurements, except in standing water.

More detailed analyses of the SV and BC variabilities for each of the three measurement probes are provided in the statistical summaries of Tables A13 - A18. The average, standard deviation, minimum, maximum, and ratio of max/min have been calculated for each test point for three time periods: July-Oct. 1987, May-Oct. 1988, and July 1987 - Oct. 1988. The first two periods were chosen because they cover the time of year when annual grounds monitoring safety measurements are usually made. As indicated by the statistical data, measurement variability over these periods is considerably less than over the entire year.

The data in each statistical table is also organized by terrain type. As shown, gravel treated areas have the highest SV and BC variability, regardless of probe type, followed by sandy soil and then loamy soil. Bogs, as expected, have the lowest variability of measurement data in any season, especially when data is collected using fixed electrode probes. Overall, the statistical summaries lend further support to the selection of fixed rod electrodes as the choice for all season monitoring because they exhibit the least variability in measurement data for all conditions.

3.2 Data Logger Measurements

3.2.1 Data Presentation

Plots of the SV and BC measurement data taken by data loggers for the period of 20 July 1987 through 2 November 1988 are contained in Appendix B. The plots in Figures B1 - B7, which cover this entire period, are of the daily averages of data logger measurements taken hourly. The averages are based only on the time when the WTF was actually transmitting. Transmitter off times were determined by inspection of the WTF operating log, and are indicated by vertical marks along the top of the graphs. Similarly, periods when a data logger was not operating are marked by a pair of X's. On these plots, each division of the horizontal axis represents a two-week period of time.

Actual hourly measurements are plotted in Figures B8-B14. Each figure is comprised of eight individual plot graphs, labeled A through H, which cover a two month period. On these plots, each horizontal axis division represents two days. Periods of transmitter off time or data logger inoperation are marked as previously indicated.

Weather information is provided on all figures on a separate graph below the SV/BC plot. Daily minimum and maximum temperatures in degrees fahrenheit are charted as continuous curves. Daily rainfall or rain equivalent of snowfall amounts in inches are represented as solid vertical bars, snowfall in inches by open vertical bars.

3.2.2 Analyses of Hourly Data

A brief review of the hourly SV and BC data presented in Appendix B gives indication of the same season-to-season trends in these parameters as were evident from the monthly comparative measurements. These variations, however, are shown in much greater detail, as illustrated in Figure 9. Closer scrutiny of the hourly data reveals several additional types of variation other than those which occur from season-to-season, and which are not evident from the monthly data. These new variations affect primarily the BC's, and can be summarized as follows:

- BC's exhibit day-to-day variations, usually increases, which correspond to the occurrence, duration, and amount of rainfall.
- BC's (and to some extent SV's) exhibit hourly variations on a twenty-four hour cycle for some soil and weather conditions which appear to be correlated to surface moisture (dew) and/or temperatures.
- BC's exhibit year-to-year variations for the same seasons because of drought or abnormal precipitation.

These variations are discussed more thoroughly in the following sections.

3.2.2.1 Rainfall-Induced BC Variations

Body current measurements for all terrains exhibit abrupt increases during the spring through fall months which can be correlated visually to the occurrence of rainfall. See Figure 10 and graphs a,b,e,f,g,h of Figures B8 through B14. The magnitude and rate of the increases in BC, which generally

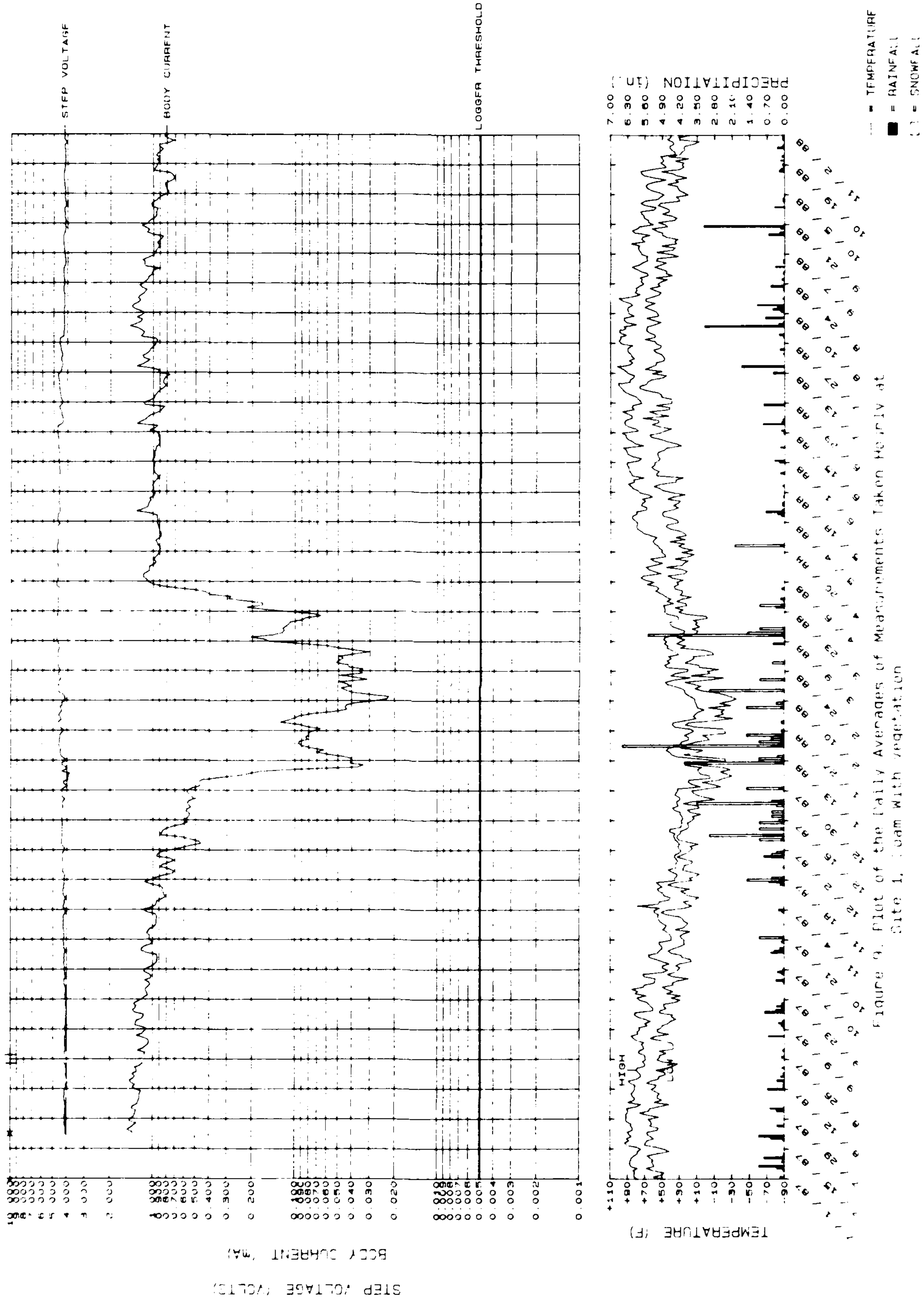


Figure 9. Plot of the Daily Averages of Measurements Taken Hourly at Site 1, Loam With Vegetation

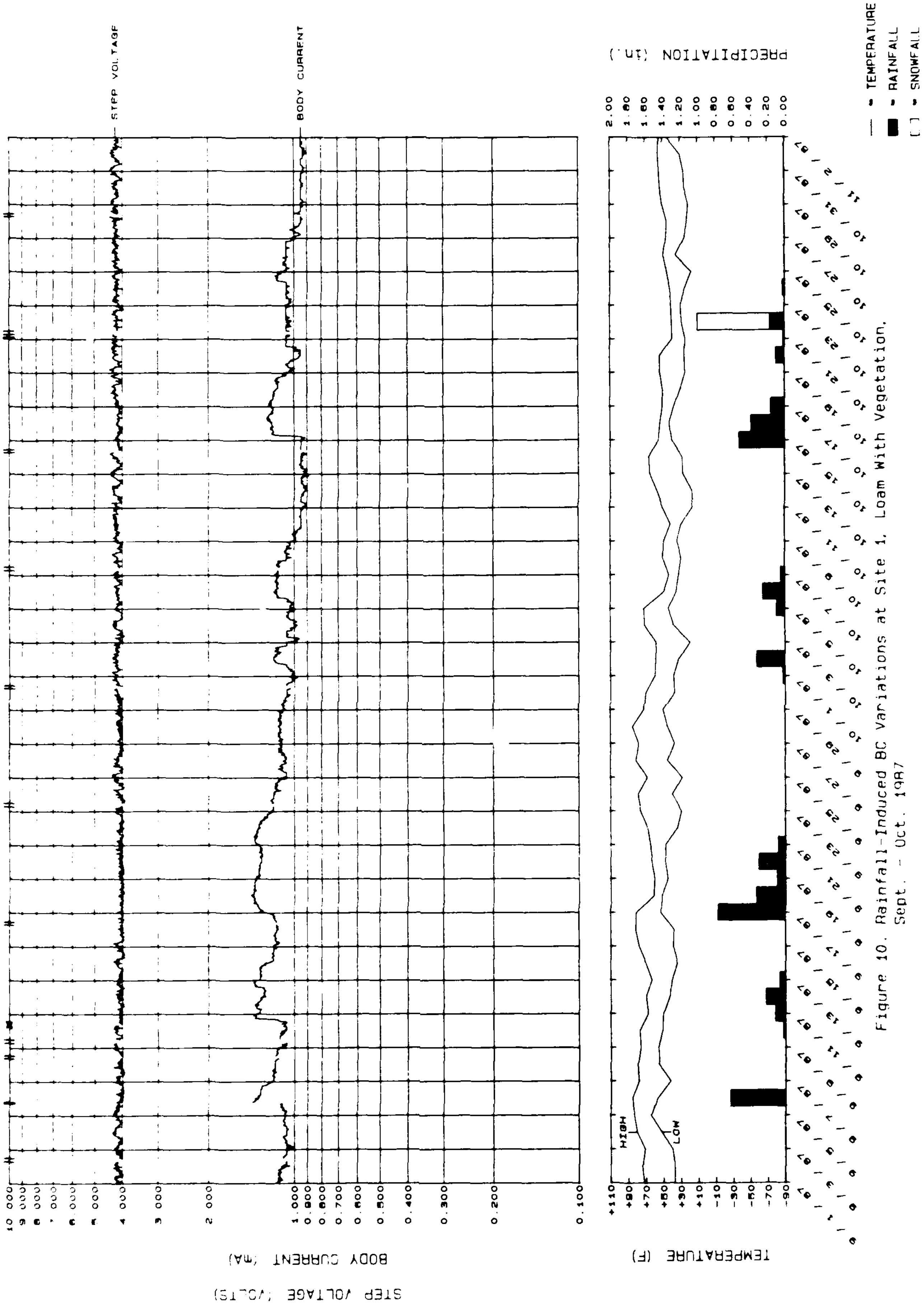


Figure 10. Rainfall-Induced BC Variations at Site 1, Loam With Vegetation.
Sept. - Oct. 1987

take place over a period of twenty-four hours or less, appear to be dependent on many factors. These include the amount and duration of the rainfall, the length of time elapsed since the previous rainfall, the overall soil moisture conditions, and the type of terrain.

Rainfall-induced BC increase factors, organized by terrain type and year, are summarized in Table 2. Two sets of factors are given for 1988: one set for the main drought period of May through July, and one set for August through October when rainfall returned to near normal. A typical and a maximum BC increase factor are given in the table for each time period.

The hourly measurement data indicate that during periods with normal rainfall and soil moisture, such as July - October 1987, BC increases due to rain are typically less than five to ten percent in bogs and in loamy soil terrains (Figures B11 and B12 plots a,b,c). This is expected, because these terrains normally have standing water or are kept moist by vegetation cover. In these areas, BC's decrease gradually from one rain to the next. Rain-induced BC increases in sandy soils are slightly greater, typically twenty to forty percent. This is because sandy soils dry out quickly, allowing greater decreases in BC's between rainfalls. Gravel treated areas dry out even more rapidly and to a much greater extent than do sandy soils. As a result, BC increases on gravel are more dramatic, with wet/dry ratios of ten or more. (Figure B9 a,b,c). Gravel treatments in bogs are a special case. Here, BC wet/dry ratios can approach a hundred, as the bog water level rises and falls. (Figure B14 a,b).

Extended drought conditions, such as those experienced in May - July 1988, can greatly depress "normal" baseline BC measurements. Thus, when rain does come, BC increases are substantially greater as the BC's temporarily return to "normal" levels. As illustrated by the August - October 1988 period, several substantial rainfalls can be required to return to a relatively normal (pre-drought) BC baseline (Figures B12, B13, and B14 plots g and h). Sites 3 and 8 had not recovered as of November 1988 (Figures B10 and B11 plots g,h).

3.2.2.2 Daily (24 hr) BC Cycles

A twenty-four hour cycle in BC variations can be observed to some extent at all test points during the months when the soil is not frozen, as illustrated in Figure 11. The phenomenon is most evident for sandy soils (sites 8 and 9), as

Table 2
Rainfall-Induced BC Increase Factors

Terrain type	Site no.	1987 July - Oct. Typ.	1987 July - Oct. Max.	1988 May - July Typ.	1988 May - July Max.	1988 Aug. - Oct. Typ.	1988 Aug. - Oct. Max.
Loam with vegetation	1	<1.1	1.3	<1.3	1.5	<1.2	1.3
Bare sandy soil	8	1.2	2.0	10	40	1.6	2.5
	9	1.4	1.4	1.4	9.0	2.0	10
Bog with standing water	3	<1.05	1.2	10	10	10	10
	10	1.1	1.3	<1.3	1.5	1.2	1.3
Gravel fill	2	6.0	12	10	15	5.0	12
	11	10	90	<3.0	10	2.0	10

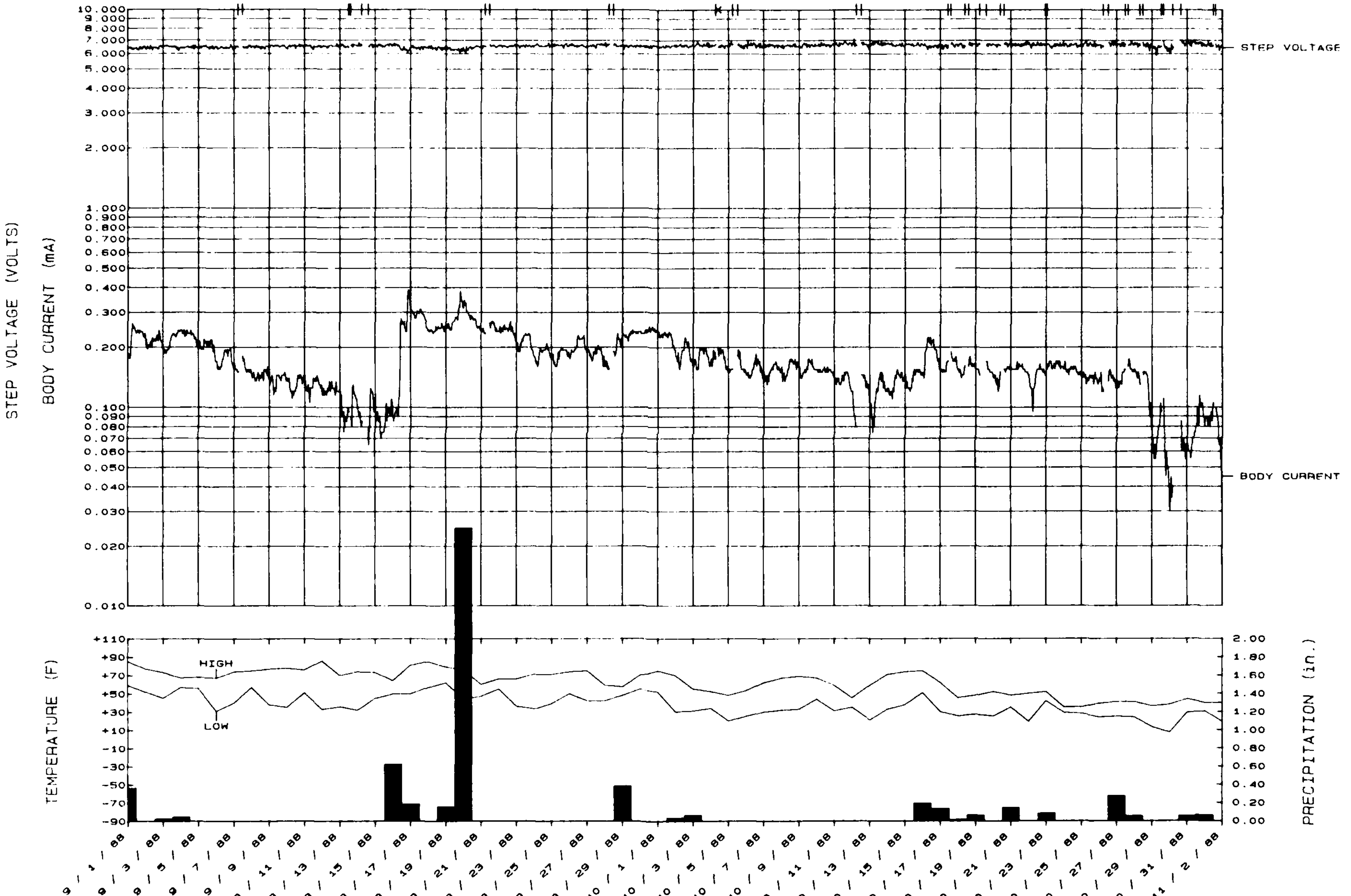


Figure 11. 24 Hour BC Cyclic Variations at Site 8, Sandy Soil,
Sept. - Oct. 1988

illustrated in Figures B11 and B12. For these sites a daily cyclic BC variation of up to thirty percent or more can be seen almost continuously from April through November. The BC cycle peaks about mid-day, and bottoms out at night. Daily cycles are less noticeable for the other terrains which have lower cycle amplitudes because of the compressed scales of the graphs in the figures. However, some good examples can be found at bog Site 10 in Sept.-Oct. 1987 (Fgiure B13-b) , gravel-treated Site 11 in Apr.-May 1988 (Figure B14-e,f) and gravel-treated Site 2 in May-June 1988 (Figure B9-f). At loamy-soil Site 1 (Figure B-8), daily cycles were very slight or not detectible at all, even when examined with expanded current and time scales on the BC plots.

Daily cycles in BC measurements can be explained in terms of the dependence of soil conductivity/resistivity on soil temperature and its co-dependence on soil moisture content. Soil conductivity versus temperature tables given in Appendix A of the NAS report indicate that the conductivity of 400 ohm-m soil with about ten percent moisture content will nearly double with a temperature increase from 68 to 77 degrees fahrenheit. At thirty percent moisture content the increase is only about ten percent. As soil conductivity increases, the effects of temperature and moisture diminish.

Thus, on sandy soils, which typically have low conductivities and moisture content, body current measurements might well be expected to vary by thirty percent from day to night with a soil temperature swing of only nine degrees fahrenheit. Sandy soil temperature changes of this magnitude seem plausible in light of the ability of sand to absorb and radiate heat quickly, and with summer day-to-night air temperature excursions of forty degrees being common in northern Wisconsin. Gravel-treated areas show less daily BC variation because gravel piles probably retain heat better and cool down slower than sandy areas. Similarly, soils with higher conductivities and moisture contents such as loams and bogs should have lower daily BC variations because their conductivities are much less sensitive to changes in temperature. Soil temperature changes at loamy soil Site 1 should also be less than at other sites because this site is partially shaded by trees.

3.2.2.3 Year-to-Year BC Variations

Year-to-year variations in BC measurements occur primarily because of abnormal weather patterns during a given year. Usually the abnormalities would involve getting too much or too little precipitation, but extremes in temperature could also be a factor. For example, a very cold winter or the early onset of below freezing temperatures could cause the soil to remain frozen over longer periods than normal. This would result in lower BC's in the early spring or late fall.

May through July 1988 was a prime example of the effects of an extended drought. BC "baseline" measurements for all sites during this period are significantly lower than those in the summer of 1987 and the early spring of 1988. Even after the resumption of more normal rainfall in August through October of 1988, the BC measurement levels at most sites still have not returned to 1987 levels for the same period. A typical example is found in Figure 12. Furthermore, 1987 also had below-average rainfall, so the BC baselines for 1987 are probably depressed as well. Thus it can be expected that the BC measurement baselines will continue to change in future years, especially with changes in the amount and distribution of annual precipitation.

3.2.2.4 Hourly Measurement Statistics

Detailed analyses of the SV and BC variabilities for the hourly measurement data are provided by the statistical summaries of Tables 3 and 4, respectively. The average, standard deviation, maximum, minimum, and the ratio of max/min have been calculated for each of the seven sites for three time periods: July-Oct. 1987, May-Oct. 1988, and July 1987 - Oct. 1988. As with the monthly measurement statistics, the first two periods were chosen as covering the time of year when annual safety measurements are made.

The SV statistics in Table 3 indicate that the SV averages have changed little over the eighteen month study period. Some increase in variability can be seen in 1988, however, probably because of the drought conditions. The BC statistics in Table 4 show more changes. BC averages decreased by twenty to fifty percent in the summer of 1988 from 1987 at the bog and loamy and sandy soil sites, while at one gravel-treated site the average doubled. In general, the variability of the BC measurements in 1988 also increased over 1987.

4. SUMMARY AND CONCLUSIONS

A Grounds Seasonal Variation Pilot Study was conducted at the WTF ground terminals from May of 1987 through early November of 1988. The data obtained

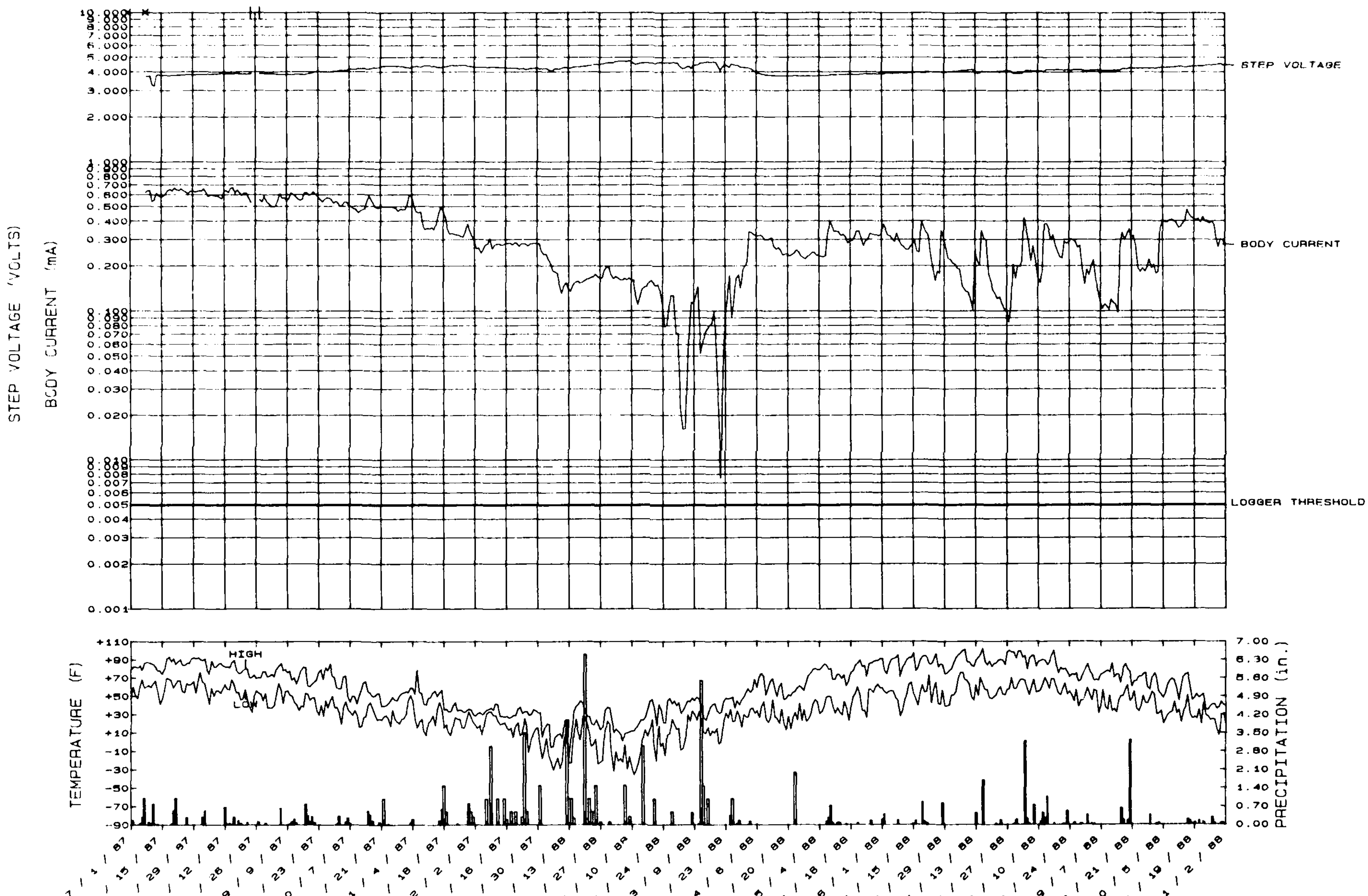


Figure 12. Year-to-Year Variations in Daily BC Averages Due to Drought in 1988 at Site 9, Sandy Soil

Table 3
Statistical Summary
for
Hourly Step Voltage Measurements

		STEP VOLTAGE (V)					
		Average ± standard deviation			$\frac{\text{MAXIMUM}}{\text{MINIMUM}}$ = RATIO		
Terrain type	SITE no.	July 1987 - Oct 1987 (4 months)	May 1988 - Oct 1988 (7 months)	July 1987 - Oct 1988 (16 months)	July 1987 - Oct 1987 (4 months)	May 1988 - Oct 1988 (7 months)	July 1987 - Oct 1988 (16 months)
Loam with vegetation	1	4.12 ± 0.10	4.38 ± 0.20	4.35 ± 0.24	$\frac{4.44}{3.84}$ = 1.2	$\frac{4.95}{3.84}$ = 1.3	$\frac{5.04}{3.81}$ = 1.3
Sandy soil with slight vegetation	8	6.07 ± 0.22	6.36 ± 0.40	6.18 ± 0.48	$\frac{6.60}{5.48}$ = 1.2	$\frac{7.13}{4.73}$ = 1.5	$\frac{7.28}{4.65}$ = 1.6
	9	3.97 ± 0.20	4.08 ± 0.18	4.14 ± 0.26	$\frac{4.53}{3.66}$ = 1.2	$\frac{4.59}{3.69}$ = 1.2	$\frac{4.83}{3.66}$ = 1.3
Gravel fill	2	5.12 ± 0.31	4.68 ± 1.16	4.48 ± 1.30	$\frac{5.76}{2.61}$ = 2.2	$\frac{5.760}{0.005}$ = 1150	$\frac{6.090}{0.005}$ = 1220
	11	2.33 ± 0.06	2.38 ± 0.09	2.31 ± 0.22	$\frac{2.76}{2.07}$ = 1.3	$\frac{2.64}{1.98}$ = 1.3	$\frac{2.76}{1.07}$ = 2.6
Bog with standing water	3	0.44 ± 0.02	0.44 ± 0.08	0.49 ± 0.08	$\frac{0.51}{0.38}$ = 1.3	$\frac{0.60}{0.11}$ = 5.5	$\frac{0.72}{0.11}$ = 6.5
	10	2.16 ± 0.09	2.19 ± 0.14	2.19 ± 0.14	$\frac{2.43}{1.89}$ = 1.3	$\frac{2.49}{1.80}$ = 1.4	$\frac{2.88}{1.59}$ = 1.8

Table 4
Statistical Summary
for
Hourly Body Current Measurements

Terrain type	SITE no.	BODY CURRENT (mA) Average ± standard deviation: July 1987 - Oct 1987 (4 months)	May 1988 - Oct 1988 (7 months)	July 1987 - Oct 1988 (16 months)	MAXIMUM/MINIMUM = RATIO: July 1987 - Oct 1987 (4 months)	May 1988 - Oct 1988 (7 months)	July 1987 - Oct 1988 (16 months)
Loam with vegetation	1	1.19 ± 0.15	1.01 ± 0.15	0.83 ± 0.41	$\frac{1.56}{0.89}$ = 1.8	$\frac{1.52}{0.66}$ = 2.3	$\frac{1.560}{0.005}$ = 312
Sandy soil with slight vegetation	8	0.28 ± 0.07	0.20 ± 0.11	0.17 ± 0.11	$\frac{0.47}{0.11}$ = 4.3	$\frac{0.595}{0.005}$ = 120	$\frac{0.595}{0.005}$ = 120
	9	0.57 ± 0.06	0.27 ± 0.10	0.32 ± 0.17	$\frac{0.72}{0.40}$ = 1.8	$\frac{0.69}{0.04}$ = 17	$\frac{0.720}{0.005}$ = 144
Gravel fill	2	0.022 ± 0.017	0.022 ± 0.019	0.019 ± 0.017	$\frac{0.095}{0.005}$ = 19	$\frac{0.125}{0.005}$ = 25	$\frac{0.180}{0.005}$ = 36
	11	0.24 ± 0.30	0.47 ± 0.38	0.41 ± 0.38	$\frac{0.975}{0.005}$ = 195	$\frac{1.16}{0.06}$ = 19	$\frac{1.160}{0.005}$ = 232
Bog with standing water	3	0.24 ± 0.02	0.17 ± 0.11	0.20 ± 0.09	$\frac{0.20}{0.09}$ = 2.2	$\frac{0.390}{0.005}$ = 78	$\frac{0.390}{0.005}$ = 78
	10	1.36 ± 0.21	1.33 ± 0.26	1.45 ± 0.24	$\frac{1.68}{0.78}$ = 2.2	$\frac{1.80}{0.65}$ = 2.8	$\frac{1.80}{0.65}$ = 2.8

and accumulated through this study have made it possible to define the nature and magnitude of seasonal variations in ground terminal safety parameters. The extent of the seasonal monitoring of ground terminals which is required as well as the appropriate monitoring methodologies have been determined. A brief summary of the Pilot Study conclusions is as follows:

- Seasonal Variations

  - Step voltages remain quite constant over all seasons and vary by only a few tenths of a volt regardless of SV magnitude, terrain type, or soil moisture.

  - Body currents exhibit season-to-season variations related to long-term soil temperature changes and the freezing of the soil in winter.

  - Body currents exhibit day-to-day variations because of rainfall-induced soil moisture changes.

  - Body currents exhibit hourly variations on a 24 hour cycle because of daily heating and cooling of the soil.

  - Body currents exhibit year-to-year variations for the same season because of abnormal weather conditions such as prolonged drought.

  - The magnitude of each type of body current variation differs greatly as a function of terrain.

- Seasonal Measurement Technique

  - Fixed rod electrodes monitored by data loggers are the choice for measurements in all seasons because this technique eliminates positioning errors, consistently provides the most conservative BC measurements, and is efficient and cost-effective for daily measurements.

  - The standard step probes cannot be used when the soil is frozen, but are the choice for annual safety surveys of the entire ground terminals because they are portable and make repeatable and conservative BC measurements.

  - Pad probes are unsatisfactory for seasonal measurements because they offer none of the advantages of rod electrodes listed above.

- Seasonal Monitoring Scope

  - Daily measurements are required to adequately define the seasonal variations in ground terminal SV's and BC's.

- Seasonal measurements must include the major soil and terrain groups with at least a few examples of each.
- Seasonal measurements must be conducted over several years in order to define year-to-year cycles.
- Seasonal measurement test points should include all ground terminals in order to account for localized temperature and weather patterns.

The remaining point to be concluded from the Pilot Study concerns the assurance that ELF ground terminals are safe in all seasons and under all weather conditions. The annual safety survey measurements include the entire area of all the ground terminals, but are taken over only a few weeks' time. While they address the spatial aspects of ground terminal safety, they cannot answer the seasonal questions. Daily monitoring of the ground terminal SV and BC variations at a number of representative test points can provide the "seasonal calibration point" that is missing from the annual survey data. That is, seasonal monitoring can help determine the best time of year to take a conservative annual safety survey, and then can be used to verify whether or not the survey was in fact a worst-case test of safety.

5. FUTURE SEASONAL MONITORING

In light of the results of the Pilot Study, IITRI has recommended that the monthly comparative measurements with step and pad probes be discontinued. These measurements are no longer required to define measurement technique, are not adequate to characterize BC variations, and are very labor intensive. This action was approved by the ERC in September, and the last set of monthly comparative measurements was taken on 8 November 1988.

Recommendations were also made to expand the number of seasonal monitoring data loggers from seven to twelve. This will allow for three monitored sites of each terrain type. With Project Office approval, the principal hardware components for the additional data loggers have been purchased. Their fabrication and assembly is expected to begin in late February 1989, with deployment at the WTF in the spring. A re-assesment of the ground terminal seasonal monitoring test point locations will be made at this time. It is expected that several of the original twelve test points will be relocated in order to have monitored sites at all four ground terminals. In addition, test points with low body current measurements will be replaced in favor of test locations with higher BC values. Sites with BC levels in excess of one milliampere are those for which seasonal variations can be expected to have the greatest impact on ground terminal safety.

Manpower requirements for the maintenance and monthly interrogation of the twelve data loggers are expected to be slightly less than the level of effort expended on the Pilot Study. Time gained by the elimination of the comparative measurements will be partially offset by visiting a fourth ground terminal. During the present interim period the existing seven data loggers at the north and south ground terminals are still being visited and read out on a monthly basis.

APPENDIX A

Grounds Seasonal Variation Pilot Study

Monthly Comparative Measurements

Data, Statistics, Graphs

Table A1
Monthly Fixed Electrode, Step Probe, and Pad Probe Measurements
Site 1 (Loam with vegetation)

Month	Day	Year	Fixed SV (V)	Step SV (V)	Pad SV (V)	Fixed BC (mA)	Step BC (mA)	Pad BC (mA)
5	28	87	4.34	4.35	4.35	1.26	1.26	0.55
7	10	87	4.22	4.07	3.90	1.60	1.47	0.69
8	13	87	4.06	4.02	3.83	1.37	1.22	1.10
9	10	87	4.14	4.02	3.83	1.10	1.11	0.60
10	7	87	4.02	4.00	3.92	1.14	1.03	0.66
11	6	87	4.16	4.18	3.88	0.98	0.88	0.110
12	4	87	4.32	4.22	3.98	0.66	0.69	0.0088
1	8	88	4.50	4.50	3.39	0.34	0.27	0.0010
2	8	88	4.89	4.07	2.79	0.0860	0.0044	0.0005
3	1	88	4.92	4.87	5.17	0.0710	0.0087	0.0076
3	30	88	4.71	4.63	4.62	0.41	0.0201	0.0167
4	26	88	4.70	4.60	4.33	0.94	0.89	0.0490
5	20	88	4.64	4.65	4.34	1.00	0.90	0.0401
6	24	88	4.49	4.68	4.36	0.94	0.85	0.1760
7	20	88	4.54	4.48	4.40	0.94	0.95	0.1200
8	31	88	4.28	4.24	4.27	0.91	1.00	0.0420
10	4	88	4.23	4.22	4.23	0.89	0.70	0.34
11	7	88	4.29	4.30	4.18	0.96	0.82	0.0120

Table A2
Monthly Fixed Electrode, Step Probe, and Pad Probe Measurements
Site 2 (Gravel fill)

Month	Day	Year	Fixed SV (V)	Step SV (V)	Pad SV (V)	Fixed BC (mA)	Step BC (mA)	Pad BC (mA)
5	28	87	5.72	5.67	1.80	0.0310	0.0430	0.0006
7	10	87	5.70	5.85	0.97	0.0440	0.0230	0.0002
8	13	87	5.72	5.50	5.05	0.0810	0.0320	0.0011
9	10	87	5.68	5.59	4.73	0.0210	0.0120	0.0002
10	7	87	5.92	5.40	3.28	0.0500	0.0120	0.0006
11	6	87	5.69	4.07	2.41	0.0130	0.0010	0.0001
12	4	87	4.75	4.36	3.98	0.0032	0.0011	0.0014
1	8	88	6.00	2.61	3.00	0.0146		0.0013
2	8	88	5.49	2.92	3.21	0.0039	0.0017	0.0027
3	1	88	5.50	3.53	1.37	0.0039	0.0037	0.0018
3	30	88	6.53	5.85	6.00	0.0270	0.0150	0.0113
4	26	88	6.00	5.60	0.69	0.0100	0.0020	0.0200
5	20	88	5.62	5.61	0.78	0.0078	0.0089	<0.0001
6	24	88	5.88	5.29	1.82	0.0320	0.0042	<0.0001
7	20	88	5.74	5.14	1.70	0.0134	0.0007	<0.0001
8	31	88	5.60	5.00	0.78	0.0250	0.0037	<0.0001
10	4	88	5.67	5.34	2.01	0.0370	0.0140	<0.0001
11	7	88	5.98	5.40	5.40	0.0005	0.0002	0.0003

Table A3
Monthly Fixed Electrode, Step Probe, and Pad Probe Measurements
Site 3 (Bog with standing water)

Month	Day	Year	Fixed SV (V)	Step SV (V)	Pad SV (V)	Fixed BC (mA)	Step BC (mA)	Pad BC (mA)
5	28	87	0.53	0.56	0.52	0.37	0.34	0.35
7	10	87	0.47	0.47	0.47	0.33	0.32	0.30
8	13	87	0.45	0.45	0.47	0.30	0.28	0.22
9	10	87	0.45	0.46	0.47	0.24	0.24	0.14
10	7	87	0.48	0.48	0.49	0.27	0.24	0.17
11	6	87	0.50	0.50	0.50	0.28	0.25	0.155
12	4	87	0.52		0.47	0.29		0.0002
1	7	88	0.58	0.22	0.35	0.28		0.0010
2	8	88	0.62	0.52	0.52	0.123	<0.0001	<0.0001
3	1	88	0.62	0.60	0.62	0.0980	0.0004	0.0002
3	30	88	0.66	0.65	0.62	0.25	0.0611	0.0823
4	26	88	0.59	0.59	0.59	0.31	0.30	0.38
5	20	88	0.54	0.56	0.52	0.32	0.33	0.36
6	24	88	0.54	0.55	0.53	0.22	0.22	
7	20	88	0.47	0.47	0.46	0.26	0.25	0.29
8	31	88	0.45	0.46	0.46	0.25	0.26	0.20
10	4	88	0.48	0.48	0.47	0.26	0.26	0.21
11	7	88	0.50	0.55	0.57	0.26	0.22	0.0003

Table A4
Monthly Fixed Electrode, Step Probe, and Pad Probe Measurements
Site 4 (Gravel fill)

Month	Day	Year	Fixed SV (V)	Step SV (V)	Pad SV (V)	Fixed BC (mA)	Step BC (mA)	Pad BC (mA)
5	28	87	2.15	2.05	0.58	0.38	0.1260	<0.0001
7	10	87	1.91	1.85	0.55	0.22	0.1500	<0.0001
8	10	87	1.85	1.80	0.57	0.1500	0.1000	<0.0001
9	10	87	1.80	1.78	0.61	0.0240	0.0140	<0.0001
10	5	87	1.83	1.77	1.51	0.0910	0.0330	0.0100
11	6	87	1.98	1.98	0.96	0.1740	0.1160	<0.0001
12	4	87	1.76	1.58	1.47	0.0012	0.0004	0.0003
1	7	88	2.24	1.27	1.72	0.0235	0.0040	0.0008
2	9	88	2.36	1.75	1.83	0.19	0.0003	0.0014
2	29	88	2.42	1.95	1.94	0.26	0.0020	0.0020
3	29	88	2.32	2.31	2.14	0.36	0.1500	0.0045
4	25	88	2.30	2.25	0.43	0.35	0.20	<0.0001
5	19	88	2.12	2.10	0.29	0.33	0.1000	<0.0001
6	24	88	1.85	1.83	0.29	0.0190	0.0055	
7	19	88	1.80	1.75	0.26	0.22	0.1900	<0.0001
8	30	88	1.73	1.69	0.28	0.24	0.1604	<0.0001
10	4	88	1.82	1.71	1.45	0.21	0.1750	0.0020
11	8	88	2.05	1.90	1.56	0.22	0.0030	<0.0001

Table A5
Monthly Fixed Electrode, Step Probe, and Pad Probe Measurements
Site 5 (Sandy soil with slight vegetation)

Month	Day	Year	Fixed SV (V)	Step SV (V)	Pad SV (V)	Fixed BC (mA)	Step BC (mA)	Pad BC (mA)
5	28	87	3.54	3.51	3.52	2.02	1.34	0.30
7	10	87	3.51	3.48	3.26	1.66	1.28	0.0600
8	10	87	3.60	3.55	3.60	1.26	0.99	0.0650
9	10	87	3.57	3.55	3.60	1.13	0.67	0.0560
10	5	87	3.65	3.62	3.50	1.32	0.70	0.1550
11	6	87	3.70	3.74	3.74	1.28	0.66	0.0400
12	4	87	4.04		3.45	0.85		0.0058
1	7	88	4.21	2.15	3.08	0.40		0.0011
2	9	88	4.43	3.55	3.29	0.159	0.0021	0.0018
2	29	88	4.45	3.70	3.85	0.21	0.0028	0.0065
3	29	88	4.48	4.02	3.83	0.66	0.0250	0.0169
4	25	88	4.17	4.14	4.17	1.94	1.50	0.1400
5	19	88	3.89	3.88	4.12	1.94	1.48	0.0760
6	24	88	3.87	3.85		1.04	0.73	
7	19	88	3.57	3.50	3.35	1.43	1.03	0.0243
8	30	88	3.31	3.24	3.35	1.57	1.07	0.0376
10	4	88	3.57	3.51	3.53	1.34	0.81	0.1700
11	8	88	3.81	3.73	3.15	1.01	0.81	0.0002

Table A6
Monthly Fixed Electrode, Step Probe, and Pad Probe Measurements
Site 6 (Bog with standing water)

Month	Day	Year	Fixed SV (V)	Step SV (V)	Pad SV (V)	Fixed BC (mA)	Step BC (mA)	Pad BC (mA)
5	28	87	3.41	3.36	3.32	1.90	1.84	1.86
7	10	87	3.30	3.26	3.28	2.18	2.01	1.78
8	10	87	3.15	3.31	3.20	2.13	1.93	1.61
9	10	87	3.35	3.33	3.31	2.07	1.85	1.53
10	5	87	3.40	3.44	3.41	2.14	1.90	1.87
11	6	87	3.61	3.70	3.46	2.20	2.22	1.36
12	4	87	3.89	3.74	3.32	2.05	1.56	0.0023
1	7	88	4.02	2.82	3.80	2.03	0.0016	0.0113
2	9	88	4.15	2.75	3.34	2.01	0.0010	0.0023
2	29	88	4.27	3.00	3.66	1.99	0.0048	0.0041
3	29	88	4.20	4.14	3.48	2.16	0.0485	0.0025
4	25	88	3.89	3.83	3.74	2.31	2.11	2.10
5	19	88	3.70	3.61	3.53	2.35	2.11	2.05
6	24	88	3.48	3.42		2.25	1.98	
7	19	88	3.35	3.35	3.20	2.23	2.04	1.70
8	30	88	3.23	3.16	3.14	2.14	1.93	1.88
10	4	88	3.42	3.23	3.31	2.11	1.83	1.76
11	8	88	3.69	3.58	2.71	2.04	1.53	0.0113

Table A7
Monthly Fixed Electrode, Step Probe, and Pad Probe Measurements
Site 7 (Loam with vegetation)

Month	Day	Year	Fixed SV (V)	Step SV (V)	Pad SV (V)	Fixed BC (mA)	Step BC (mA)	Pad BC (mA)
5	28	87	3.80	3.62	3.70	0.76	0.70	0.33
7	10	87	3.51	3.41	3.35	0.56	0.49	0.1010
8	10	87	4.31	4.23	3.82	0.23	0.33	0.0330
9	10	87	4.40	3.99	3.84	0.30	0.38	0.0160
10	5	87	3.88	3.76	3.74	0.54	0.56	0.43
11	6	87	3.98	3.92	3.85	0.50	0.49	0.31
12	4	87	4.15	4.05	3.71	0.45	0.41	0.0050
1	7	88	4.26	3.00	3.13	0.13		0.0013
2	9	88	4.72	3.95	3.75	0.27	0.0038	0.0022
2	29	88	4.63	3.80	4.02	0.26	0.0039	0.0046
3	29	88	4.38	2.86	3.90	0.53	0.0007	0.0057
4	25	88	4.12	4.10	4.05	0.50	0.54	0.0236
5	19	88	4.03	3.97	3.82	0.48	0.51	0.0650
6	24	88	3.91	3.91		0.31	0.43	
7	19	88	3.72	3.63	3.64	0.45	0.53	0.0340
8	30	88	3.44	3.40	3.41	0.46	0.53	0.1120
10	4	88	3.51	3.41	3.41	0.45	0.54	0.38
11	8	88	3.62	3.40	2.58	0.44	0.50	0.0053

Table A8
Monthly Fixed Electrode, Step Probe, and Pad Probe Measurements
Site 8 (Sandy soil with slight vegetation)

Month	Day	Year	Fixed SV (V)	Step SV (V)	Pad SV (V)	Fixed BC (mA)	Step BC (mA)	Pad BC (mA)
5	29	87	5.45	5.56	5.87	0.33	0.29	0.26
7	8	87	6.24	6.16	6.19	0.25	0.31	0.0800
8	13	87	6.08	6.03	5.96	0.36	0.27	0.1800
9	9	87	6.07	6.01	5.82	0.36	0.32	0.0950
10	5	87	6.45	6.41	6.37	0.31	0.26	0.27
11	5	87	6.58	6.50	6.38	0.25	0.21	0.1200
12	3	87	6.56	6.48	5.73	0.1570	0.1350	0.0061
1	8	88	7.01	6.20	5.40	0.1220		0.0032
2	11	88	7.30	6.10	6.04	0.1240	0.0053	0.0039
2	29	88	7.72	6.96	6.80	0.0820	0.0115	0.0090
3	28	88	6.10	5.70	5.70	0.1630	0.0040	0.0109
4	25	88	5.60	5.53	5.49	0.1200	0.1660	0.0860
4	27	88	6.46	5.66	5.45	0.0930	0.1740	0.0550
5	17	88	5.93	5.90	5.95	0.1500	0.21	0.0948
6	23	88	6.72	6.63	6.55	0.0900	0.17	0.0510
7	19	88	6.48	6.60	6.10	0.1570	0.20	0.1500
8	30	88	6.72	6.70	6.77	0.25	0.21	0.23
10	4	88	6.87	6.83	6.79	0.23	0.21	0.20
11	8	88	6.75	6.35	6.00	0.26	0.23	<0.0001

Table A9
Monthly Fixed Electrode, Step Probe, and Pad Probe Measurements
Site 9 (Sandy soil with slight vegetation)

Month	Day	Year	Fixed SV (V)	Step SV (V)	Pad SV (V)	Fixed BC (mA)	Step BC (mA)	Pad BC (mA)
5	29	87	3.68	3.62	3.72	0.55	0.46	0.18
7	8	87	3.84	3.79	3.90	0.65	0.52	0.0800
8	13	87	4.03	3.95	3.94	0.67	0.55	0.25
9	9	87	3.93	3.88	4.00	0.58	0.48	0.0830
10	5	87	4.18	4.18	4.04	0.52	0.47	0.48
11	5	87	4.49	4.37	4.17	0.52	0.36	0.0220
12	3	87	4.45	4.36	4.15	0.30	0.24	0.0066
1	8	88	4.40	4.20	3.40	0.23		0.0028
2	11	88	4.82	3.72	4.10	0.21	0.0019	0.0023
2	29	88	4.86	3.66	4.31	0.15	0.0025	0.0065
3	29	88	4.53	4.35	4.54	0.20	0.0900	0.20
4	25	88	3.84	3.17	3.58	0.28	0.21	0.0960
5	17	88	3.95	3.98	3.94	0.27	0.32	0.1200
6	23	88	4.08	4.03	4.20	0.30	0.43	0.1200
7	19	88	4.10	3.80	4.00	0.21	0.41	0.1000
8	30	88	4.31	4.20	3.90	0.34	0.51	0.44
10	4	88	4.41	4.21	4.11	0.43	0.53	0.42
11	8	88	4.50	4.19	3.92	0.37	0.26	0.0060

Table A10
Monthly Fixed Electrode, Step Probe, and Pad Probe Measurements
Site 10 (Bog with standing water)

Month	Day	Year	Fixed SV (V)	Step SV (V)	Pad SV (V)	Fixed BC (mA)	Step BC (mA)	Pad BC (mA)
5	29	87	2.23	2.24	2.21	1.75	1.75	1.81
7	8	87	2.34	2.38	2.31	1.56	1.61	0.87
8	12	87	2.23	2.22	2.35	1.29	1.37	0.48
9	9	87	2.27	2.25	2.38	0.90	1.35	0.45
10	5	87	2.29	2.28	2.41	1.49	1.49	1.13
11	5	87	2.29	2.31	2.28	1.62	1.62	1.63
12	3	87	2.45		2.25	1.68		0.0021
1	11	88	2.60	1.68	2.27	1.72		0.0011
2	11	88	2.40	1.82	2.33	1.62	0.0006	0.0012
2	29	88	2.36	2.23	2.40	1.61	0.0012	0.0028
3	29	88	2.23	0.41	1.32	1.56	<0.0001	0.0002
4	25	88	2.25	2.30	2.26	1.70	1.63	1.76
5	17	88	2.14	2.17	2.13	1.68	1.67	1.80
6	23	88	2.43	2.44	2.45	1.25	1.51	
7	19	88	2.30	2.33	2.30	1.29	1.38	0.68
8	30	88	2.10	2.16	2.20	1.39	1.41	1.11
10	4	88	2.11	2.05	2.06	1.42	1.44	1.40
11	7	88	2.17	2.10	2.12	1.47	1.38	1.49

Table A11
Monthly Fixed Electrode, Step Probe, and Pad Probe Measurements
Site 11 (Gravel fill)

Month	Day	Year	Fixed SV (V)	Step SV (V)	Pad SV (V)	Fixed BC (mA)	Step BC (mA)	Pad BC (mA)
5	29	87	2.26	2.28	2.21	1.04	0.95	0.0057
7	8	87	2.46	2.42	0.36	0.0400	0.0200	0.0010
8	13	87	2.42	2.40	2.41	0.1290	0.0559	0.0011
9	9	87	2.49	2.49	0.77	0.0550	0.0420	<0.0001
10	5	87	2.37	2.41	2.41	0.0710	0.0180	0.0060
11	5	87	2.30	2.30	0.80	0.75	0.69	<0.0001
12	3	87	2.36	2.42	1.97	0.75	0.64	0.0010
1	11	88	2.16	1.64	2.09	0.0015	0.0002	0.0007
2	11	88	2.23	1.94	1.98	0.0022	0.0011	0.0012
2	29	88	2.26	2.24	2.43	0.0047	0.0023	0.0032
3	29	88	2.47	2.45	2.32	0.37	0.0084	0.0040
4	25	88	2.41	2.42	2.33	0.87	0.75	0.0070
5	17	88	2.38	2.36	0.53	0.95	0.48	<0.0001
6	23	88	2.50	2.38	0.79	0.1500	0.0085	<0.0001
7	19	88	2.50	2.49	0.70	0.0290	0.0820	0.0004
8	30	88	2.35	2.30	2.28	0.0312	0.0200	0.0070
10	4	88	2.30	2.21	2.23	0.88	0.89	0.33
11	8	88	2.32	2.20	2.10	0.77	0.39	0.0050

Table A12
Monthly Fixed Electrode, Step Probe, and Pad Probe Measurements
Site 12 (Loam with vegetation)

Month	Day	Year	Fixed SV (V)	Step SV (V)	Pad SV (V)	Fixed BC (mA)	Step BC (mA)	Pad BC (mA)
5	30	87	6.42	6.65	6.70	0.88	0.89	0.62
7	10	87	6.07	6.08	6.24	0.78	0.72	0.52
8	10	87	5.71	5.82	5.75	0.59	0.59	0.25
9	10	87	5.68	5.79	6.03	0.51	0.55	0.28
10	5	87	5.65	5.46	5.85	0.51	0.60	0.54
11	6	87	5.96	6.03	5.95	0.42	0.39	0.110
12	4	87	6.12	6.28	5.52	0.32	0.40	0.0042
1	7	88	6.67	5.17	5.33	0.1500		0.0048
2	9	88	6.75	2.75	2.46	0.1602	0.0041	0.0038
2	29	88	6.73	5.23	5.22	0.0604	0.0060	0.0045
3	29	88	6.44	5.71	5.31	0.45	0.0056	0.0032
4	25	88	6.01	6.20	6.41	0.40	0.64	0.35
5	19	88	5.68	5.74	6.15	0.42	0.53	0.35
6	24	88	5.36	5.52		0.34	0.53	
7	19	88	5.01	5.11	5.31	0.43	0.55	0.23
8	30	88	4.84	4.98	5.05	0.46	0.50	0.43
10	4	88	5.19	5.26	5.31	0.47	0.53	0.46
11	8	88	5.48	5.65	4.54	0.39	0.45	0.0141

Table A13
Monthly Fixed Electrode SV Statistics

Terrain type	SITE no.	STEP VOLTAGE (V): Average $\pm$ standard deviation, July 1987 - Oct 1987 (4 months)	May 1988 - Oct 1988 (7 months)	July 1987 - Oct 1988 (16 months)	$\frac{\text{MAXIMUM}}{\text{MINIMUM}}$ = RATIO: July 1987 - Oct 1987 (4 months)	May 1988 - Oct 1988 (7 months)	July 1987 - Oct 1988 (16 months)
Loam with vegetation	1	4.16 $\pm$ 0.13	4.41 $\pm$ 0.17	4.41 $\pm$ 0.27	$\frac{4.34}{4.02}$ = 1.1	$\frac{4.64}{4.23}$ = 1.1	$\frac{4.92}{4.02}$ = 1.2
	7	3.98 $\pm$ 0.37	3.71 $\pm$ 0.23	4.02 $\pm$ 0.38	$\frac{4.40}{3.51}$ = 1.3	$\frac{4.03}{3.44}$ = 1.2	$\frac{4.72}{3.44}$ = 1.4
	12	5.91 $\pm$ 0.33	5.29 $\pm$ 0.29	5.86 $\pm$ 0.57	$\frac{6.42}{5.65}$ = 1.1	$\frac{5.68}{4.84}$ = 1.2	$\frac{6.75}{4.84}$ = 1.4
Sandy soil with slight vegetation	5	3.57 $\pm$ 0.05	3.67 $\pm$ 0.23	3.85 $\pm$ 0.36	$\frac{3.65}{3.51}$ = 1.0	$\frac{3.89}{3.31}$ = 1.2	$\frac{4.48}{3.31}$ = 1.4
	8	6.06 $\pm$ 0.37	6.58 $\pm$ 0.34	6.48 $\pm$ 0.55	$\frac{6.45}{5.45}$ = 1.2	$\frac{6.87}{5.93}$ = 1.2	$\frac{7.72}{5.45}$ = 1.4
	9	3.93 $\pm$ 0.19	4.23 $\pm$ 0.21	4.24 $\pm$ 0.34	$\frac{4.18}{3.68}$ = 1.1	$\frac{4.50}{3.95}$ = 1.1	$\frac{4.86}{3.68}$ = 1.3
Gravel fill	2	5.75 $\pm$ 0.10	5.75 $\pm$ 0.15	5.73 $\pm$ 0.34	$\frac{5.92}{5.68}$ = 1.0	$\frac{5.98}{5.60}$ = 1.1	$\frac{6.53}{4.75}$ = 1.4
	4	1.91 $\pm$ 0.14	1.90 $\pm$ 0.15	2.02 $\pm$ 0.23	$\frac{2.15}{1.80}$ = 1.2	$\frac{2.12}{1.73}$ = 1.2	$\frac{2.42}{1.73}$ = 1.4
	11	2.40 $\pm$ 0.09	2.39 $\pm$ 0.09	2.36 $\pm$ 0.10	$\frac{2.49}{2.26}$ = 1.1	$\frac{2.50}{2.30}$ = 1.1	$\frac{2.50}{2.16}$ = 1.2
Bog with standing water	3	0.48 $\pm$ 0.03	0.49 $\pm$ 0.04	0.53 $\pm$ 0.07	$\frac{0.53}{0.45}$ = 1.2	$\frac{0.54}{0.45}$ = 1.2	$\frac{0.66}{0.45}$ = 1.5
	6	3.32 $\pm$ 0.11	3.48 $\pm$ 0.19	3.64 $\pm$ 0.35	$\frac{3.41}{3.15}$ = 1.1	$\frac{3.70}{3.23}$ = 1.1	$\frac{4.27}{3.15}$ = 1.4
	10	2.27 $\pm$ 0.05	2.21 $\pm$ 0.13	2.29 $\pm$ 0.13	$\frac{2.34}{2.23}$ = 1.0	$\frac{2.43}{2.10}$ = 1.2	$\frac{2.60}{2.10}$ = 1.2

Table A14
Monthly Step Probe SV Statistics

Terrain type	SITE no.	STEP VOLTAGE (V): Average ± standard deviation, July 1987 - Oct 1987 (4 months)	May 1988 - Oct 1988 (7 months)	July 1987 - Oct 1988 (16 months)	MAXIMUM / MINIMUM = RATIO, July 1987 - Oct 1987 (4 months)	May 1988 - Oct 1988 (7 months)	July 1987 - Oct 1988 (16 months)
Loam with vegetation	1	4.09 ± 0.15	4.43 ± 0.21	4.34 ± 0.27	$\frac{4.35}{4.00}$ = 1.1	$\frac{4.68}{4.22}$ = 1.1	$\frac{4.87}{4.00}$ = 1.2
	7	3.80 ± 0.32	3.62 ± 0.26	3.69 ± 0.38	$\frac{4.23}{3.41}$ = 1.2	$\frac{3.97}{3.40}$ = 1.2	$\frac{4.23}{2.86}$ = 1.5
	12	5.96 ± 0.44	5.41 ± 0.30	5.53 ± 0.80	$\frac{6.65}{5.46}$ = 1.2	$\frac{5.74}{4.98}$ = 1.2	$\frac{6.65}{2.75}$ = 2.4
Sandy soil with slight vegetation	5	3.54 ± 0.05	3.62 ± 0.25	3.57 ± 0.43	$\frac{3.62}{3.48}$ = 1.0	$\frac{3.88}{3.24}$ = 1.2	$\frac{4.14}{2.15}$ = 1.9
	8	6.03 ± 0.31	6.50 ± 0.33	6.23 ± 0.43	$\frac{6.41}{5.56}$ = 1.2	$\frac{6.83}{5.90}$ = 1.2	$\frac{6.96}{5.53}$ = 1.3
	9	3.88 ± 0.21	4.07 ± 0.16	3.98 ± 0.32	$\frac{4.18}{3.62}$ = 1.2	$\frac{4.21}{3.80}$ = 1.1	$\frac{4.37}{3.17}$ = 1.4
Gravel fill	2	5.60 ± 0.17	5.30 ± 0.21	4.93 ± 1.00	$\frac{5.85}{5.40}$ = 1.1	$\frac{5.61}{5.00}$ = 1.1	$\frac{5.85}{2.61}$ = 2.2
	4	1.85 ± 0.12	1.83 ± 0.15	1.85 ± 0.24	$\frac{2.05}{1.77}$ = 1.2	$\frac{2.10}{1.69}$ = 1.2	$\frac{2.31}{1.27}$ = 1.8
	11	2.40 ± 0.08	2.32 ± 0.11	2.30 ± 0.21	$\frac{2.49}{2.28}$ = 1.1	$\frac{2.49}{2.20}$ = 1.1	$\frac{2.49}{1.64}$ = 1.5
Bog with standing water	3	0.48 ± 0.04	0.51 ± 0.05	0.50 ± 0.09	$\frac{0.56}{0.45}$ = 1.2	$\frac{0.56}{0.46}$ = 1.2	$\frac{0.65}{0.22}$ = 3.0
	6	3.34 ± 0.07	3.39 ± 0.18	3.39 ± 0.35	$\frac{3.44}{3.26}$ = 1.1	$\frac{3.61}{3.16}$ = 1.1	$\frac{4.14}{2.75}$ = 1.5
	10	2.27 ± 0.06	2.21 ± 0.15	2.08 ± 0.47	$\frac{2.38}{2.22}$ = 1.1	$\frac{2.44}{2.05}$ = 1.2	$\frac{2.44}{0.41}$ = 7.2

Table A15
Monthly Pad Probe SV Statistics

Terrain type	SITE no.	STEP VOLTAGE (V): Average ± standard deviation, July 1987 - Oct 1987 (4 months)	Average ± standard deviation, May 1988 - Oct 1988 (7 months)	Average ± standard deviation, July 1987 - Oct 1988 (16 months)	$\frac{\text{MAXIMUM}}{\text{MINIMUM}}$ = RATIO, July 1987 - Oct 1987 (4 months)	$\frac{\text{MAXIMUM}}{\text{MINIMUM}}$ = RATIO, May 1988 - Oct 1988 (7 months)	$\frac{\text{MAXIMUM}}{\text{MINIMUM}}$ = RATIO, July 1987 - Oct 1988 (16 months)
Loam with vegetation	1	3.97 ± 0.22	4.30 ± 0.08	4.10 ± 0.50	$\frac{4.35}{3.83}$ = 1.1	$\frac{4.40}{4.18}$ = 1.1	$\frac{5.17}{2.79}$ = 1.9
	7	3.69 ± 0.20	3.37 ± 0.48	3.63 ± 0.37	$\frac{3.84}{3.35}$ = 1.1	$\frac{3.82}{2.58}$ = 1.5	$\frac{4.05}{2.58}$ = 1.6
	12	6.11 ± 0.38	5.15 ± 0.60	5.43 ± 0.95	$\frac{6.70}{5.75}$ = 1.2	$\frac{6.15}{4.54}$ = 1.4	$\frac{6.70}{2.46}$ = 2.7
Sandy soil with slight vegetation	5	3.50 ±0.14	3.50 ± 0.37	3.55 ± 0.31	$\frac{3.60}{3.26}$ = 1.1	$\frac{4.12}{3.15}$ = 1.3	$\frac{4.17}{3.08}$ = 1.4
	8	6.04 ± 0.23	6.36 ± 0.39	6.07 ± 0.44	$\frac{6.37}{5.82}$ = 1.1	$\frac{6.79}{5.95}$ = 1.1	$\frac{6.80}{5.40}$ = 1.3
	9	3.92 ± 0.12	4.01 ± 0.12	4.00 ± 0.26	$\frac{4.04}{3.72}$ = 1.1	$\frac{4.20}{3.90}$ = 1.1	$\frac{4.54}{3.40}$ = 1.3
Gravel fill	2	3.17 ± 1.78	2.08 ± 1.71	2.72 ± 1.71	$\frac{5.05}{0.97}$ = 5.2	$\frac{5.40}{0.78}$ = 6.9	$\frac{6.00}{0.69}$ = 8.7
	4	0.76 ± 0.42	0.69 ± 0.63	1.02 ± 0.66	$\frac{1.51}{0.55}$ = 2.7	$\frac{1.56}{0.26}$ = 6.0	$\frac{2.14}{0.26}$ = 8.2
	11	1.63 ± 0.99	1.44 ± 0.84	1.71 ± 0.78	$\frac{2.41}{0.36}$ = 6.7	$\frac{2.28}{0.53}$ = 4.3	$\frac{2.43}{0.36}$ = 6.8
Bog with standing water	3	0.48 ± 0.02	0.50 ± 0.05	0.51 ± 0.07	$\frac{0.52}{0.47}$ = 1.1	$\frac{0.57}{0.46}$ = 1.2	$\frac{0.62}{0.35}$ = 1.8
	6	3.30 ± 0.08	3.18 ± 0.30	3.37 ± 0.25	$\frac{3.41}{3.20}$ = 1.1	$\frac{3.53}{2.71}$ = 1.3	$\frac{3.80}{2.71}$ = 1.4
	10	2.33 ± 0.08	2.21 ± 0.14	2.22 ± 0.25	$\frac{2.41}{2.21}$ = 1.1	$\frac{2.45}{2.06}$ = 1.2	$\frac{2.45}{1.32}$ = 1.9

Table A16
Monthly Fixed Electrode BC Statistics

		BODY CURRENT (mA)					
		Average ± standard deviation			MAXIMUM / MINIMUM = RATIO		
Terrain type	SITE no.	July 1987 - Oct 1987 (4 months)	May 1988 - Oct 1988 (7 months)	July 1987 - Oct 1988 (16 months)	July 1987 - Oct 1987 (4 months)	May 1988 - Oct 1988 (7 months)	July 1987 - Oct 1988 (16 months)
Loam with vegetation	1	1.29 ± 0.20	0.94 ± 0.04	0.87 ± 0.41	$\frac{1.60}{1.10}$ = 1.5	$\frac{1.00}{0.89}$ = 1.1	$\frac{1.60}{0.07}$ = 23
	7	0.49 ± 0.21	0.43 ± 0.06	0.42 ± 0.15	$\frac{0.76}{0.23}$ = 3.3	$\frac{0.48}{0.31}$ = 1.5	$\frac{0.76}{0.13}$ = 5.8
	12	0.65 ± 0.17	0.41 ± 0.05	0.43 ± 0.19	$\frac{0.88}{0.51}$ = 1.7	$\frac{0.47}{0.34}$ = 1.4	$\frac{0.88}{0.06}$ = 15
Sandy soil with slight vegetation	5	1.48 ± 0.36	1.39 ± 0.35	1.18 ± 0.56	$\frac{2.02}{1.13}$ = 1.8	$\frac{1.94}{1.04}$ = 1.9	$\frac{2.02}{0.16}$ = 13
	8	0.32 ± 0.05	0.19 ± 0.07	0.20 ± 0.09	$\frac{0.36}{0.25}$ = 1.4	$\frac{0.26}{0.09}$ = 2.8	$\frac{0.36}{0.08}$ = 4.5
	9	0.59 ± 0.06	0.32 ± 0.08	0.38 ± 0.17	$\frac{0.67}{0.52}$ = 1.3	$\frac{0.43}{0.21}$ = 2.0	$\frac{0.67}{0.15}$ = 4.5
Gravel fill	2	0.045 ± 0.023	0.019 ± 0.015	0.023 ± 0.021	$\frac{0.081}{0.021}$ = 3.9	$\frac{0.037}{<0.0001}$ = >370	$\frac{0.081}{<0.0001}$ = >810
	4	0.17 ± 0.14	0.21 ± 0.10	0.19 ± 0.12	$\frac{0.38}{0.02}$ = 19	$\frac{0.33}{0.02}$ = 17	$\frac{0.38}{1.0E-3}$ = 380
	11	0.27 ± 0.43	0.47 ± 0.44	0.38 ± 0.40	$\frac{1.04}{0.04}$ = 26	$\frac{0.95}{0.03}$ = 32	$\frac{1.04}{1.0E-3}$ = 380
Bog with standing water	3	0.30 ± 0.05	0.26 ± 0.03	0.26 ± 0.07	$\frac{0.37}{0.24}$ = 1.5	$\frac{0.32}{0.22}$ = 1.5	$\frac{0.37}{0.10}$ = 3.7
	6	2.08 ± 0.11	2.19 ± 0.11	2.13 ± 0.12	$\frac{2.18}{1.90}$ = 1.1	$\frac{2.35}{2.04}$ = 1.2	$\frac{2.35}{1.90}$ = 1.2
	10	1.40 ± 0.32	1.42 ± 0.15	1.50 ± 0.22	$\frac{1.75}{0.90}$ = 1.9	$\frac{1.68}{1.25}$ = 1.3	$\frac{1.75}{0.90}$ = 1.9

Table A17
Monthly Step Probe BC Statistics

Terrain type	SITE no.	BODY CURRENT (mA): Average ± standard deviation, July 1987 - Oct 1987 (4 months)	Average ± standard deviation, May 1988 - Oct 1988 (7 months)	Average ± standard deviation, July 1987 - Oct 1988 (16 months)	$\frac{\text{MAXIMUM}}{\text{MINIMUM}}$ = RATIO, July 1987 - Oct 1987 (4 months)	$\frac{\text{MAXIMUM}}{\text{MINIMUM}}$ = RATIO, May 1988 - Oct 1988 (7 months)	$\frac{\text{MAXIMUM}}{\text{MINIMUM}}$ = RATIO, July 1987 - Oct 1988 (16 months)
Loam with vegetation	1	1.22 ± 0.17	0.87 ± 0.11	0.78 ± 0.44	$\frac{1.47}{1.03} = 1.4$	$\frac{1.00}{0.70} = 1.4$	$\frac{1.47}{0.0044} = 330$
	7	0.49 ± 0.15	0.51 ± 0.04	0.41 ± 0.21	$\frac{0.70}{0.33} = 2.1$	$\frac{0.54}{0.43} = 1.3$	$\frac{0.70}{0.0007} = 1000$
	12	0.67 ± 0.14	0.51 ± 0.04	0.46 ± 0.24	$\frac{0.89}{0.55} = 1.6$	$\frac{0.55}{0.45} = 1.2$	$\frac{0.89}{0.0041} = 220$
Sandy soil with slight vegetation	5	1.00 ± 0.31	0.99 ± 0.28	0.82 ± 0.49	$\frac{1.34}{0.67} = 2.0$	$\frac{1.48}{0.73} = 2.0$	$\frac{1.50}{0.0021} = 710$
	8	0.29 ± 0.03	0.21 ± 0.02	0.19 ± 0.10	$\frac{0.32}{0.26} = 1.2$	$\frac{0.23}{0.17} = 1.4$	$\frac{0.32}{0.004} = 80$
	9	0.50 ± 0.04	0.41 ± 0.11	0.34 ± 0.18	$\frac{0.55}{0.46} = 1.2$	$\frac{0.53}{0.26} = 2.0$	$\frac{0.55}{0.0019} = 290$
Gravel fill	2	0.024 ± 0.013	0.005 ± 0.005	0.011 ± 0.012	$\frac{0.043}{0.012} = 3.6$	$\frac{0.0140}{0.0002} = 70$	$\frac{0.0430}{0.0002} = 215$
	4	0.09 ± 0.06	0.11 ± 0.08	0.09 ± 0.08	$\frac{0.150}{0.014} = 11$	$\frac{0.190}{0.003} = 63$	$\frac{0.200}{0.0003} = 670$
	11	0.22 ± 0.41	0.31 ± 0.35	0.28 ± 0.35	$\frac{0.950}{0.018} = 53$	$\frac{0.890}{0.009} = 99$	$\frac{0.95}{0.0002} = 4800$
Bog with standing water	3	0.28 ± 0.05	0.26 ± 0.04	0.22 ± 0.11	$\frac{0.34}{0.24} = 1.4$	$\frac{0.33}{0.22} = 1.5$	$\frac{0.34}{<0.0001} = >3400$
	6	1.91 ± 0.07	1.90 ± 0.21	1.50 ± 0.83	$\frac{2.01}{1.84} = 1.1$	$\frac{2.11}{1.53} = 1.2$	$\frac{2.22}{0.001} = 2200$
	10	1.51 ± 0.17	1.47 ± 0.11	1.23 ± 0.62	$\frac{1.75}{1.35} = 1.3$	$\frac{1.67}{1.38} = 1.2$	$\frac{1.75}{<0.0001} = >17500$

Table A18
Monthly Pad Probe BC Statistics

		BODY CURRENT (mA)					
		Average ± standard deviation			$\frac{\text{MAXIMUM}}{\text{MINIMUM}}$ = RATIO		
Terrain type	SITE no.	July 1987 - Oct 1987 (4 months)	May 1988 - Oct 1988 (7 months)	July 1987 - Oct 1988 (16 months)	July 1987 - Oct 1987 (4 months)	May 1988 - Oct 1988 (7 months)	July 1987 - Oct 1988 (16 months)
Loam with vegetation	1	0.72 ± 0.22	0.12 ± 0.12	0.25 ± 0.33	$\frac{1.10}{0.55} = 2.0$	$\frac{0.34}{0.012} = 83$	$\frac{1.10}{0.0005} = 2200$
	7	0.18 ± 0.19	0.12 ± 0.15	0.11 ± 0.15	$\frac{0.43}{0.016} = 27$	$\frac{0.38}{0.0053} = 72$	$\frac{0.43}{0.0013} = 330$
	12	0.44 ± 0.17	0.25 ± 0.20	0.23 ± 0.22	$\frac{0.62}{0.25} = 2.5$	$\frac{0.46}{0.014} = 33$	$\frac{0.62}{0.0032} = 190$
Sandy soil with slight vegetation	5	0.13 ± 0.11	0.06 ± 0.07	0.07 ± 0.08	$\frac{0.30}{0.056} = 5.4$	$\frac{0.17}{0.0002} = 850$	$\frac{0.30}{0.0002} = 1500$
	8	0.18 ± 0.09	0.12 ± 0.09	0.10 ± 0.09	$\frac{0.27}{0.08} = 3.4$	$\frac{0.23}{<0.0001} = >2300$	$\frac{0.27}{<0.0001} = >2700$
	9	0.22 ± 0.17	0.20 ± 0.18	0.15 ± 0.16	$\frac{0.48}{0.08} = 6.0$	$\frac{0.44}{<0.0001} = >4400$	$\frac{0.48}{<0.0001} = >4800$
Gravel fill	2	0.0005 ±0.0004	0.0001±0.0001	0.0023 ±0.0051	$\frac{0.0011}{0.0002} = 5.9$	$\frac{0.0003}{<0.0001} = >3.0$	$\frac{0.020}{<0.0001} = >200$
	4	0.0020 ±0.0045	0.0004 ±0.0009	0.0012 ±0.0026	$\frac{0.010}{<0.0001} = >100$	$\frac{0.0020}{<0.0001} = >20$	$\frac{0.010}{<0.0001} = >100$
	11	0.0028 ±0.0029	0.057 ± 0.13	0.021 ± 0.077	$\frac{0.0060}{<0.0001} = >60$	$\frac{0.33}{<0.0001} = >3300$	$\frac{0.33}{<0.0001} = >3300$
Bog with standing water	3	0.24 ± 0.09	0.21 ± 0.14	0.17 ± 0.14	$\frac{0.35}{0.14} = 2.5$	$\frac{0.36}{0.0003} = 1200$	$\frac{0.38}{<0.0001} = >3800$
	6	1.73 ± 0.15	1.48 ± 0.83	1.15 ± 0.89	$\frac{1.87}{1.53} = 1.2$	$\frac{2.05}{0.011} = 190$	$\frac{2.12}{0.0023} = 920$
	10	0.95 ± 0.56	1.30 ± 0.42	0.86 ± 0.71	$\frac{1.81}{0.45} = 4.0$	$\frac{1.80}{0.68} = 2.6$	$\frac{1.81}{0.0002} = 9100$

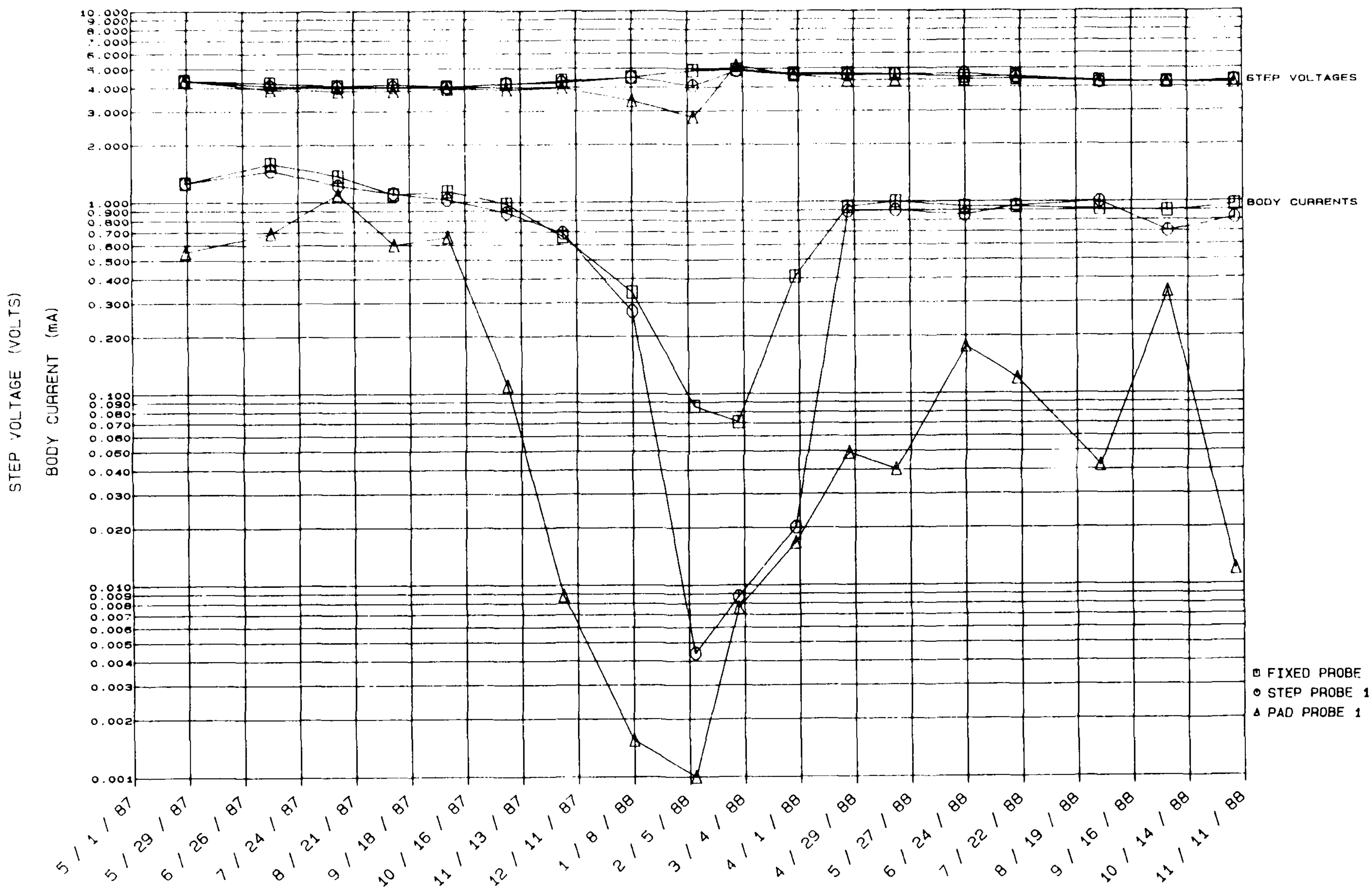


Figure A-1. Monthly Fixed Electrode, Step Probe, and Pad Probe Measurements at Site 1 (Loam with Vegetation)

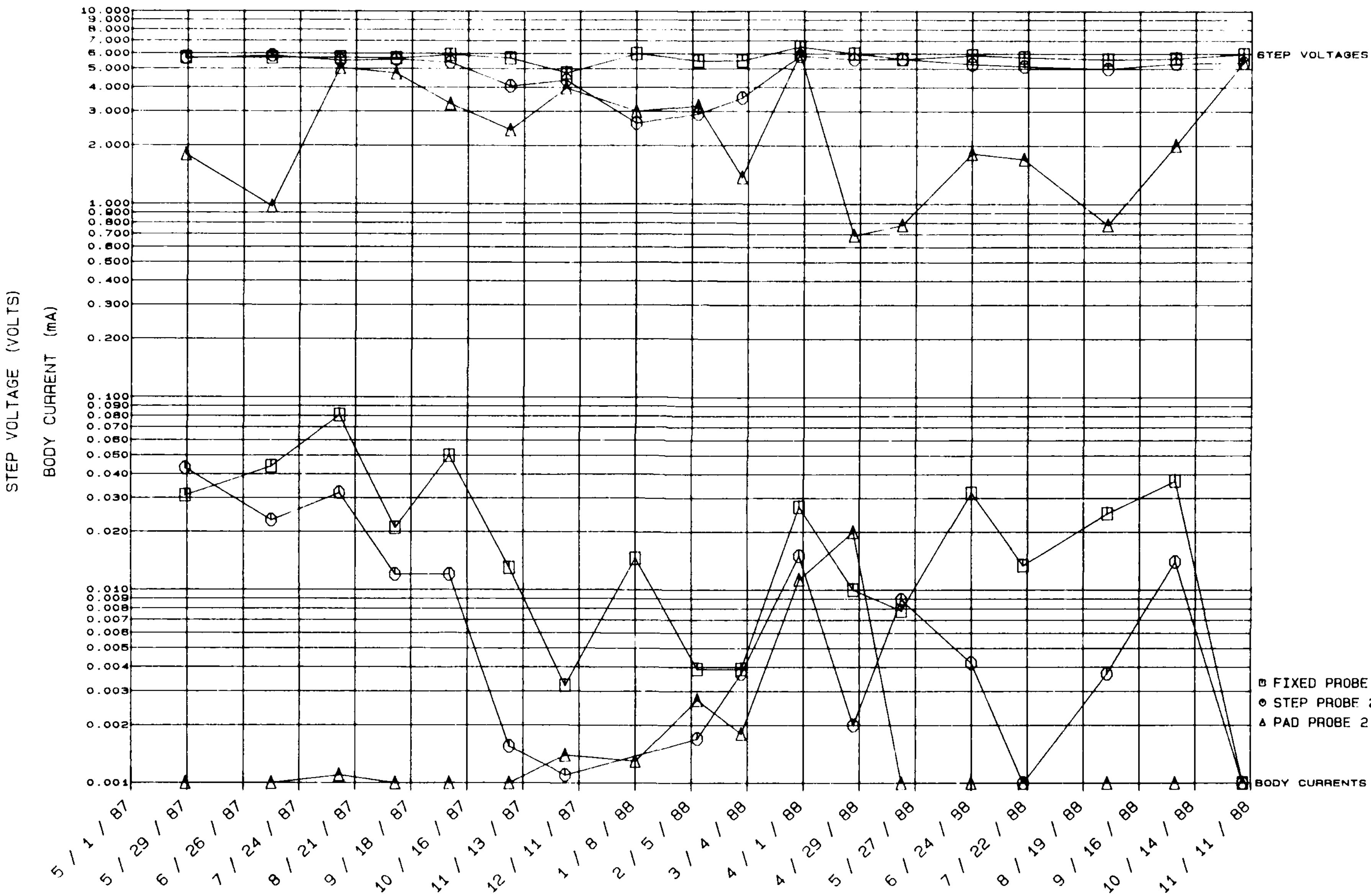


Figure A-2. Monthly Fixed Electrode, Step Probe, and Pad Probe Measurements at Site 2 (Gravel Fill)

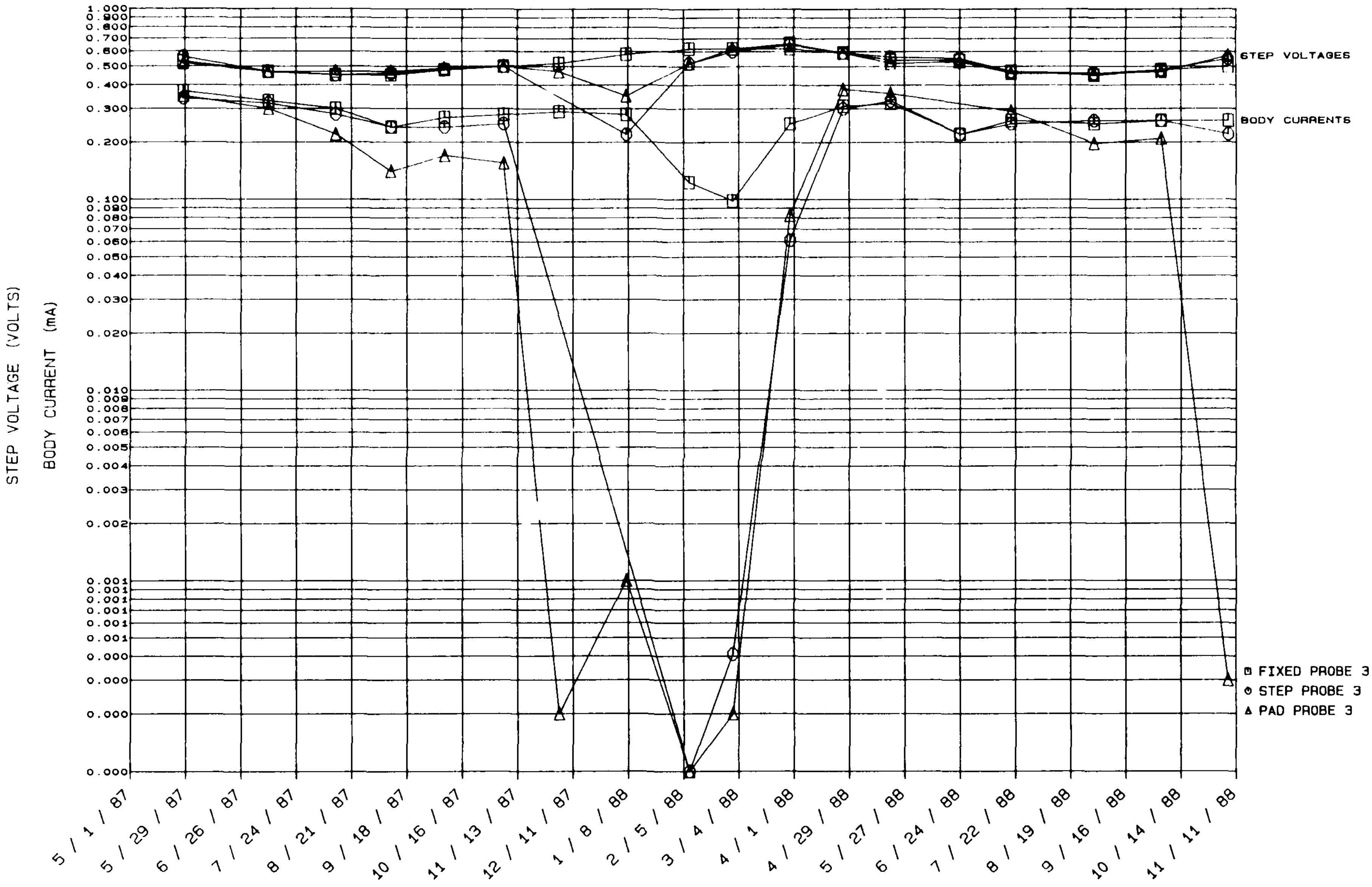


Figure A-3. Monthly Fixed Electrode, Step Probe, and Pad Probe Measurements at Site 3 (Bog with Standing Water)

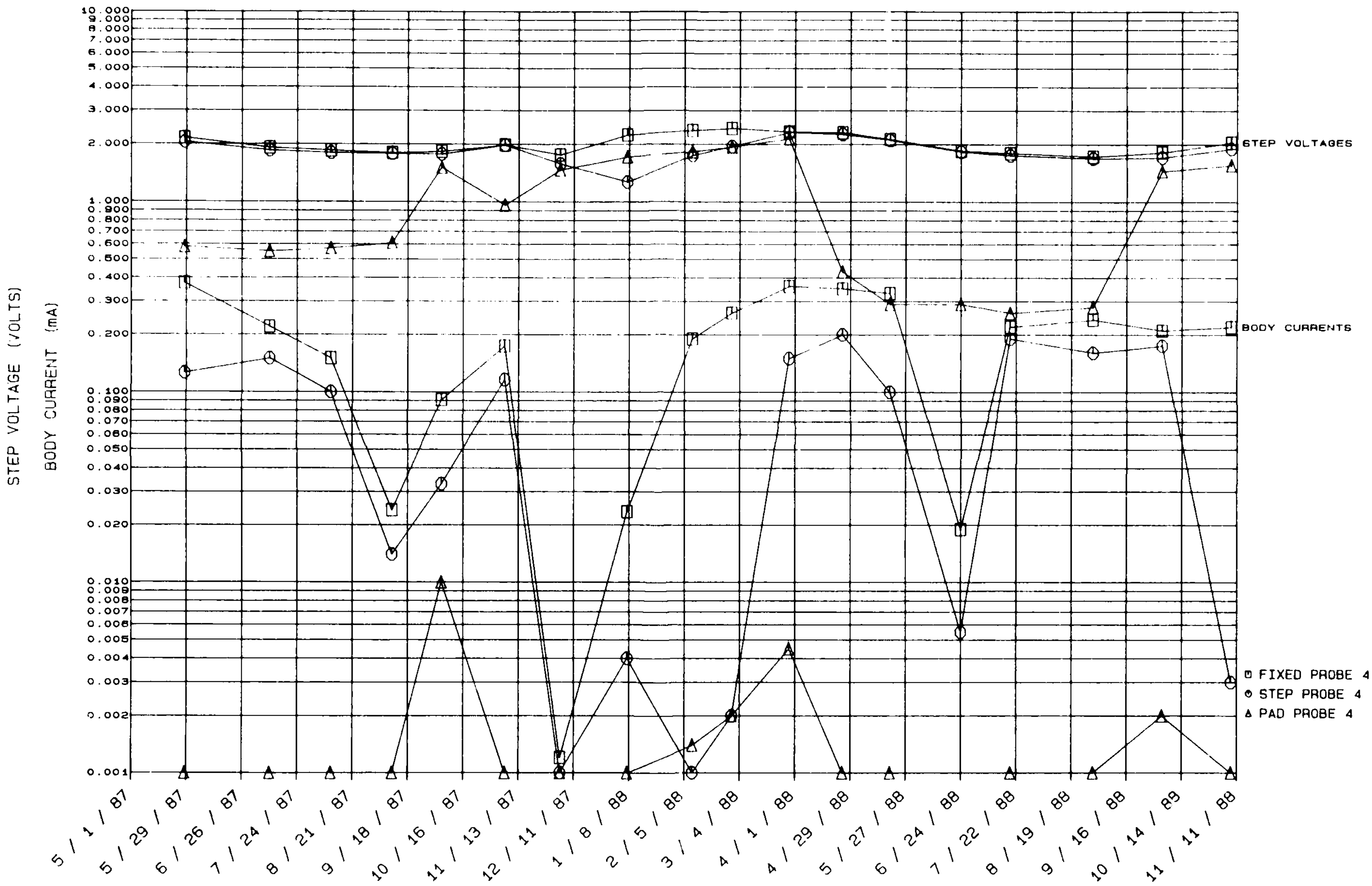


Figure A-4. Monthly Fixed Electrode, Step Probe, and Pad Probe Measurements at Site 4 (Gravel Fill)

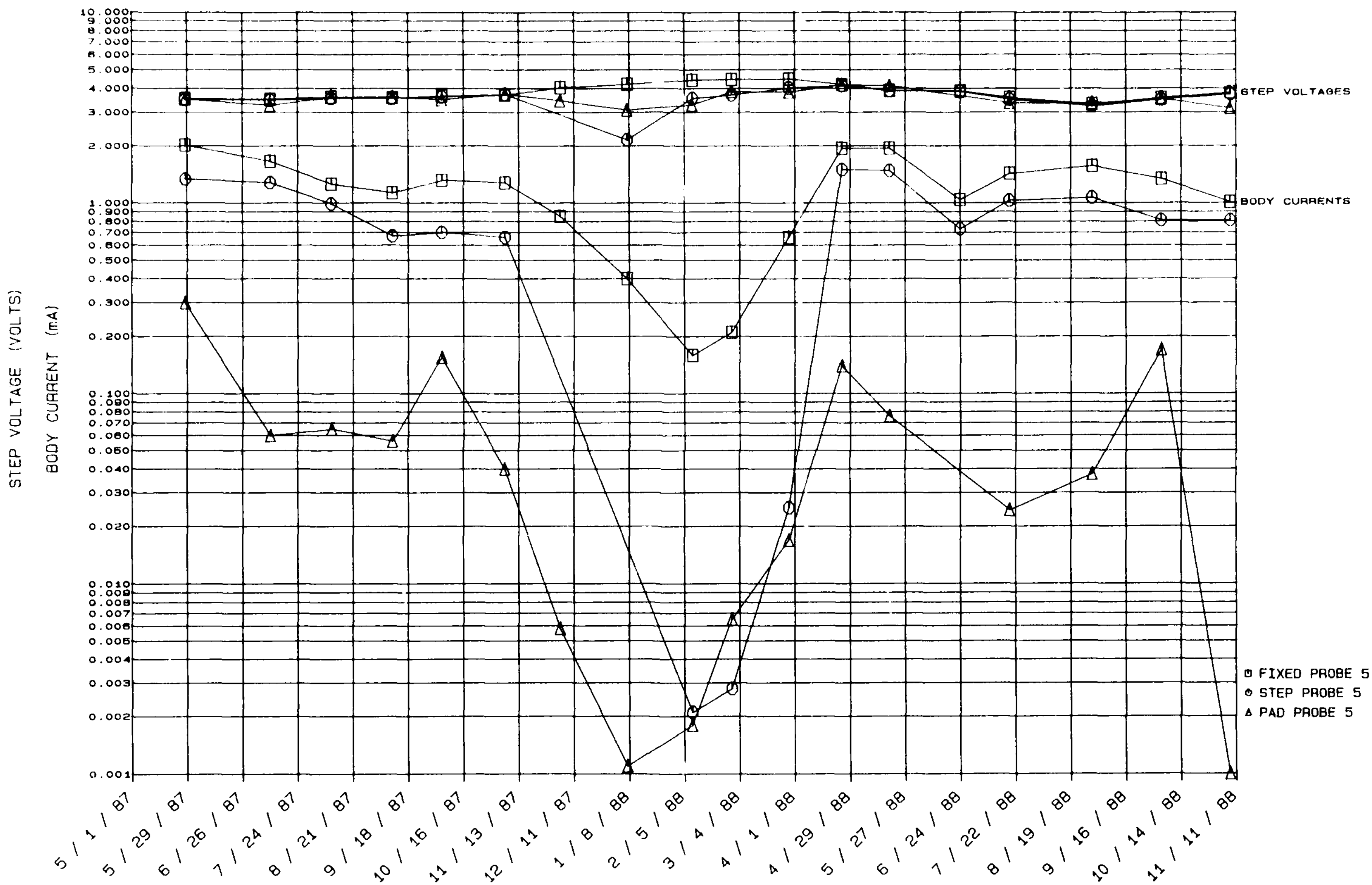


Figure A-5. Monthly Fixed Electrode, Step Probe, and Pad Probe Measurements at Site 5 (Sandy Soil with Slight Vegetation)

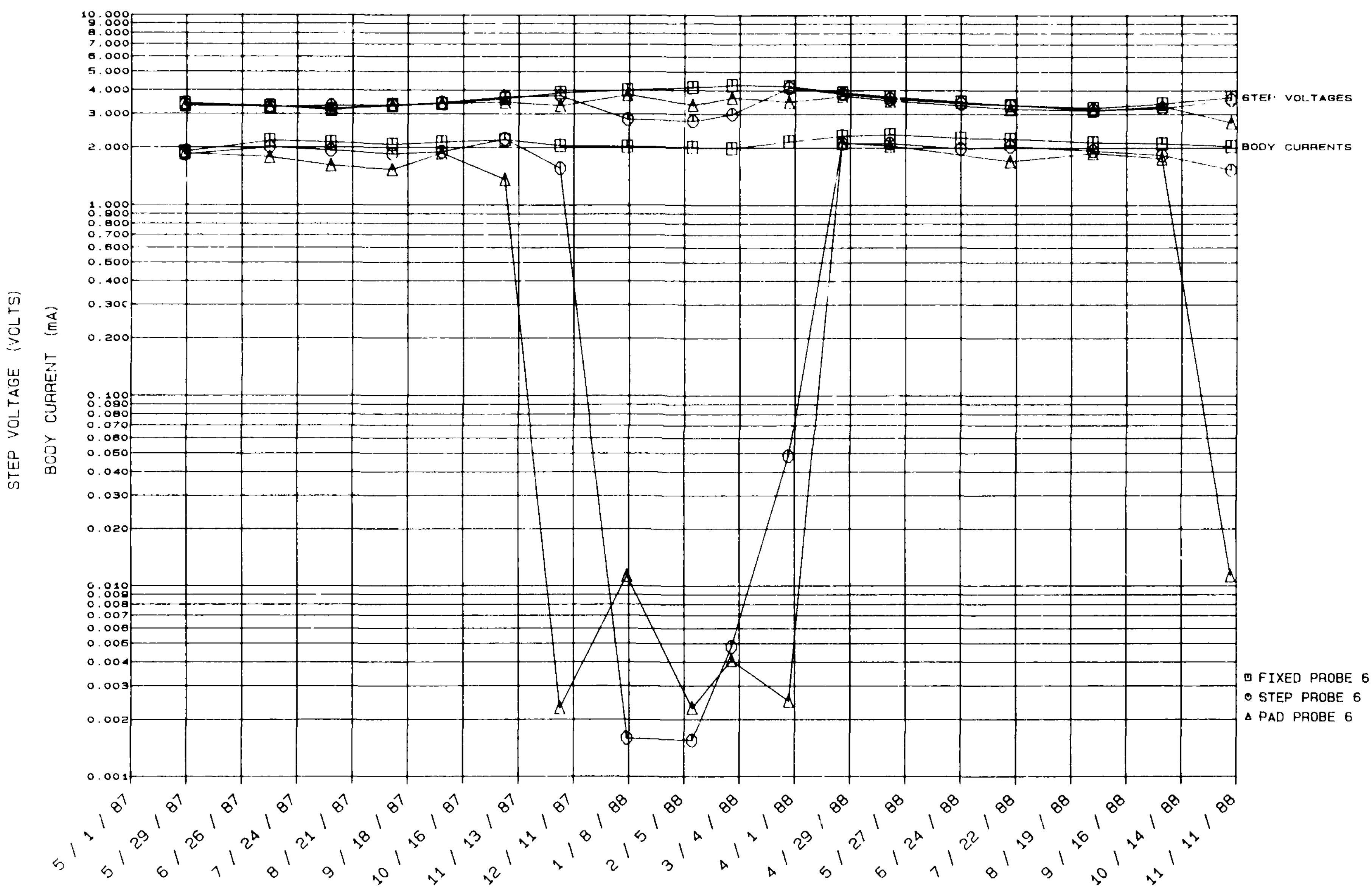


Figure A-6. Monthly Fixed Electrode, Step Probe, and Pad Probe Measurements at Site 6 (Bog with Standing Water)

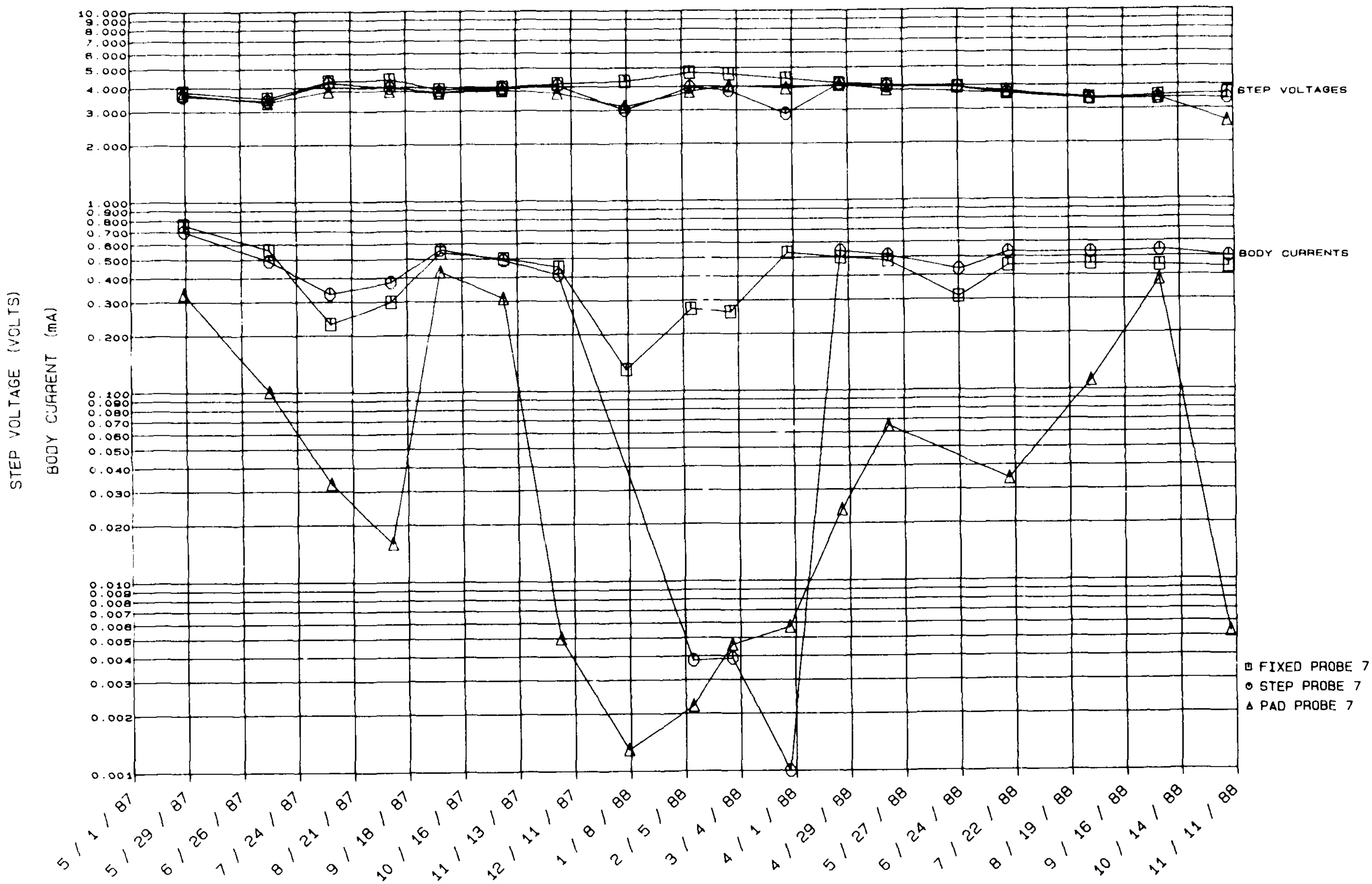


Figure A-7. Monthly Fixed Electrode, Step Probe, and Pad Probe Measurements at Site 7 (Loam with Vegetation)

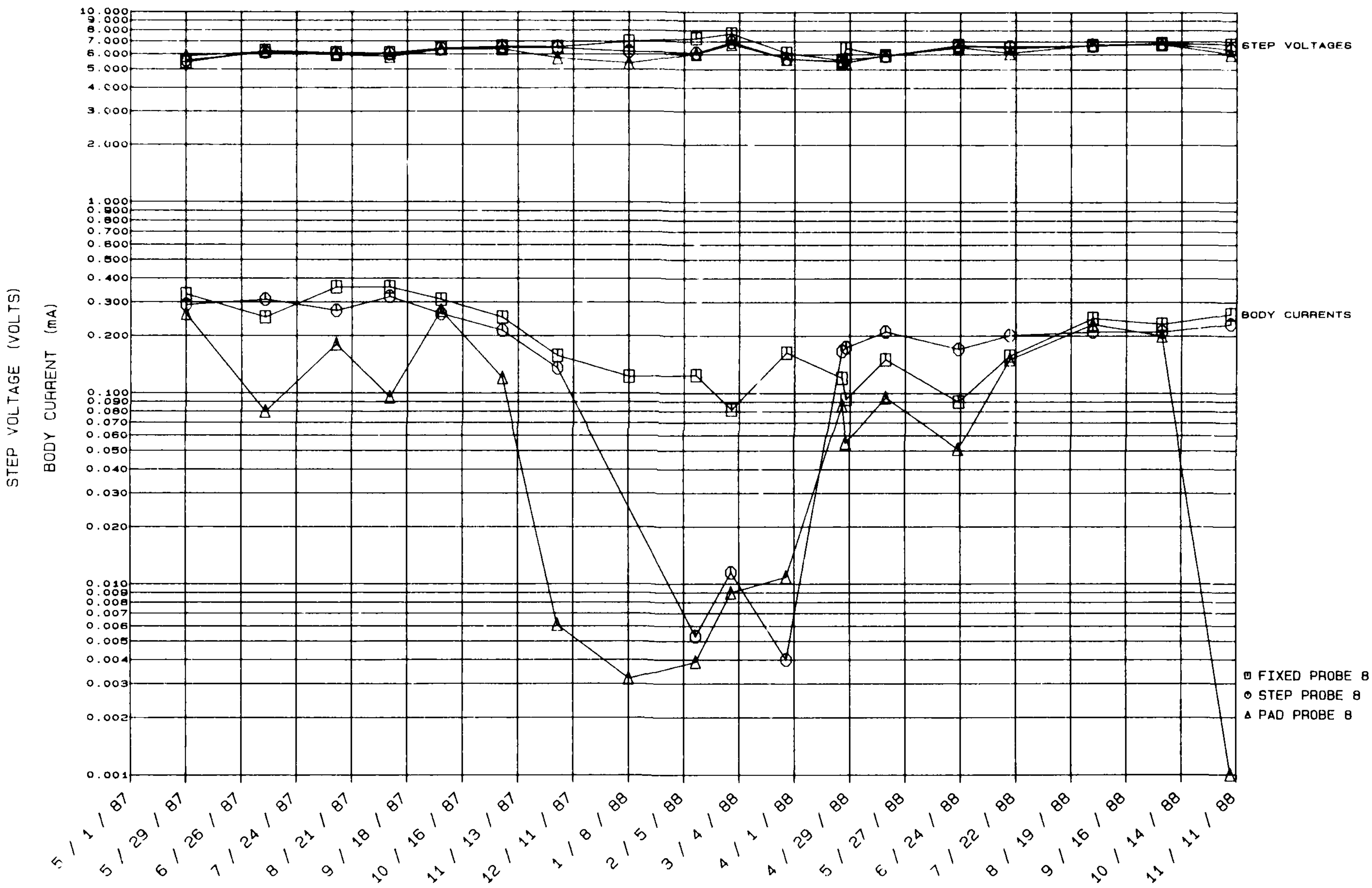


Figure A-8. Monthly Fixed Electrode, Step Probe, and Pad Probe Measurements at Site 8 (Sandy Soil with Slight Vegetation)

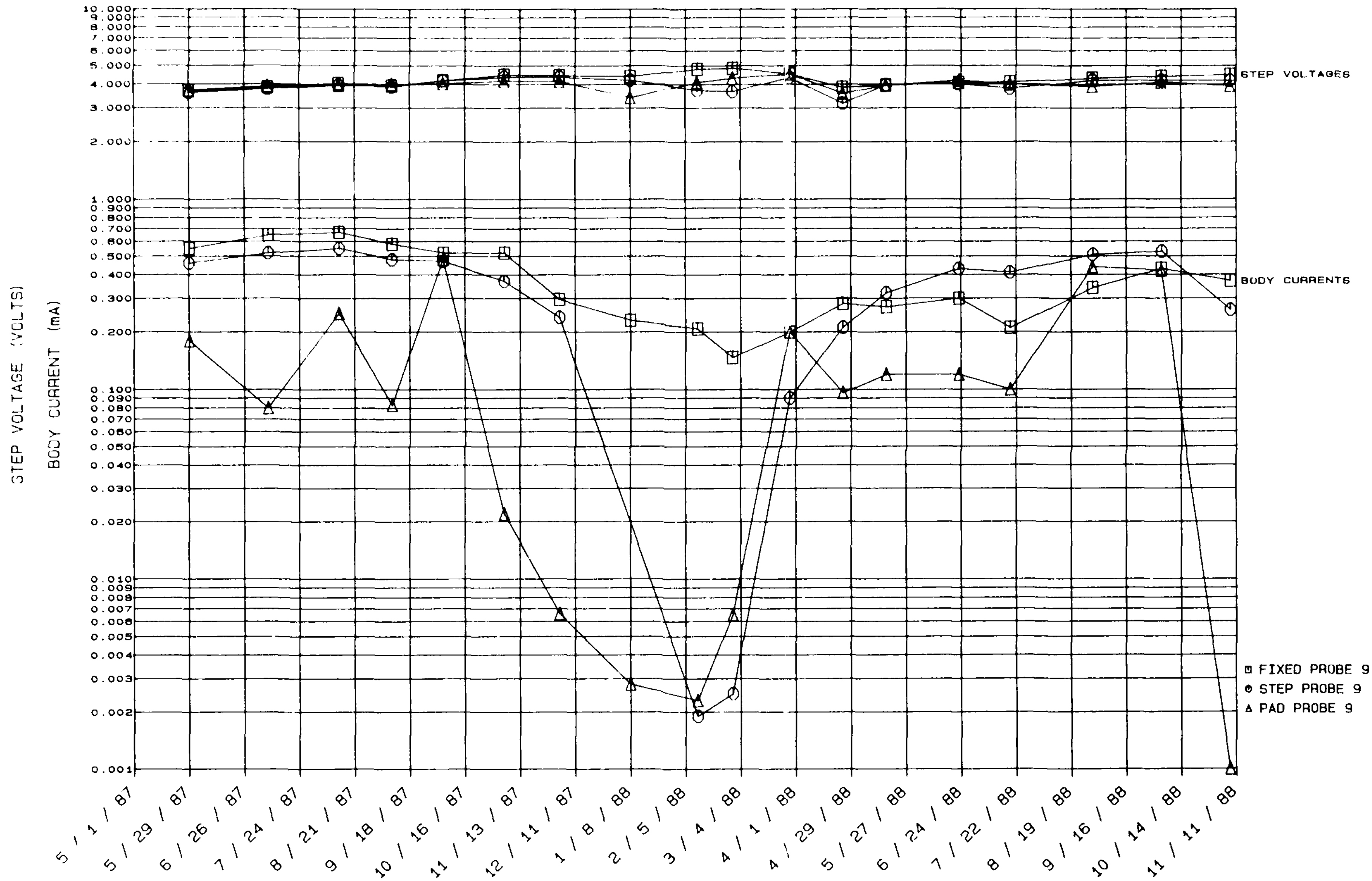


Figure A-9. Monthly Fixed Electrode, Step Probe, and Pad Probe Measurements at Site 9 (Sandy Soil with Slight Vegetation)

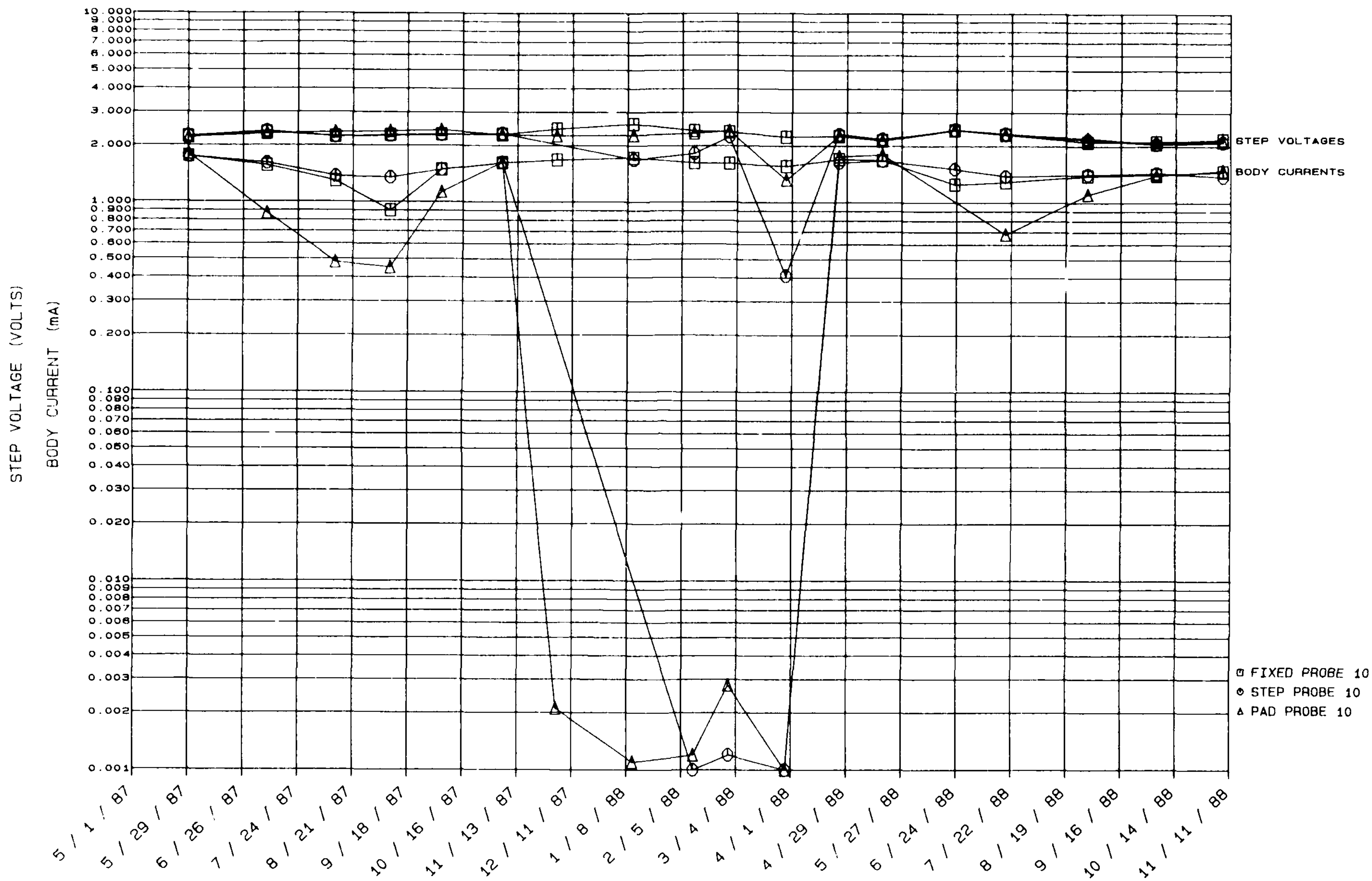


Figure A-10. Monthly Fixed Electrode, Step Probe, and Pad Probe Measurements at Site 10 (Bog with Standing Water)

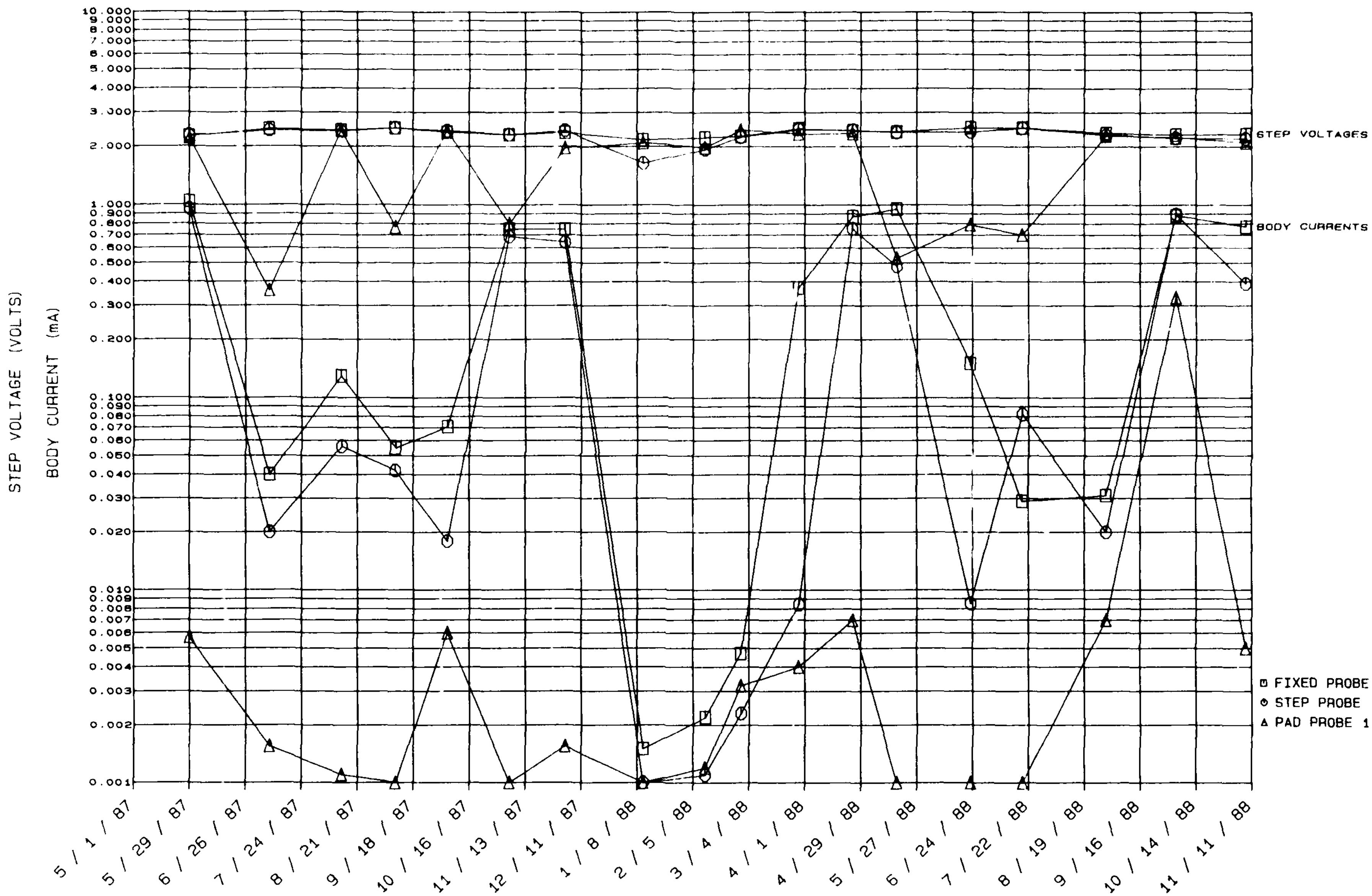


Figure A-11. Monthly Fixed Electrode, Step Probe, and Pad Probe Measurements at Site 11 (Gravel Fill)

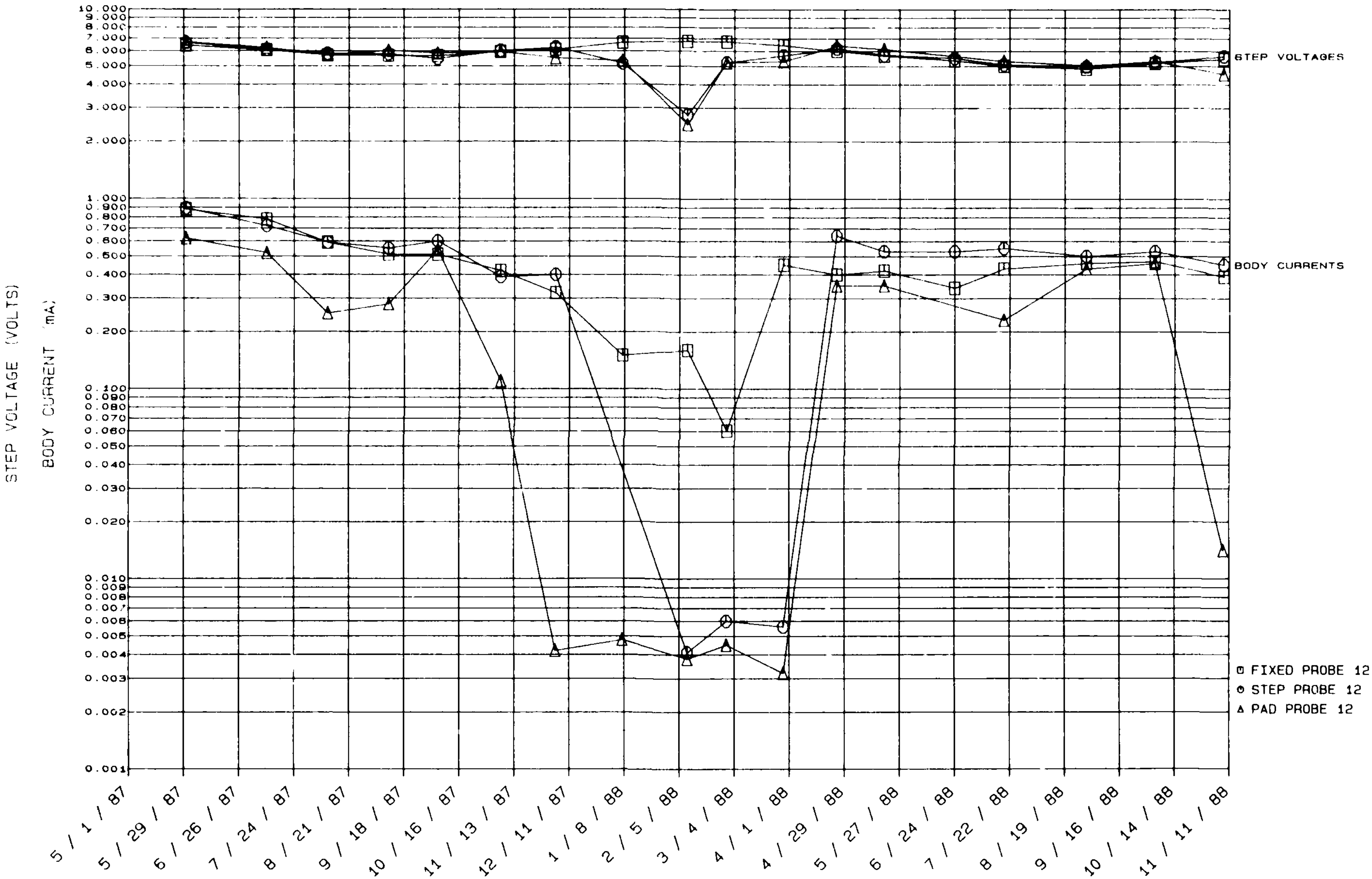


Figure A-12. Monthly Fixed Electrode, Step Probe, and Pad Probe Measurements at Site 12 (Loam with Vegetation)

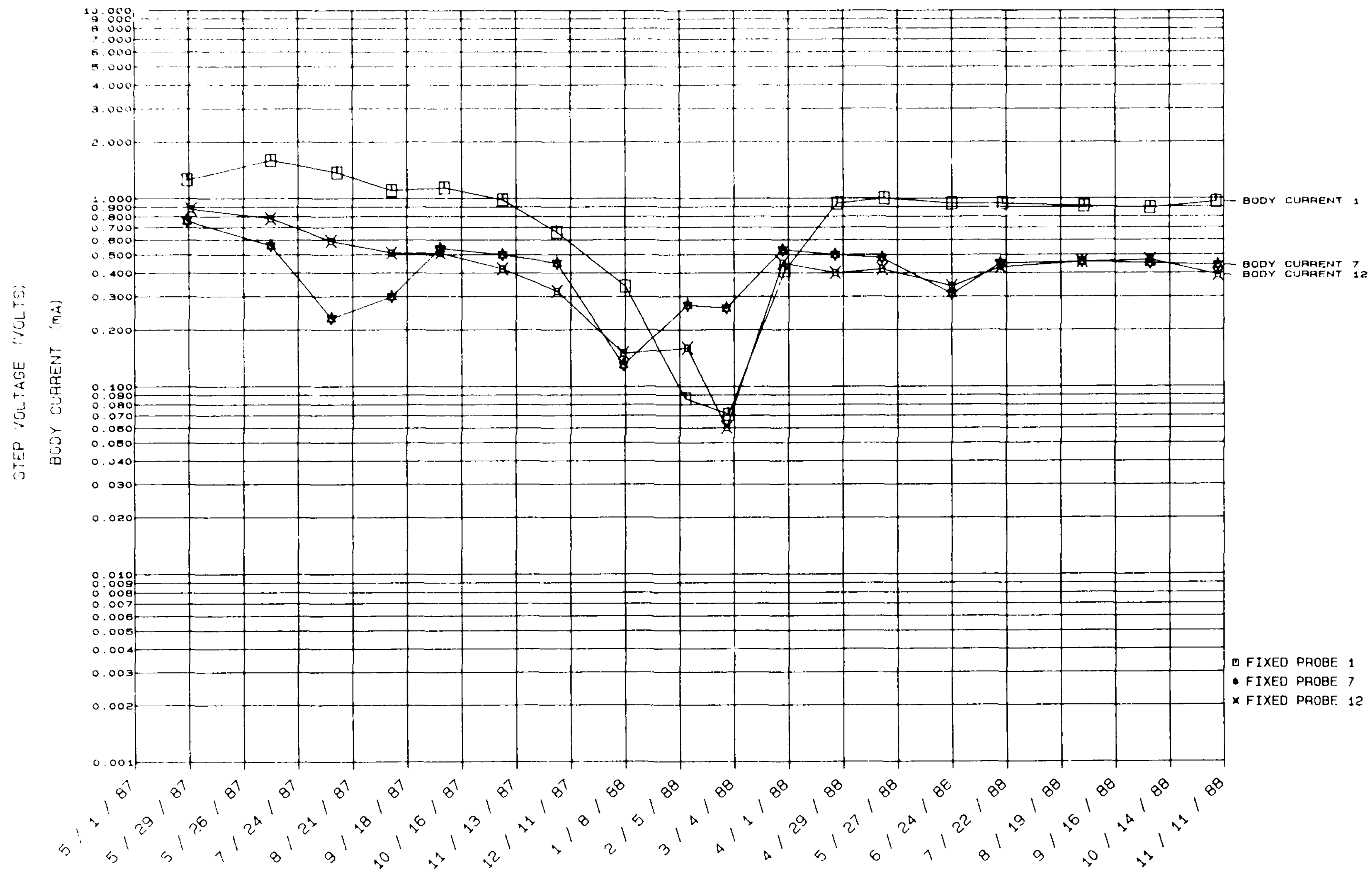


Figure A-13. Monthly Fixed Electrode Body Current Measurements for Sites 1, 7, and 12 (Loam with Vegetation)

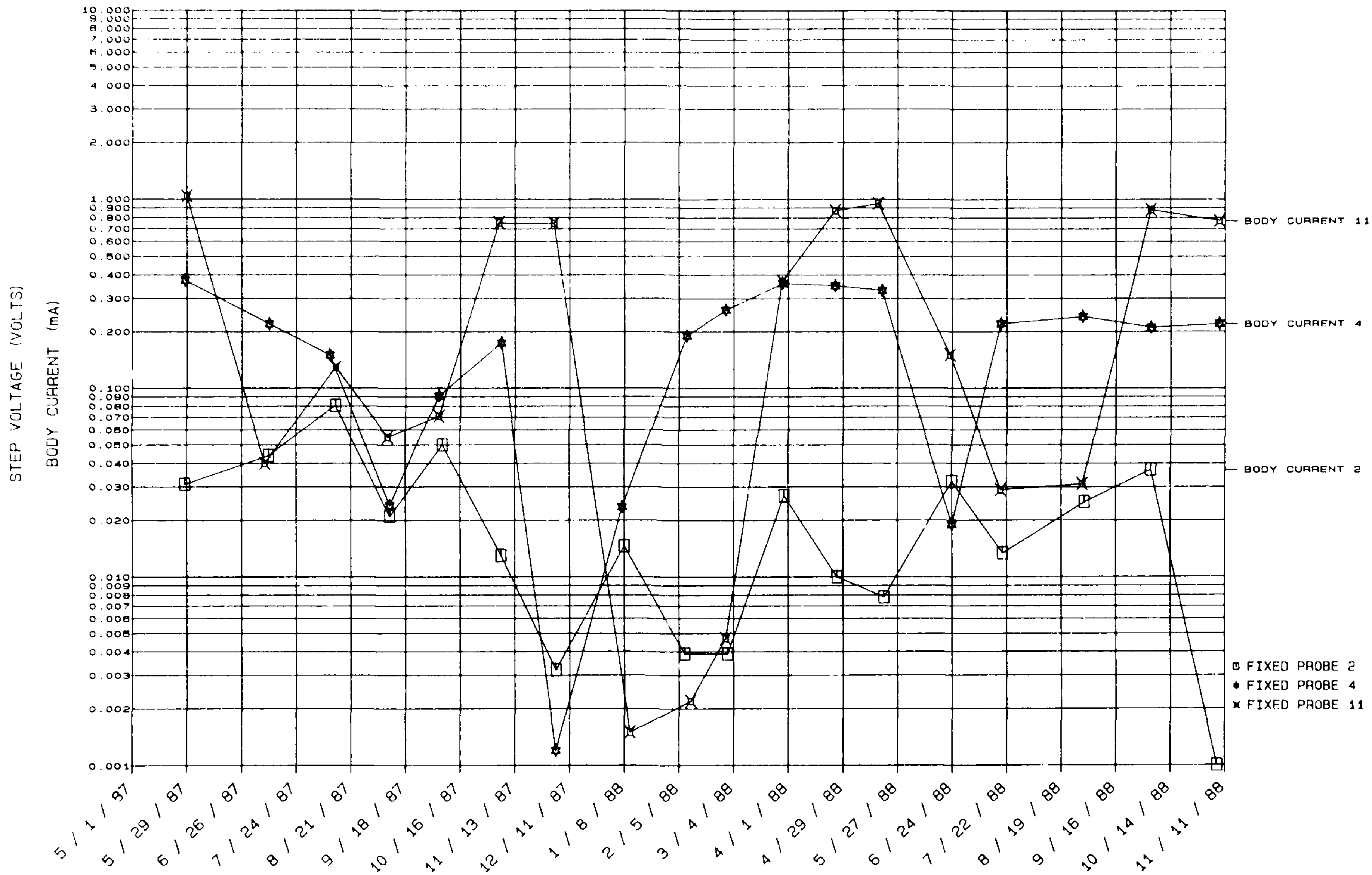


Figure A-14. Monthly Fixed Electrode Body Current Measurements for Sites 2, 4, and 11 (Gravel Fill)

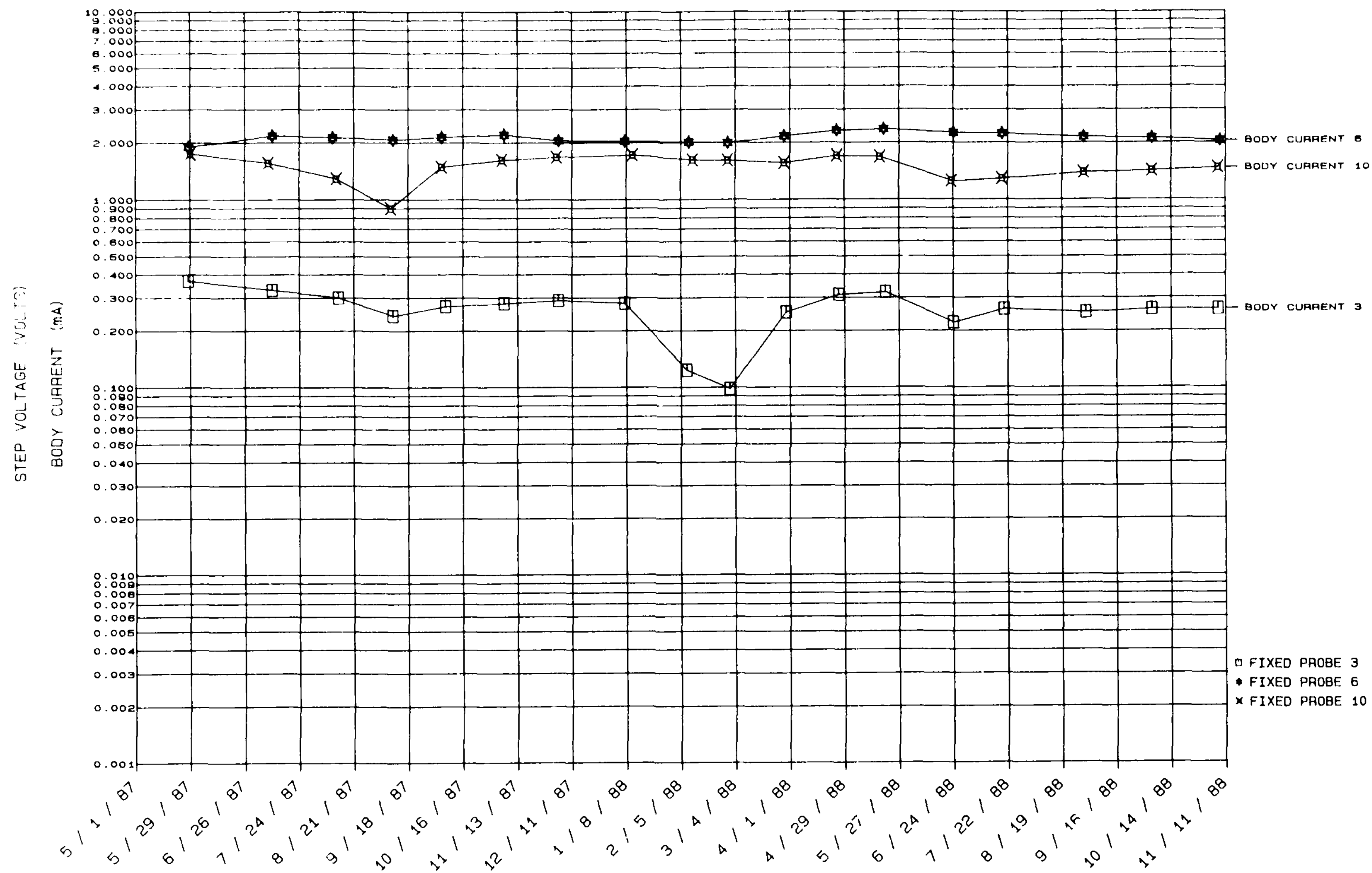


Figure A-15. Monthly Fixed Electrode Body Current Measurements for Sites 3, 6, and 10 (Bog with Standing Water)

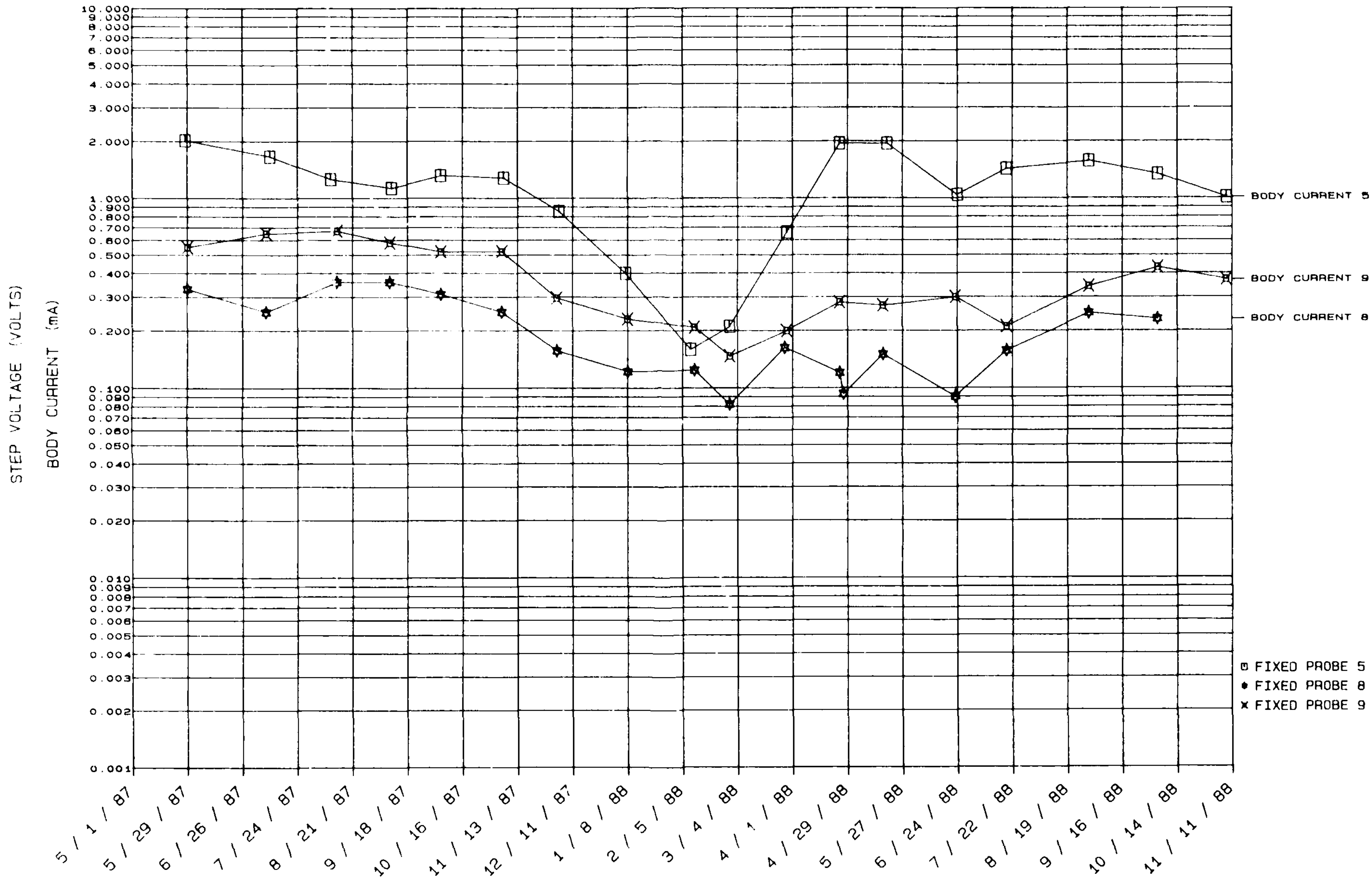


Figure A-16. Monthly Fixed Electrode Body Current Measurements for Sites 5, 8, and 9 (Sandy Soil with Slight Vegetation)

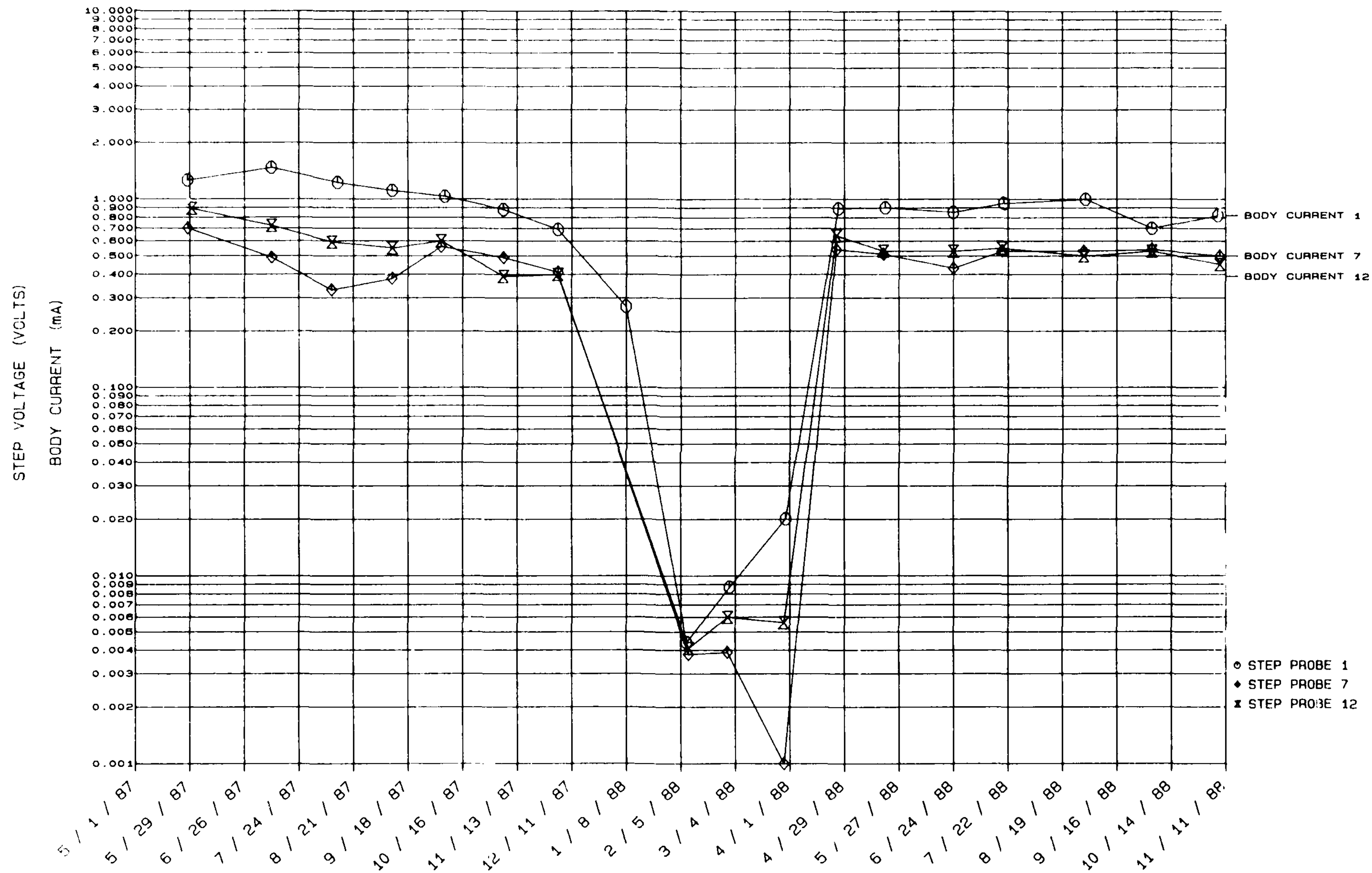


Figure A-17. Monthly Step Probe Body Current Measurements for Sites 1, 7, and 12 (Loam with Vegetation)

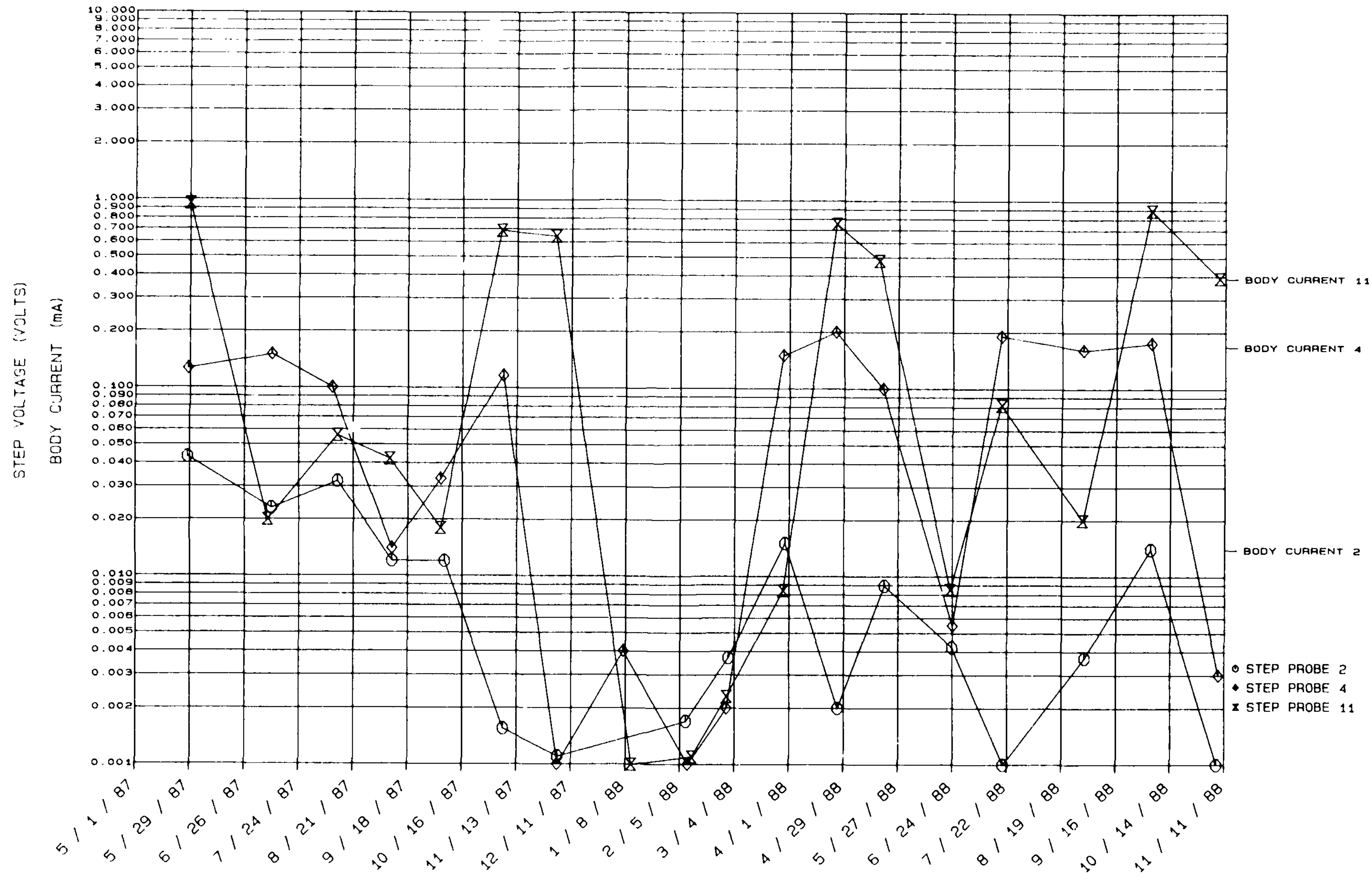


Figure A-18. Monthly Step Probe Body Current Measurements for Sites 2, 4, and 11 (Gravel Fill)

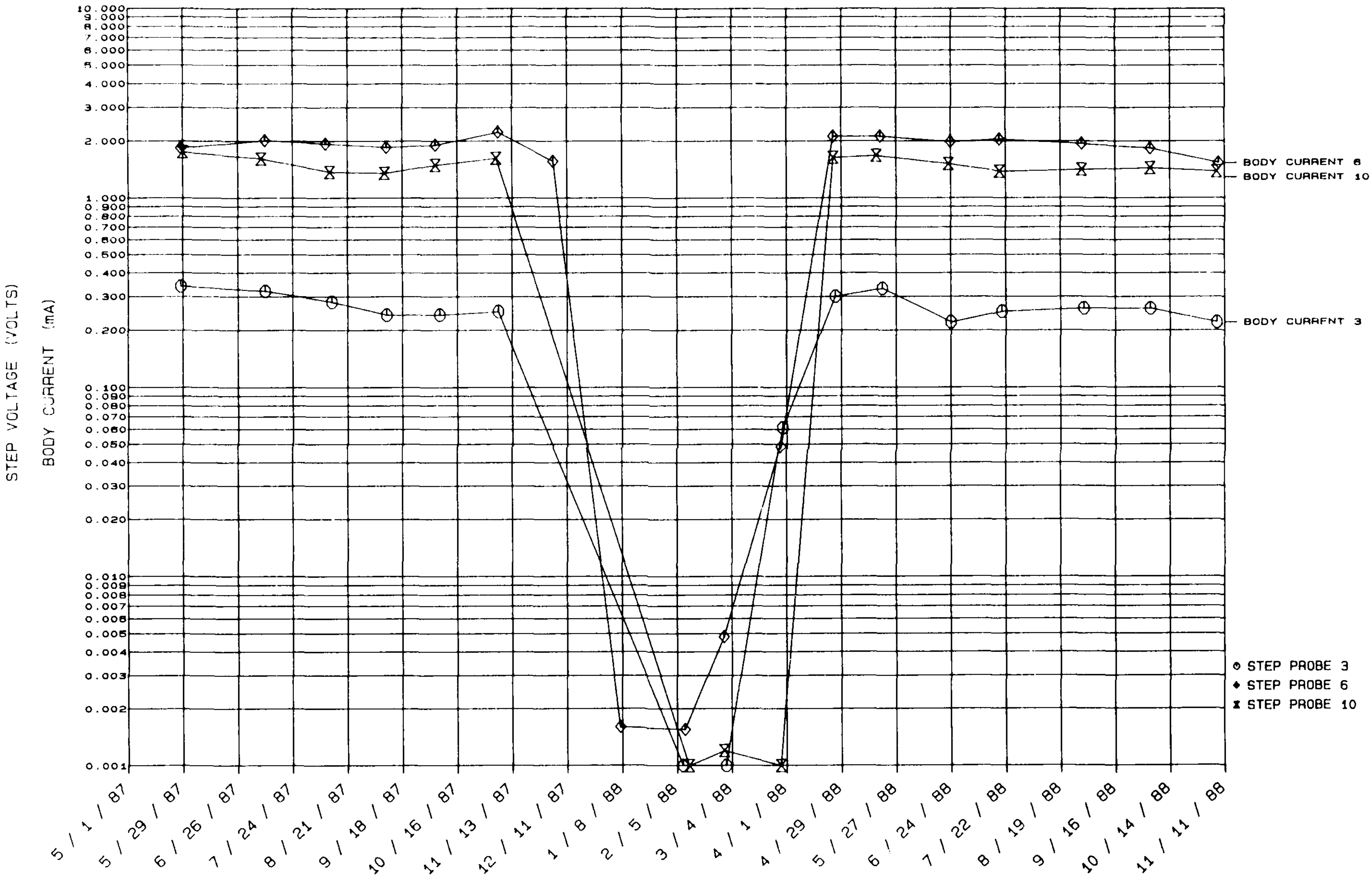


Figure A-19. Monthly Step Probe Body Current Measurements for Sites 3, 6, and 10 (Bog with Standing Water)

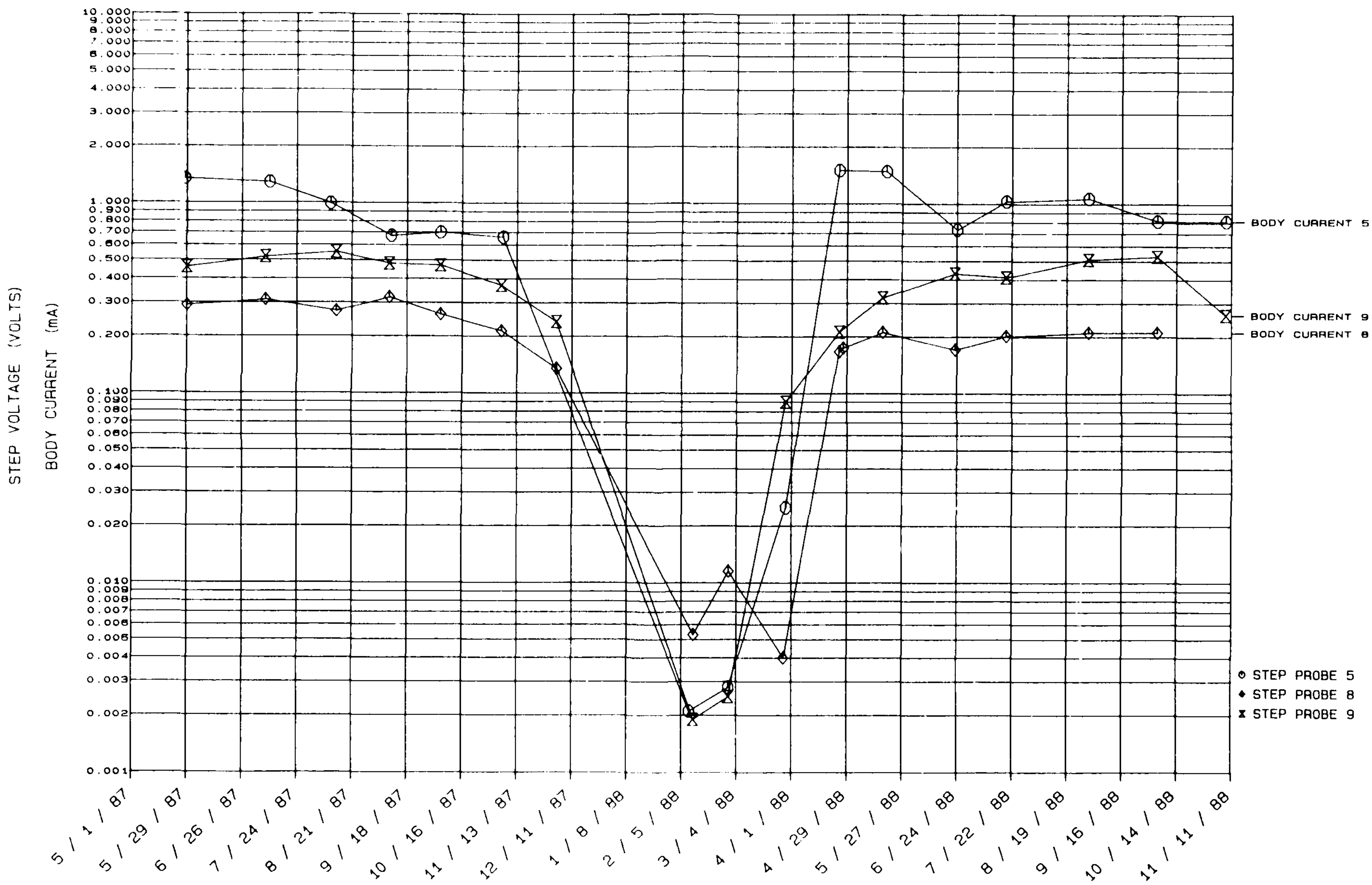


Figure A-20. Monthly Step Probe Body Current Measurements for Sites 5, 8, and 9 (Sandy Soil with Slight Vegetation)

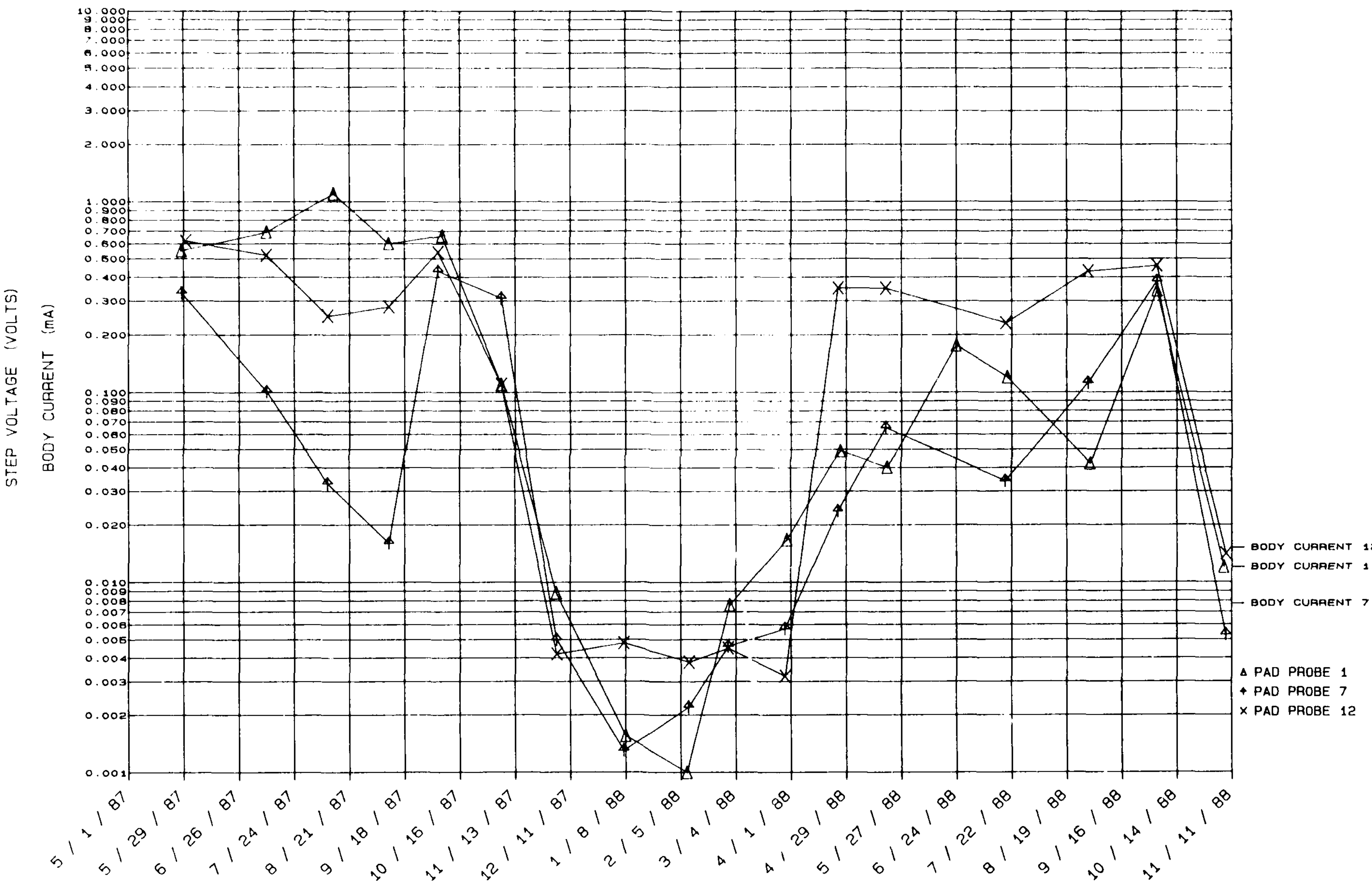


Figure A-21. Monthly Pad Probe Body Current Measurements for Sites 1, 7, and 12 (Loam with Vegetation)

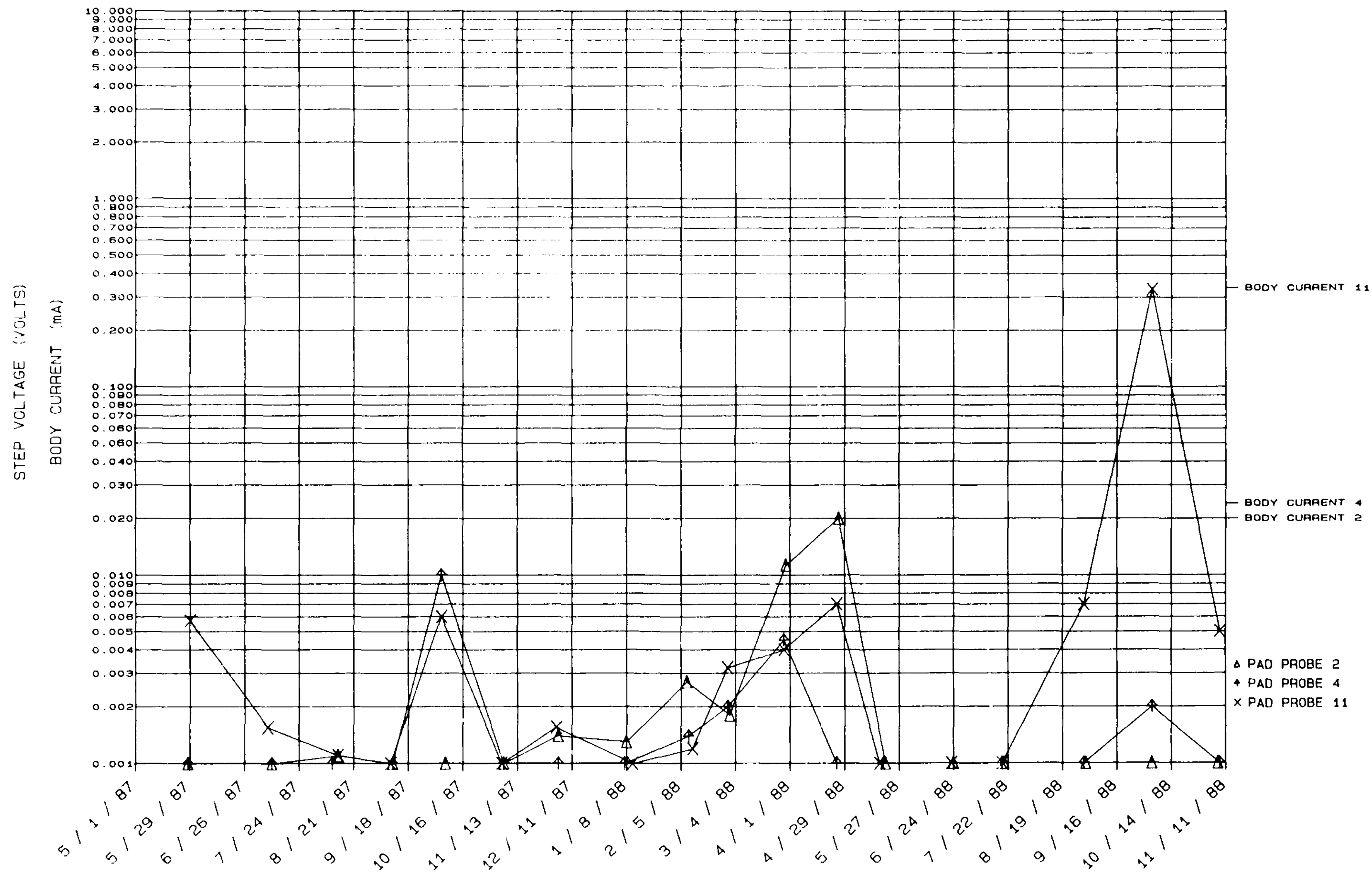


Figure A-22. Monthly Pad Probe Body Current Measurements for Sites 2, 4, and 11 (Gravel Fill)

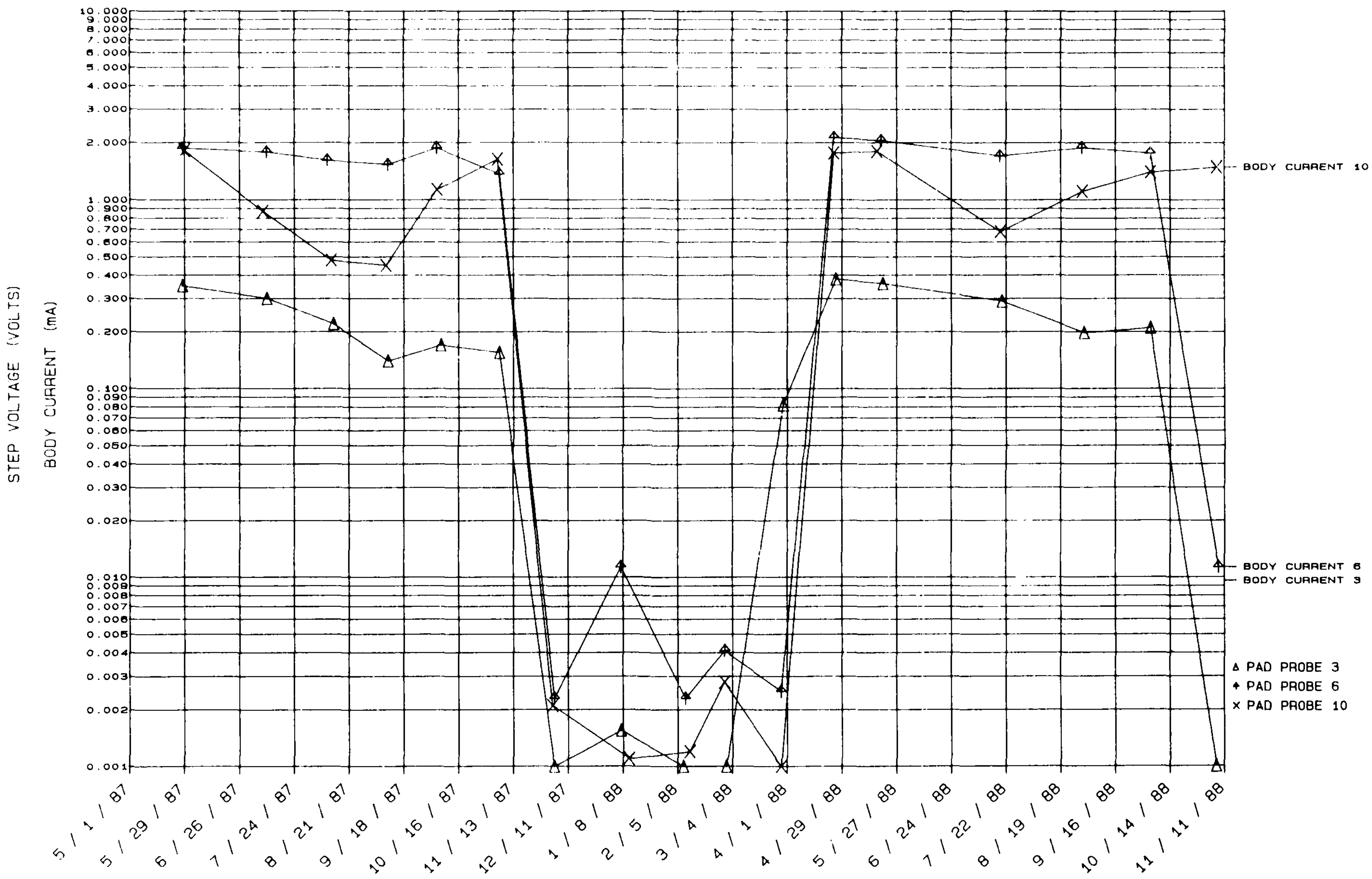


Figure A-23. Monthly Pad Probe Body Current Measurements for Sites 3, 6, and 10 (Bog with Standing Water)

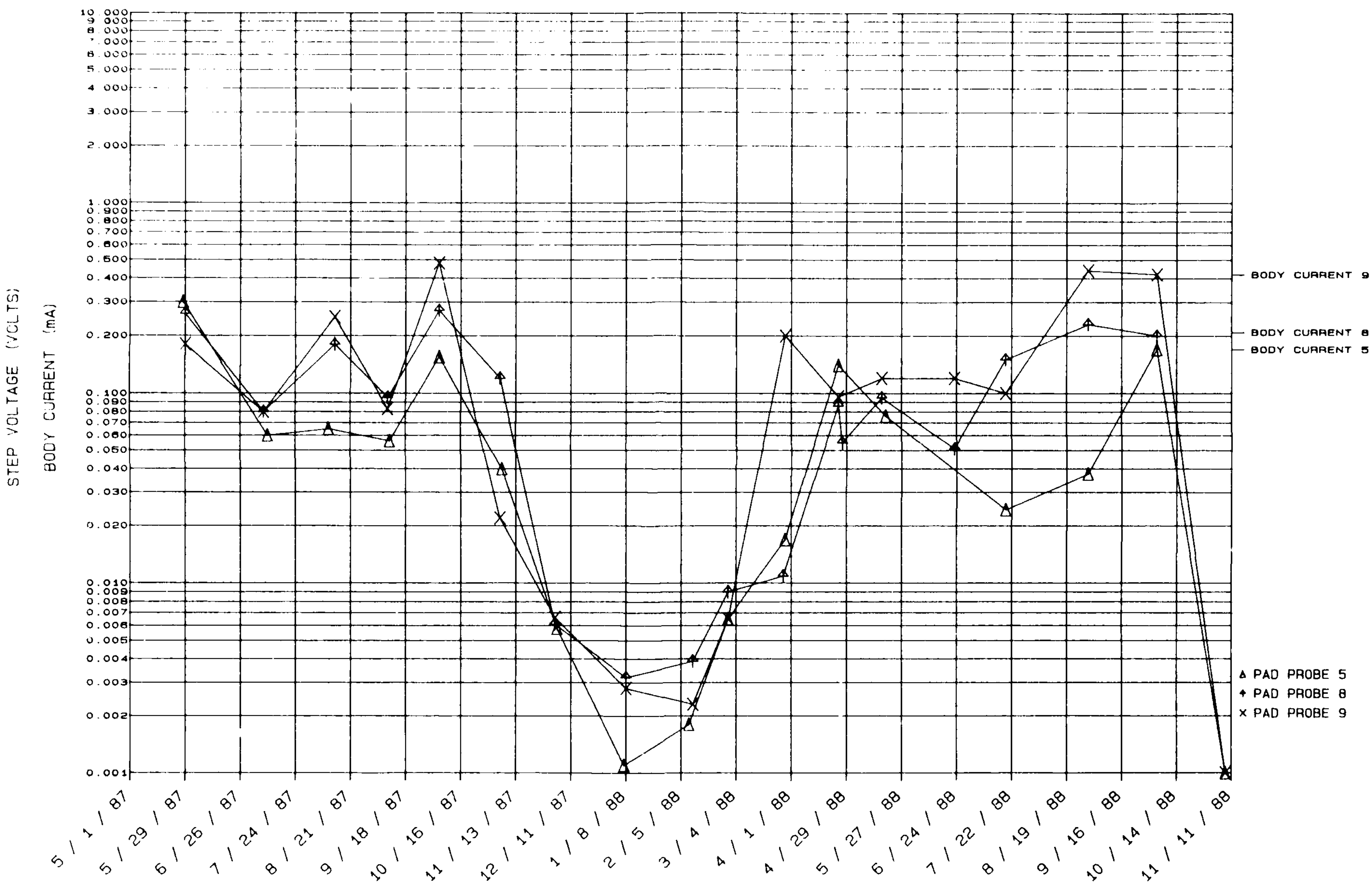


Figure A-24. Monthly Pad Probe Body Current Measurements for
Sites 5, 8, and 9 (Sandy Soil with Slight Vegetation)

APPENDIX B

Grounds Seasonal Variation Pilot Study

Daily Average Plots

Hourly Measurements Plots

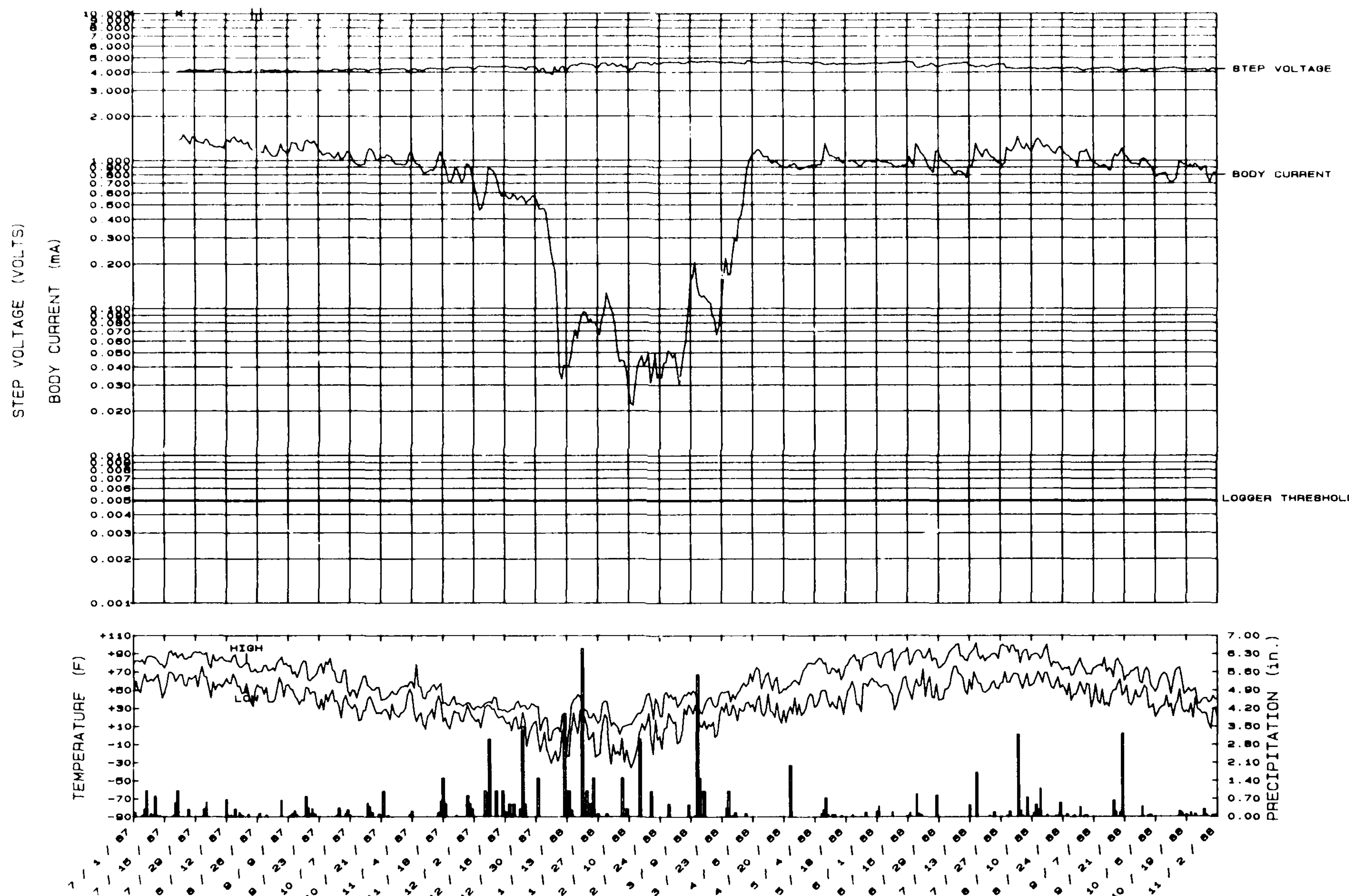


Figure B-1. Daily Average of Hourly Data Logger Measurements at Site 1 (Loam with Vegetation)

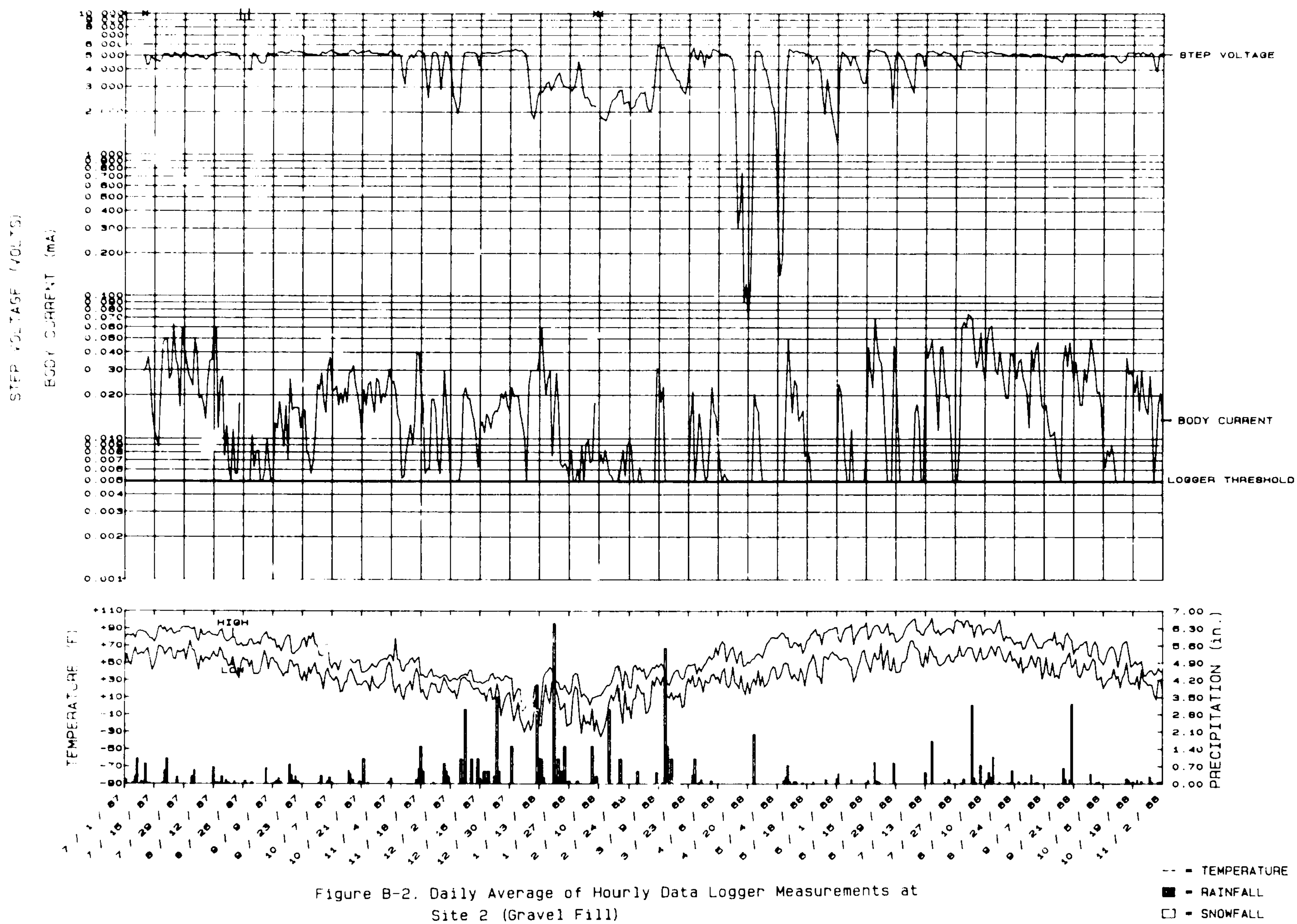


Figure B-2. Daily Average of Hourly Data Logger Measurements at Site 2 (Gravel Fill)

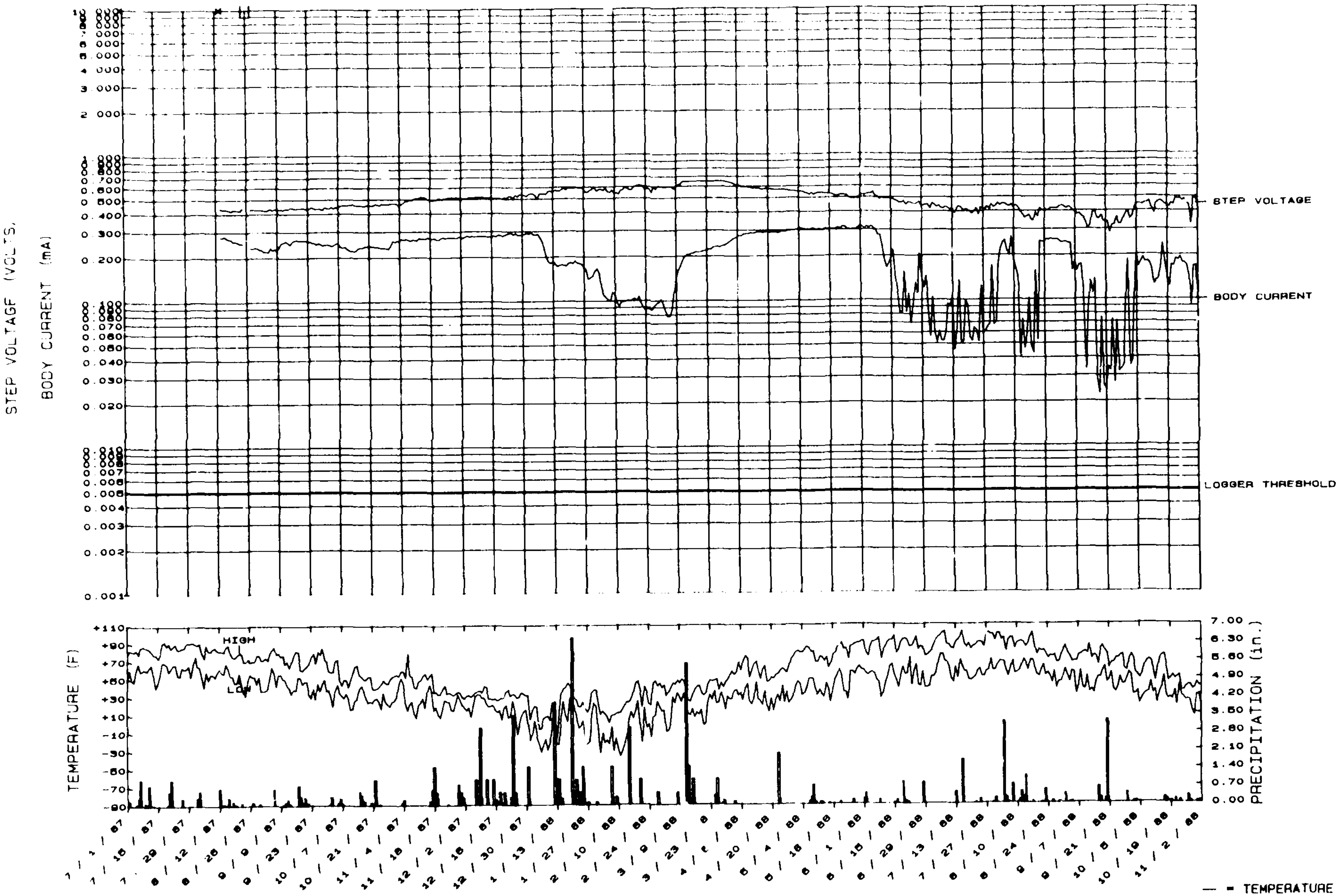


Figure B-3. Daily Average of Hourly Data Logger Measurements at Site 3 (Bog with Standing Water)

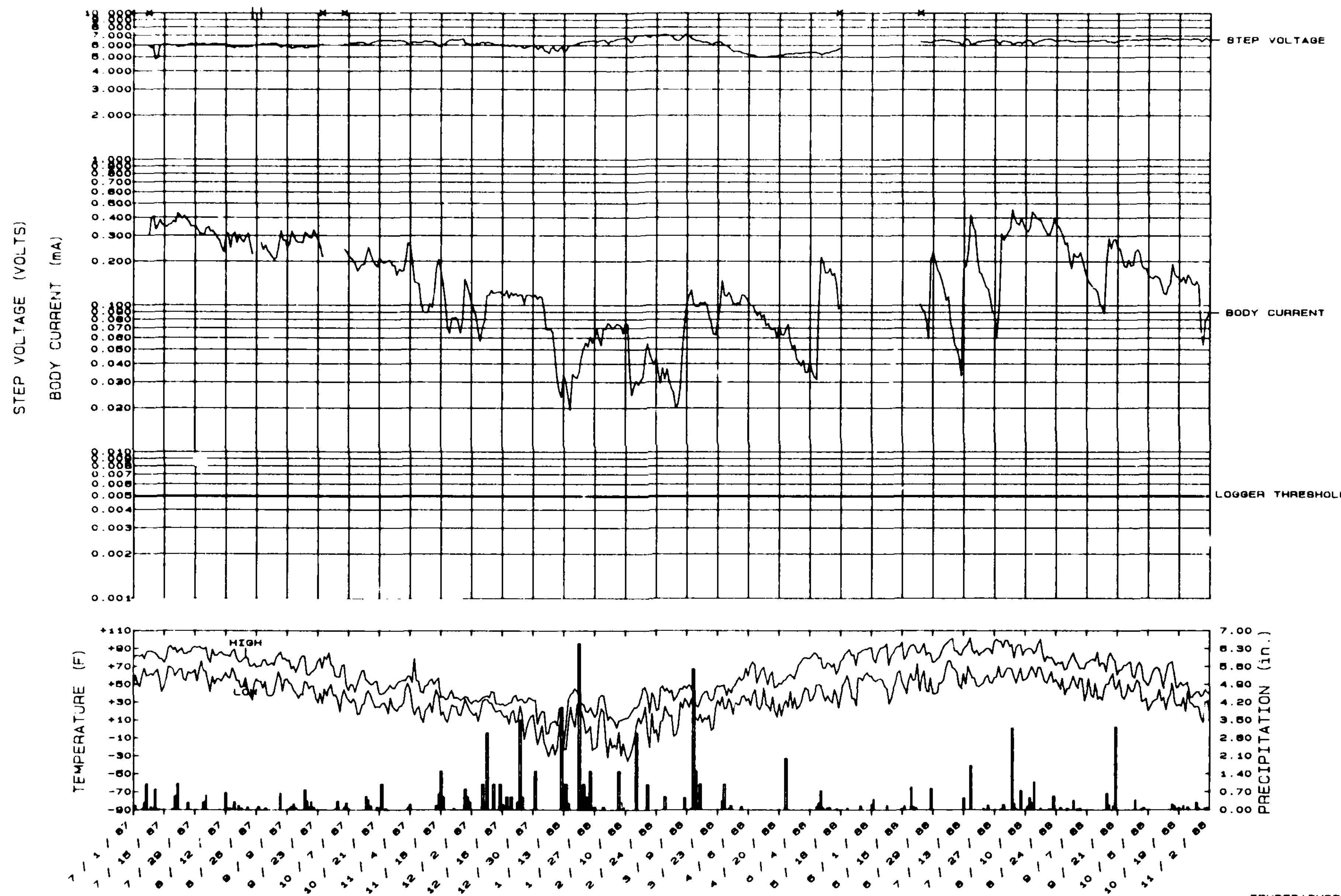


Figure B-4. Daily Average of Hourly Data Logger Measurements at Site 8 (Sandy Soil with Slight Vegetation)

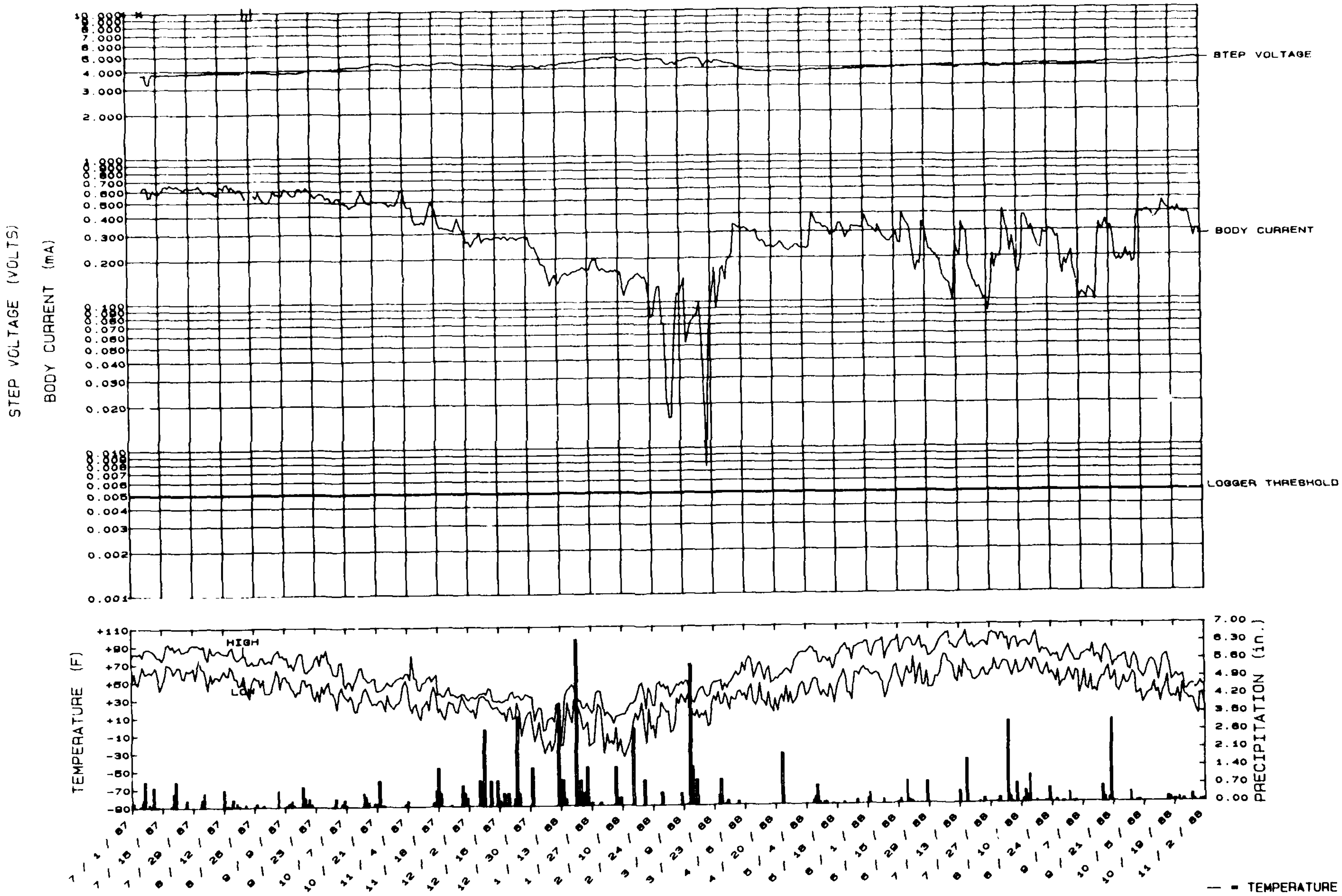


Figure B-5. Daily Average of Hourly Data Logger Measurements at Site 9 (Sandy Soil with Slight Vegetation)

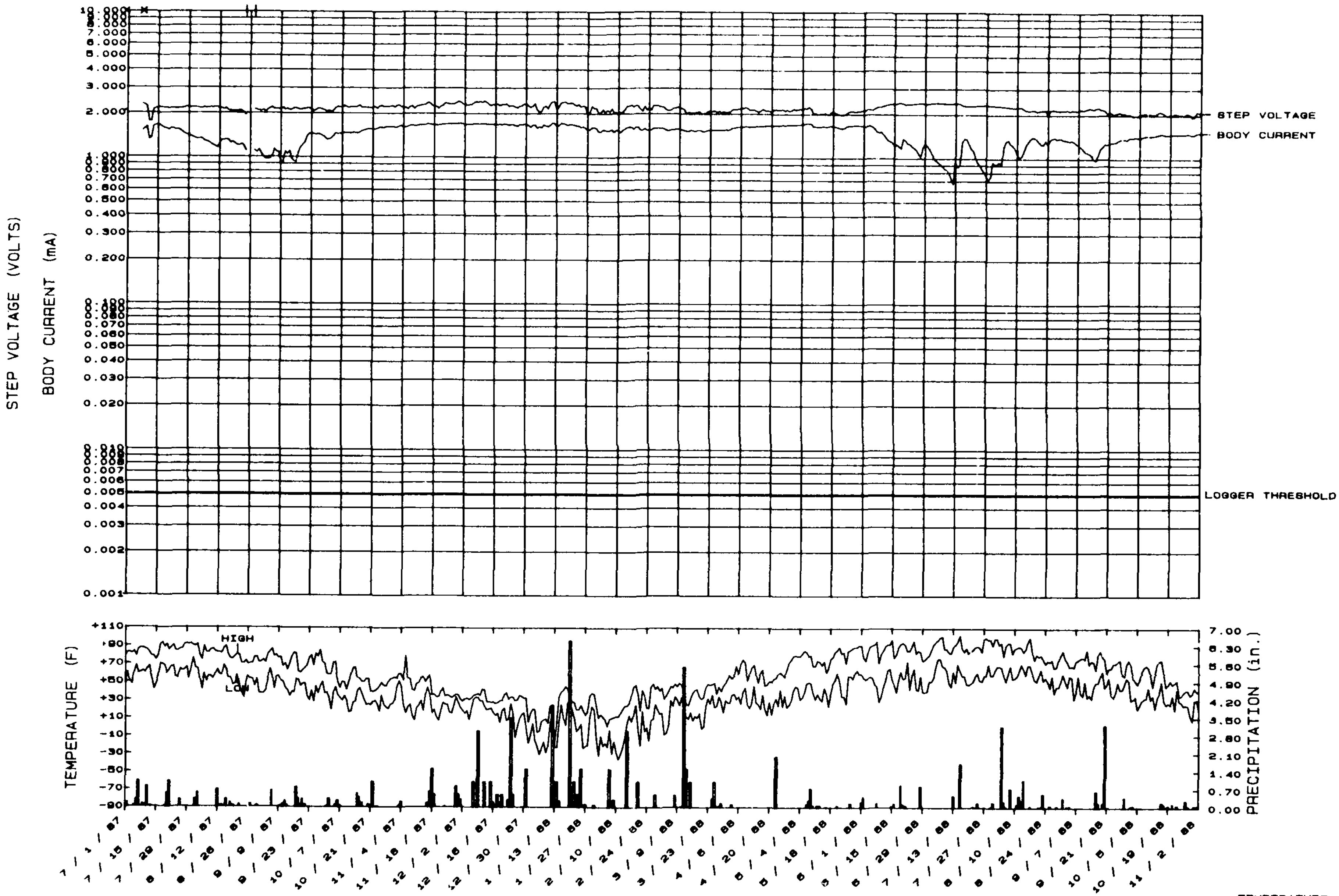


Figure B-6. Daily Average of Hourly Data Logger Measurements at Site 10 (Bog with Standing Water)

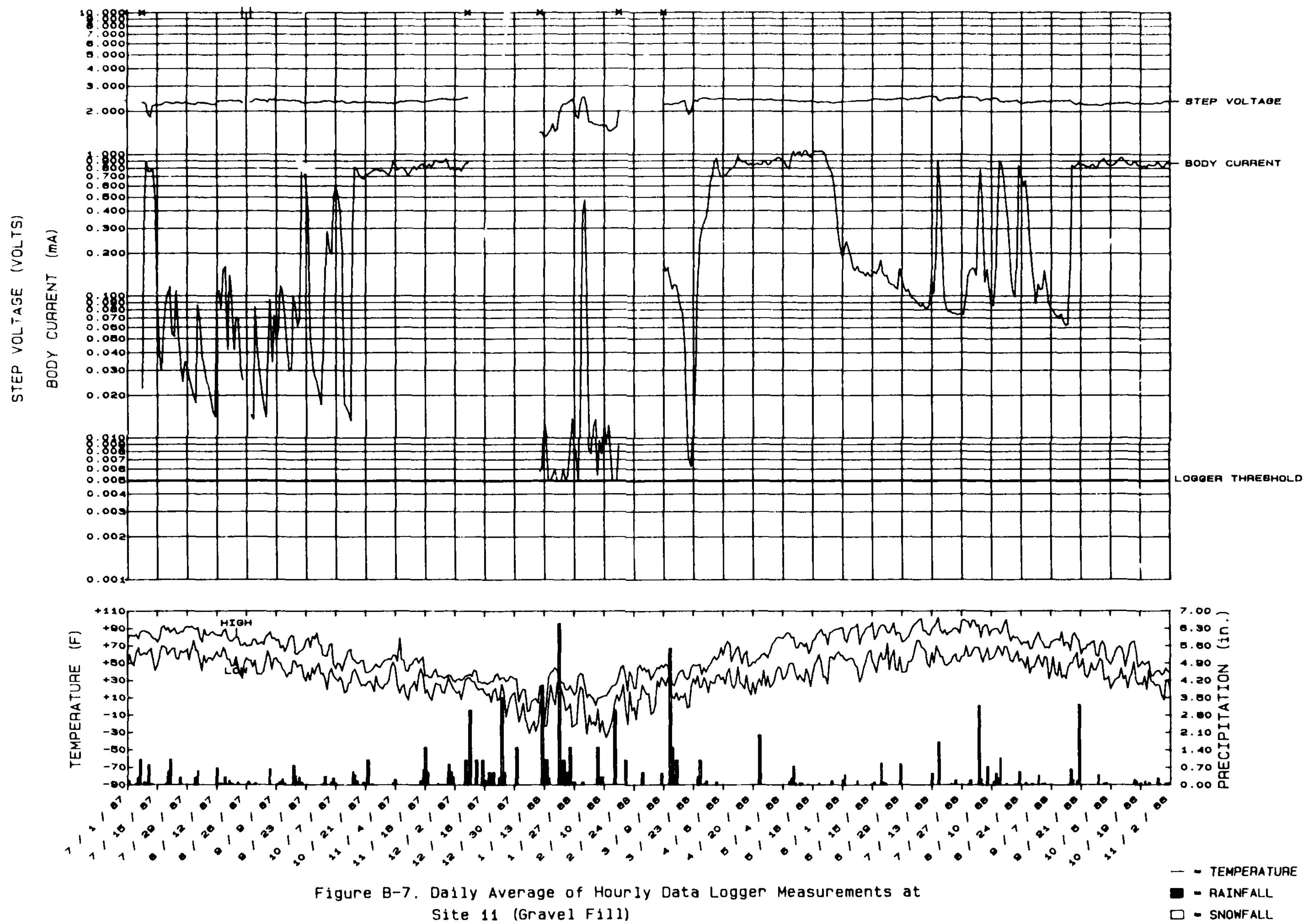


Figure B-7. Daily Average of Hourly Data Logger Measurements at Site 11 (Gravel Fill)

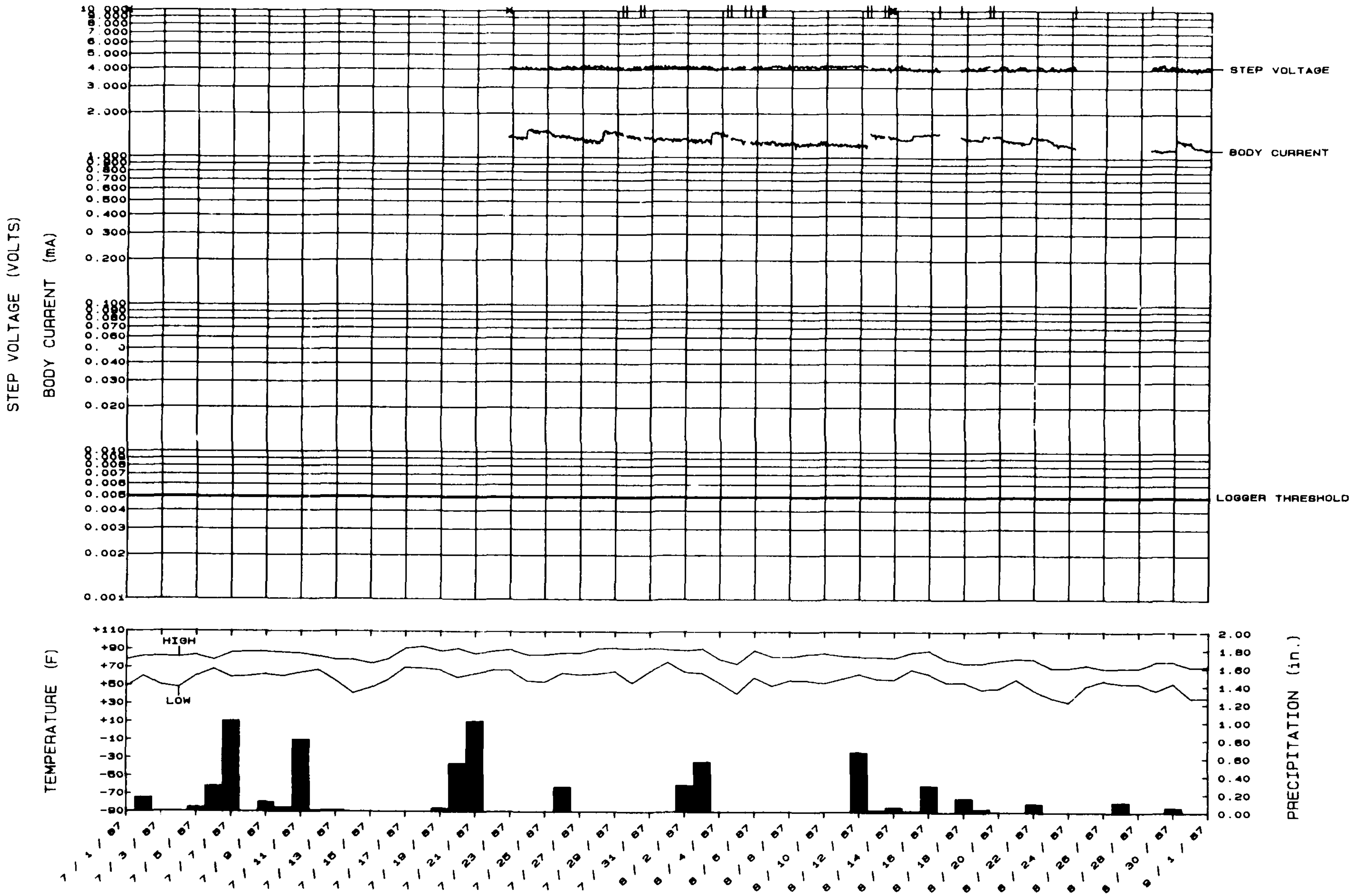


Figure B-8a. Hourly Data Logger Measurements at Site 1 (Loam with Vegetation)
July - August 1987

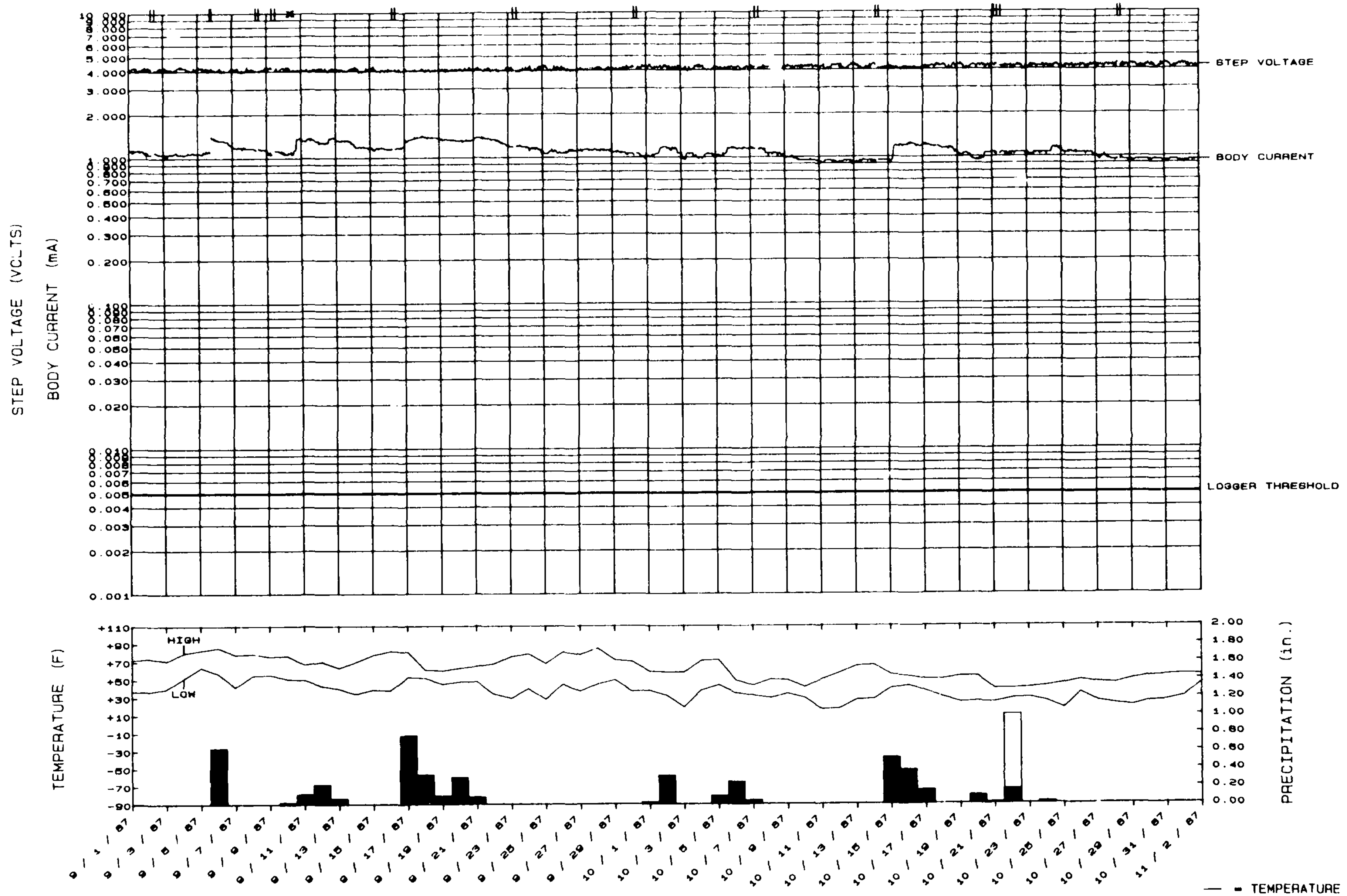


Figure B-8b. Hourly Data Logger Measurements at Site 1 (Loam with Vegetation) September - October 1987

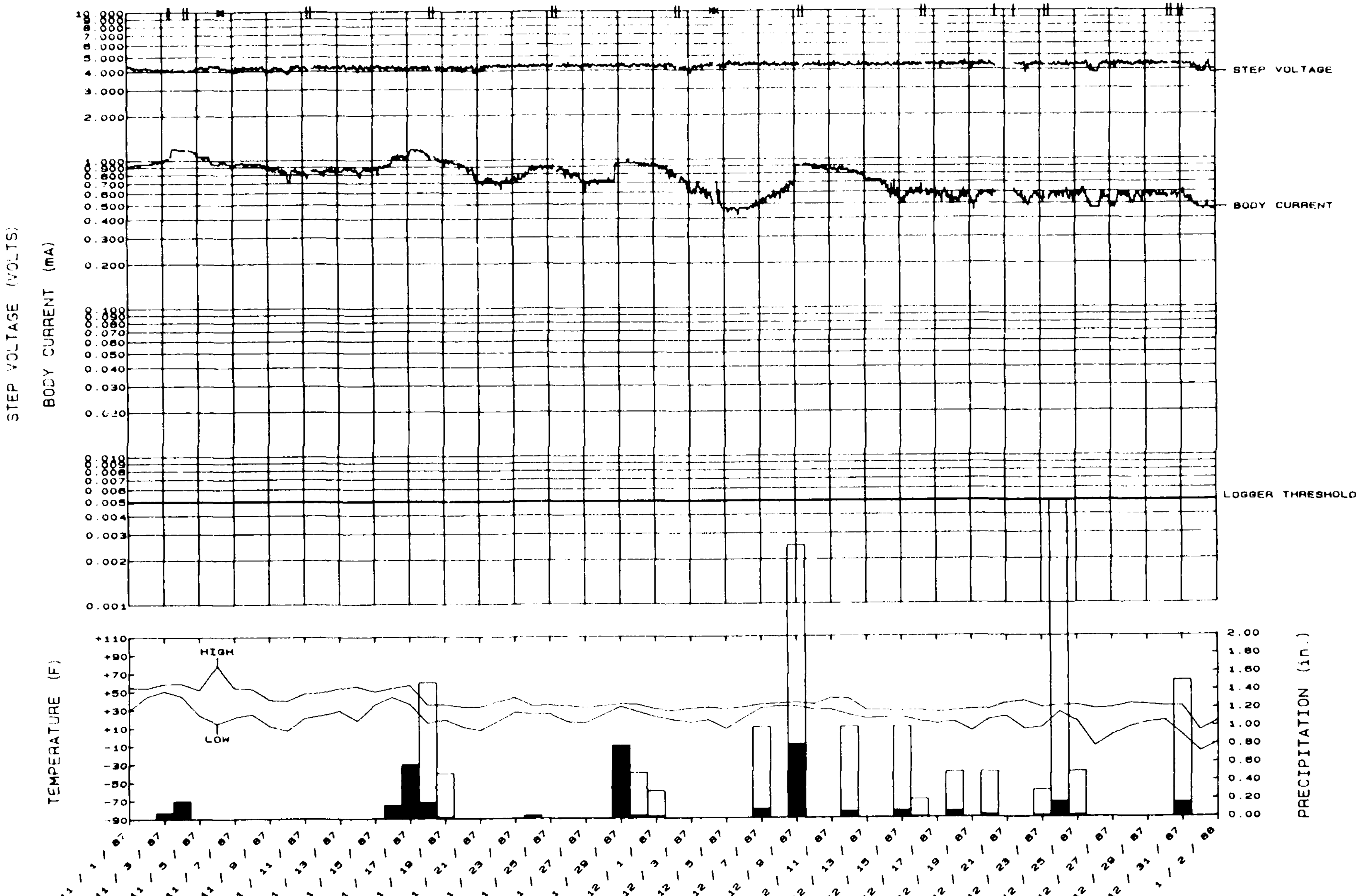


Figure B-8c. Hourly Data Logger Measurements at Site 1 (Loam with Vegetation)
November - December 1987

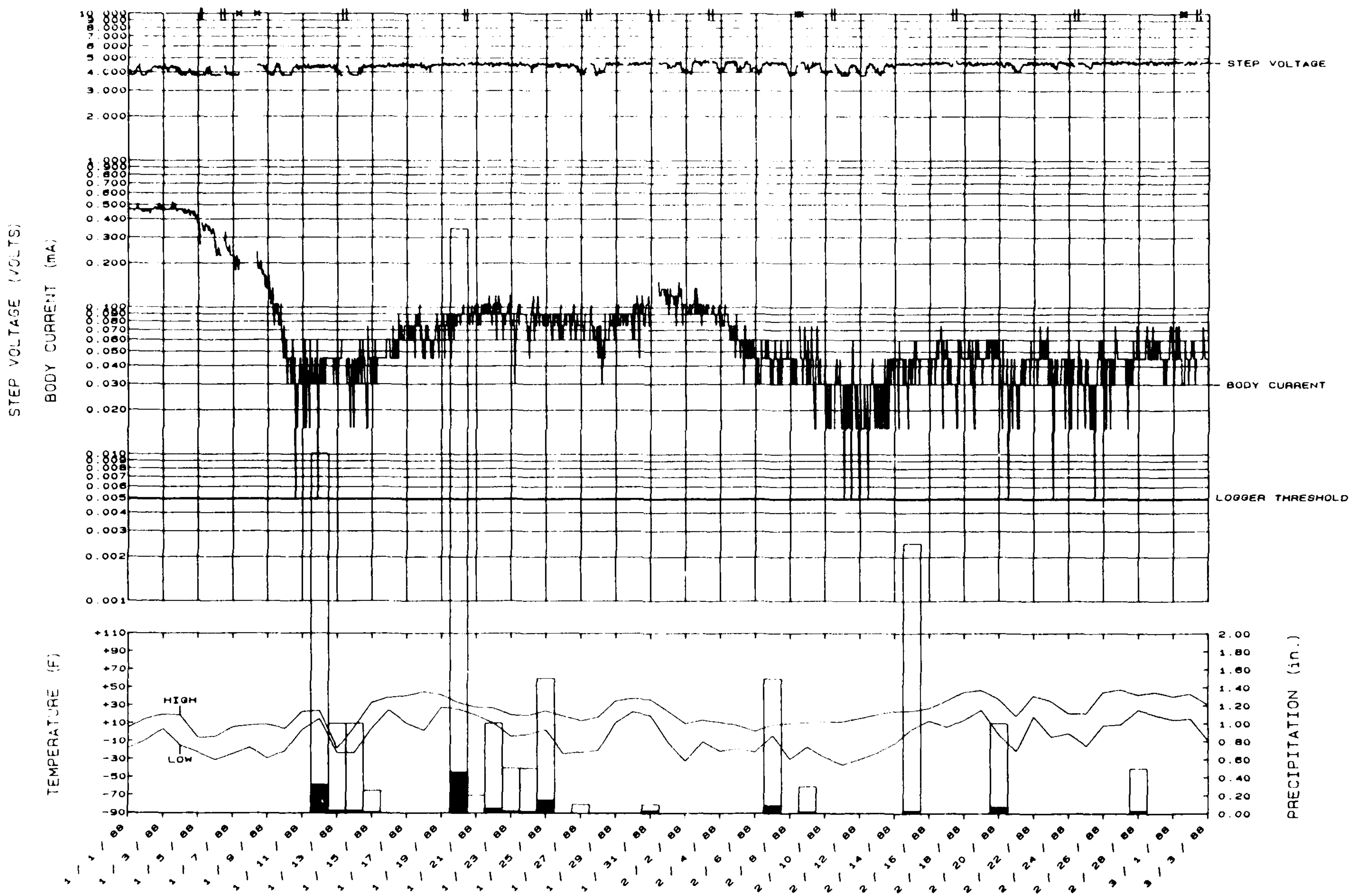


Figure B-8d. Hourly Data Logger Measurements at Site 1 (Loam with Vegetation)
January - February 1988

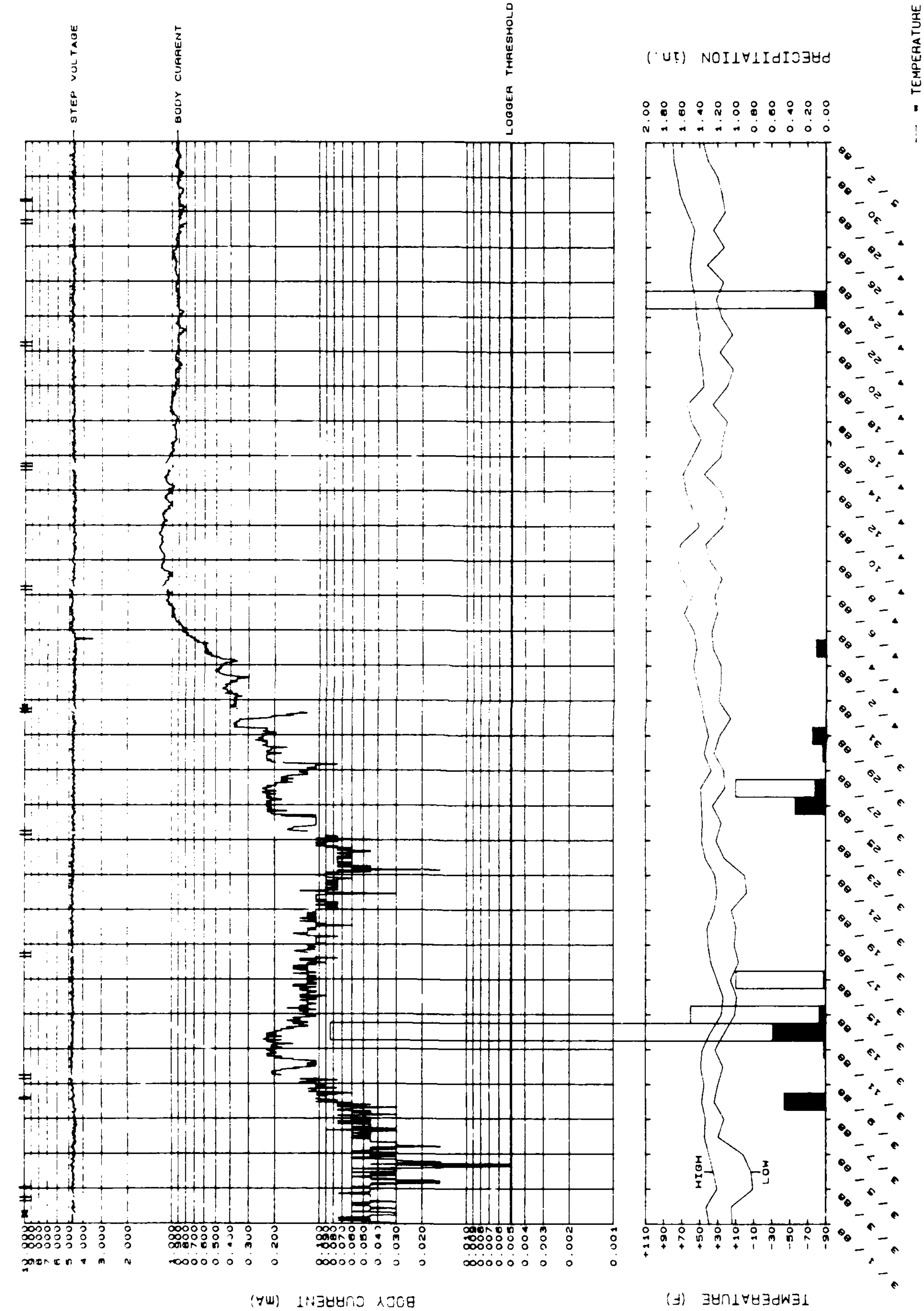


Figure B-8e. Hourly Data Logger Measurements at Site 1 (Loam with Vegetation)
March - April 1988

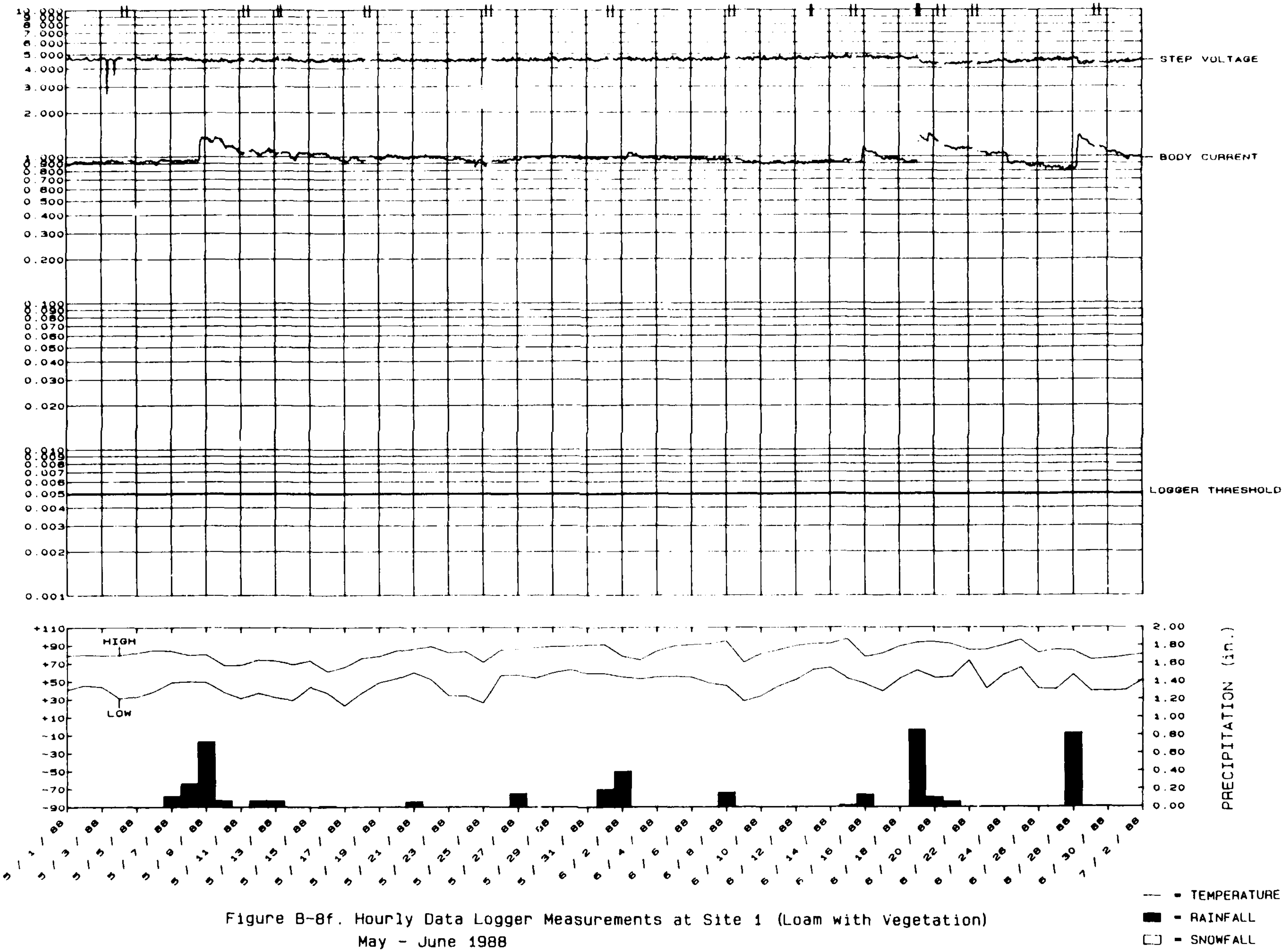


Figure B-8f. Hourly Data Logger Measurements at Site 1 (Loam with Vegetation)
May - June 1988

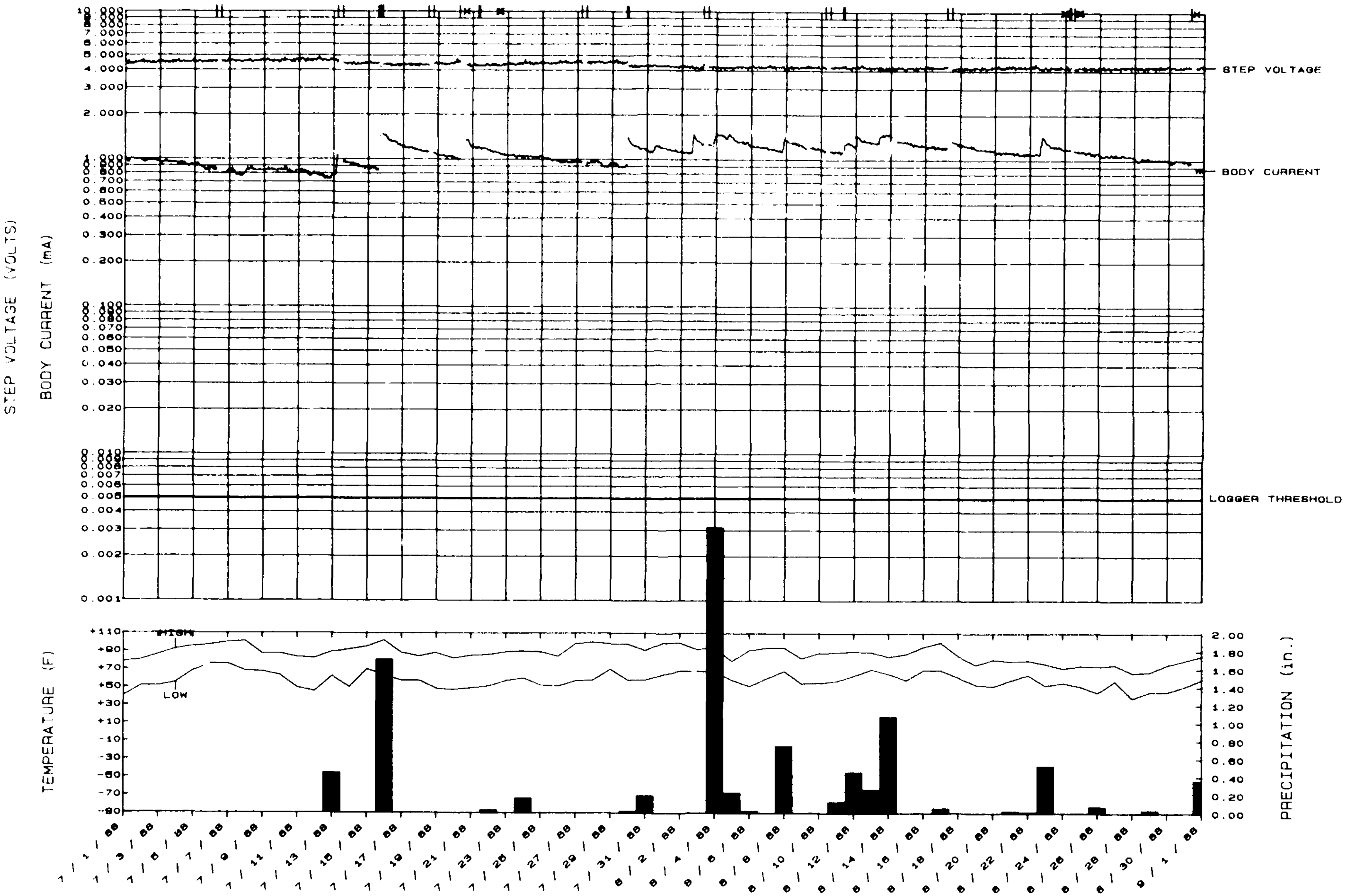


Figure B-8g. Hourly Data Logger Measurements at Site 1 (Loam with Vegetation)
July - August 1988

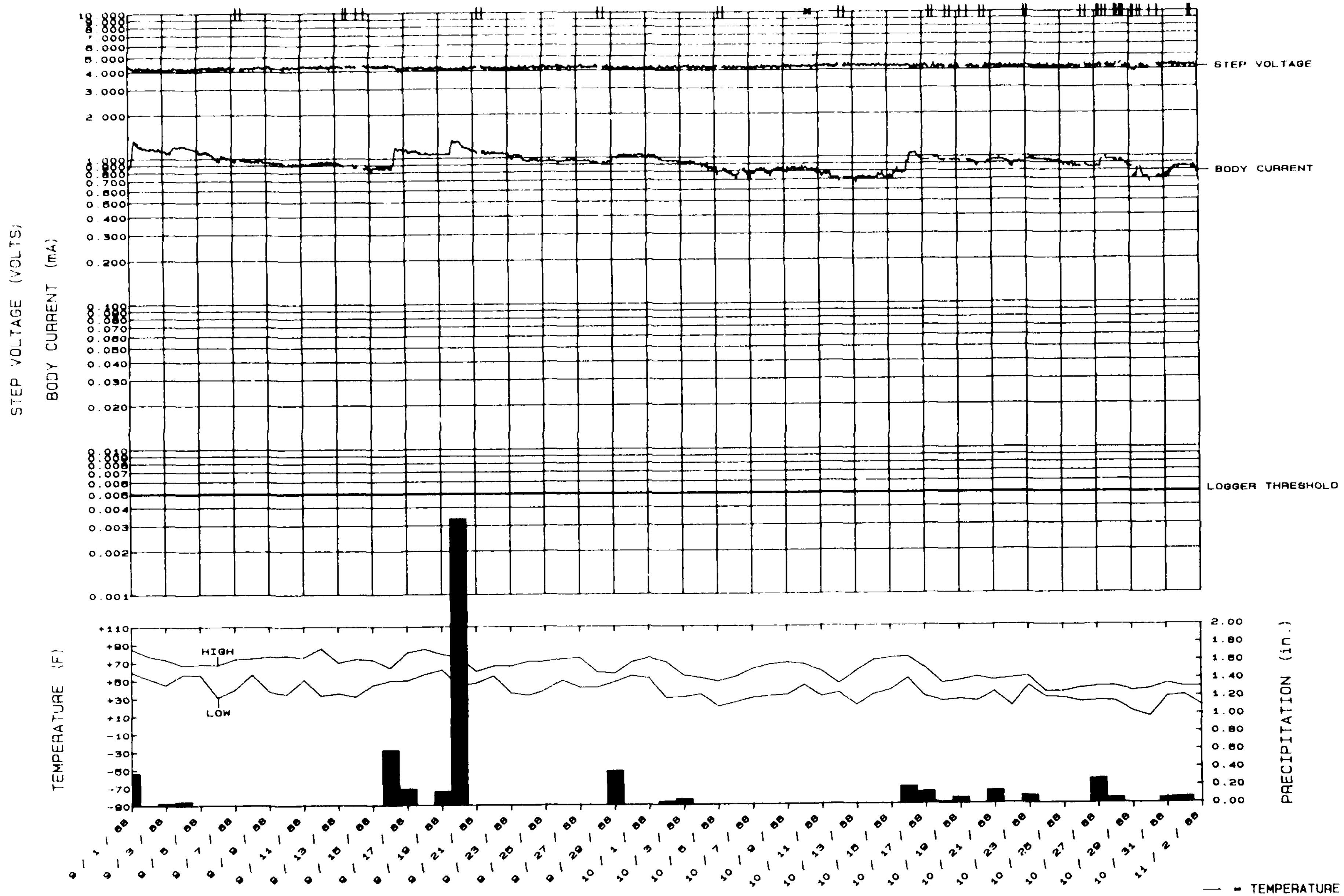


Figure B-8h. Hourly Data Logger Measurements at Site 1 (Loam with Vegetation)
September - October 1988

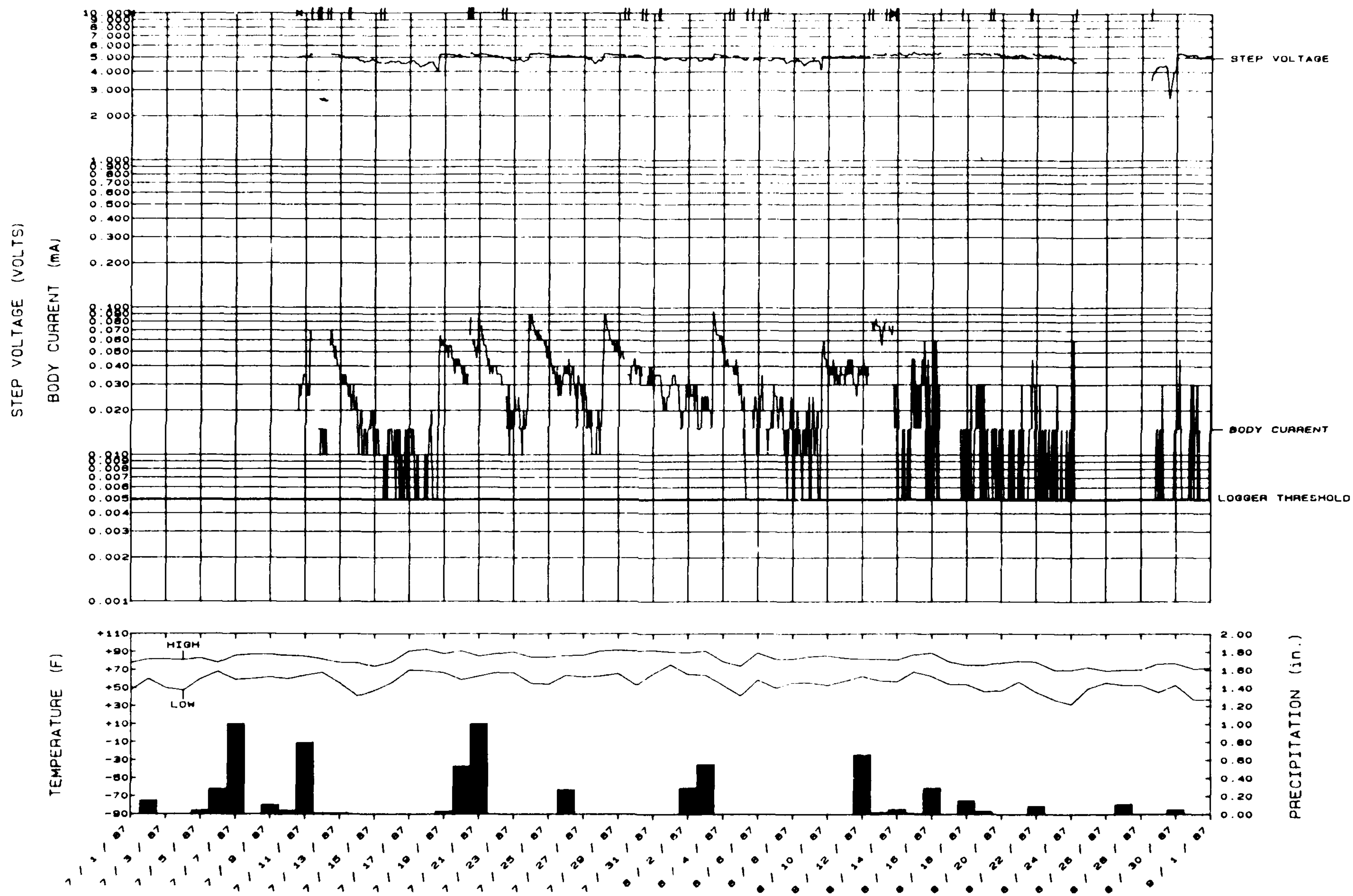


Figure B-9a. Hourly Data Logger Measurements at Site 2 (Gravel Fill)
July - August 1987

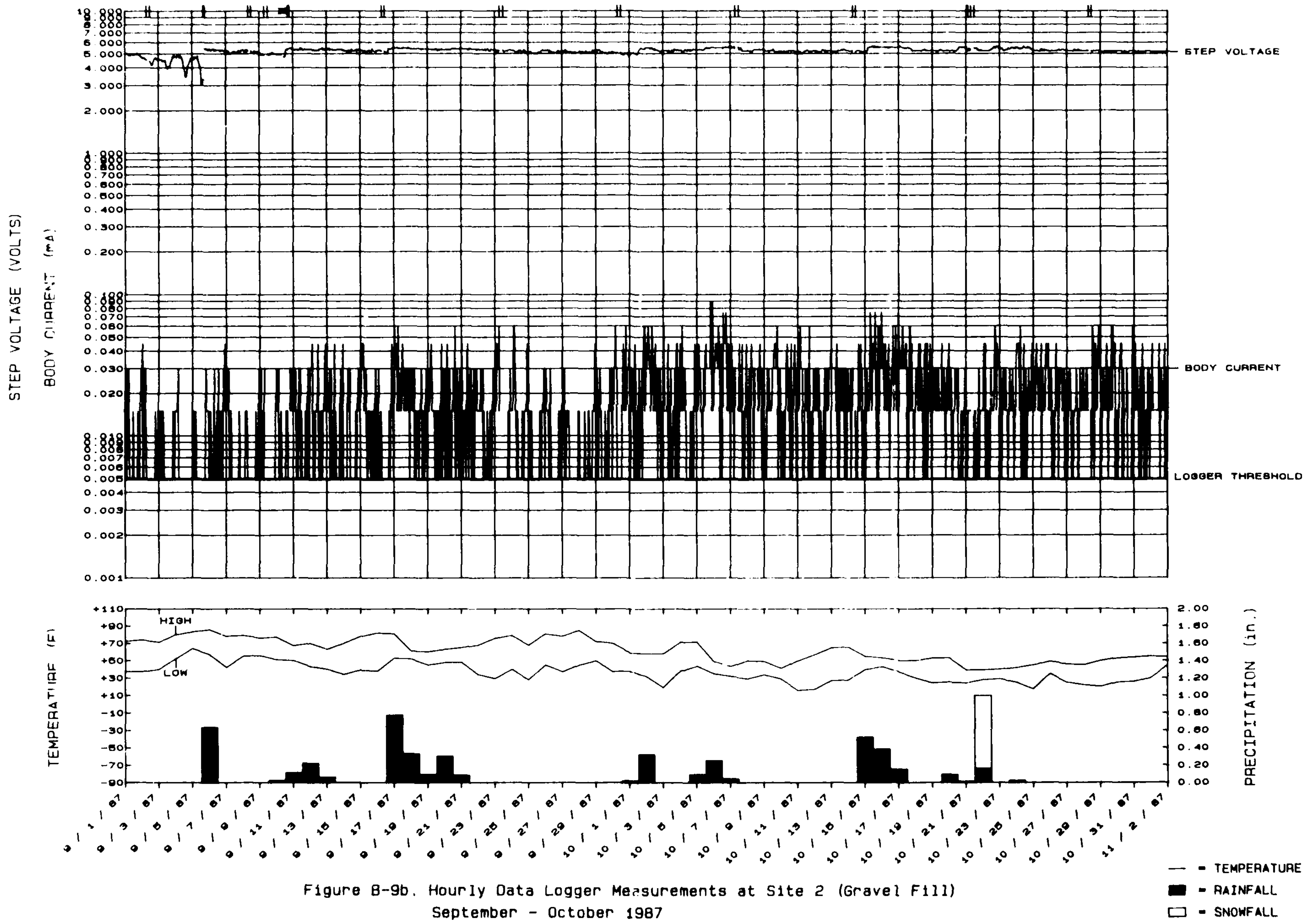


Figure B-9b. Hourly Data Logger Measurements at Site 2 (Gravel Fill)
September - October 1987

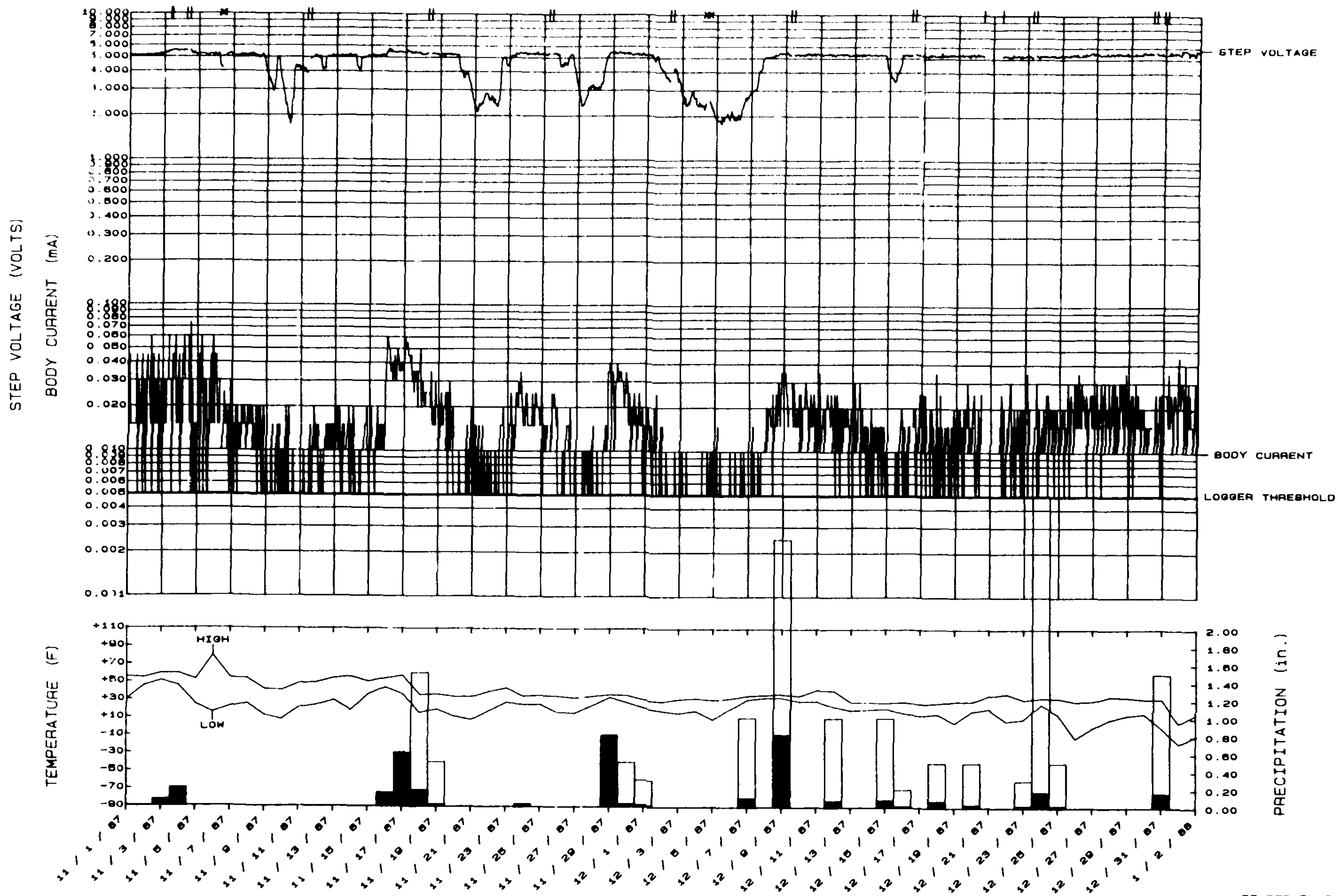


Figure B-9c. Hourly Data Logger Measurements at Site 2 (Gravel Fill)
November - December 1987

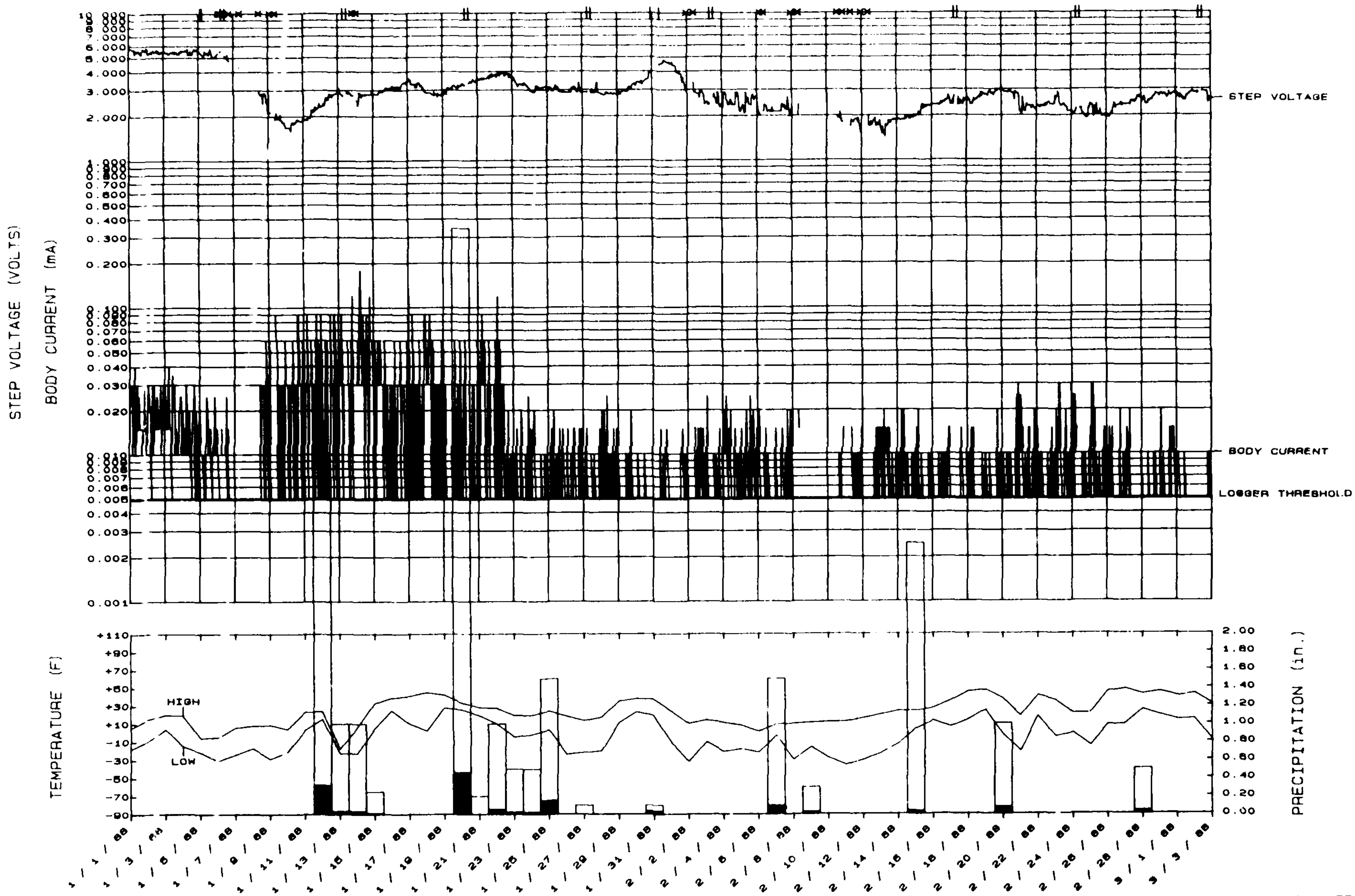


Figure B-9d. Hourly Data Logger Measurements at Site 2 (Gravel Fill)
January - February 1988

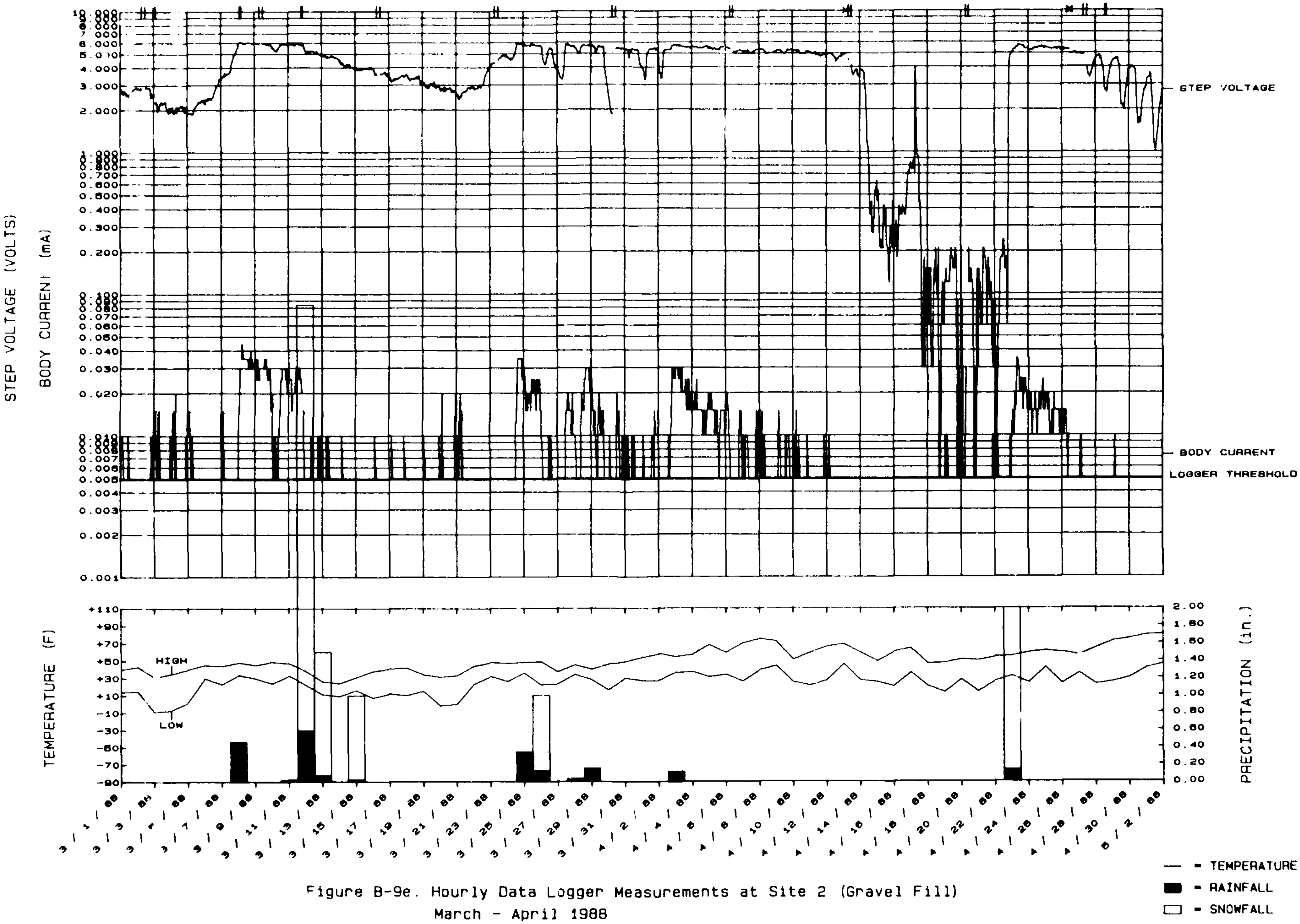


Figure B-9e. Hourly Data Logger Measurements at Site 2 (Gravel Fill)
March - April 1988

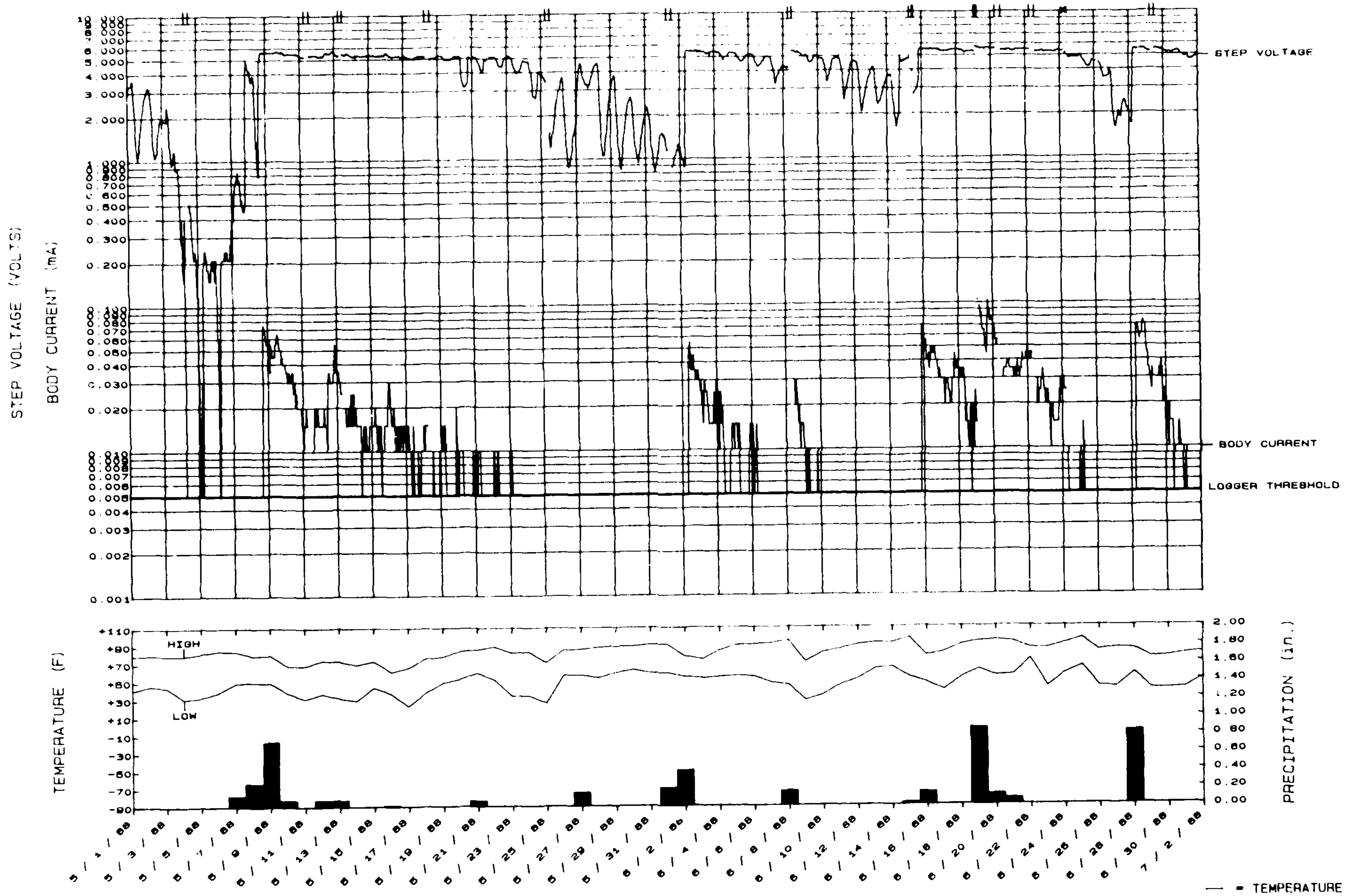


Figure B-9f. Hourly Data Logger Measurements at Site 2 (Gravel Fill)
May - June 1988

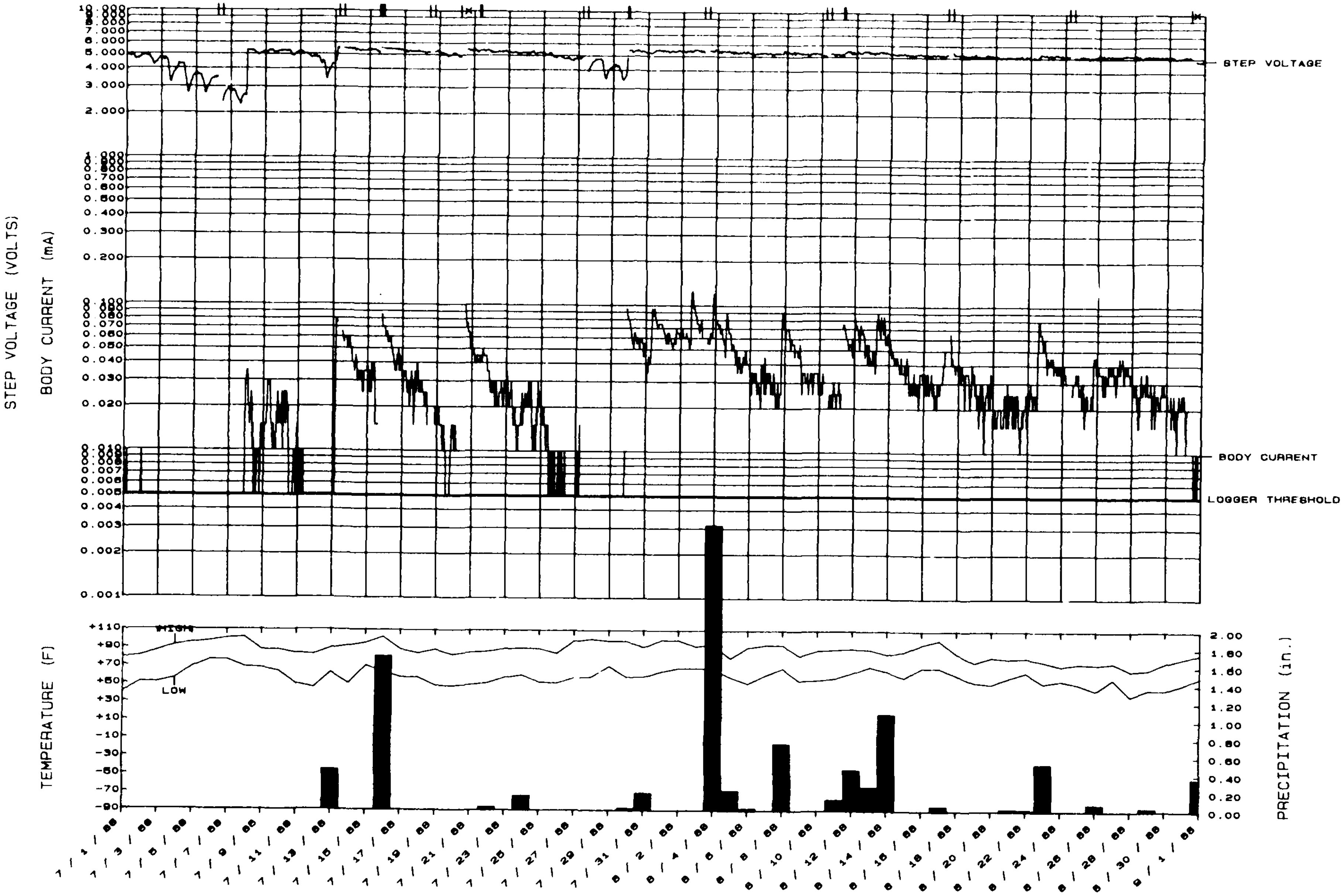
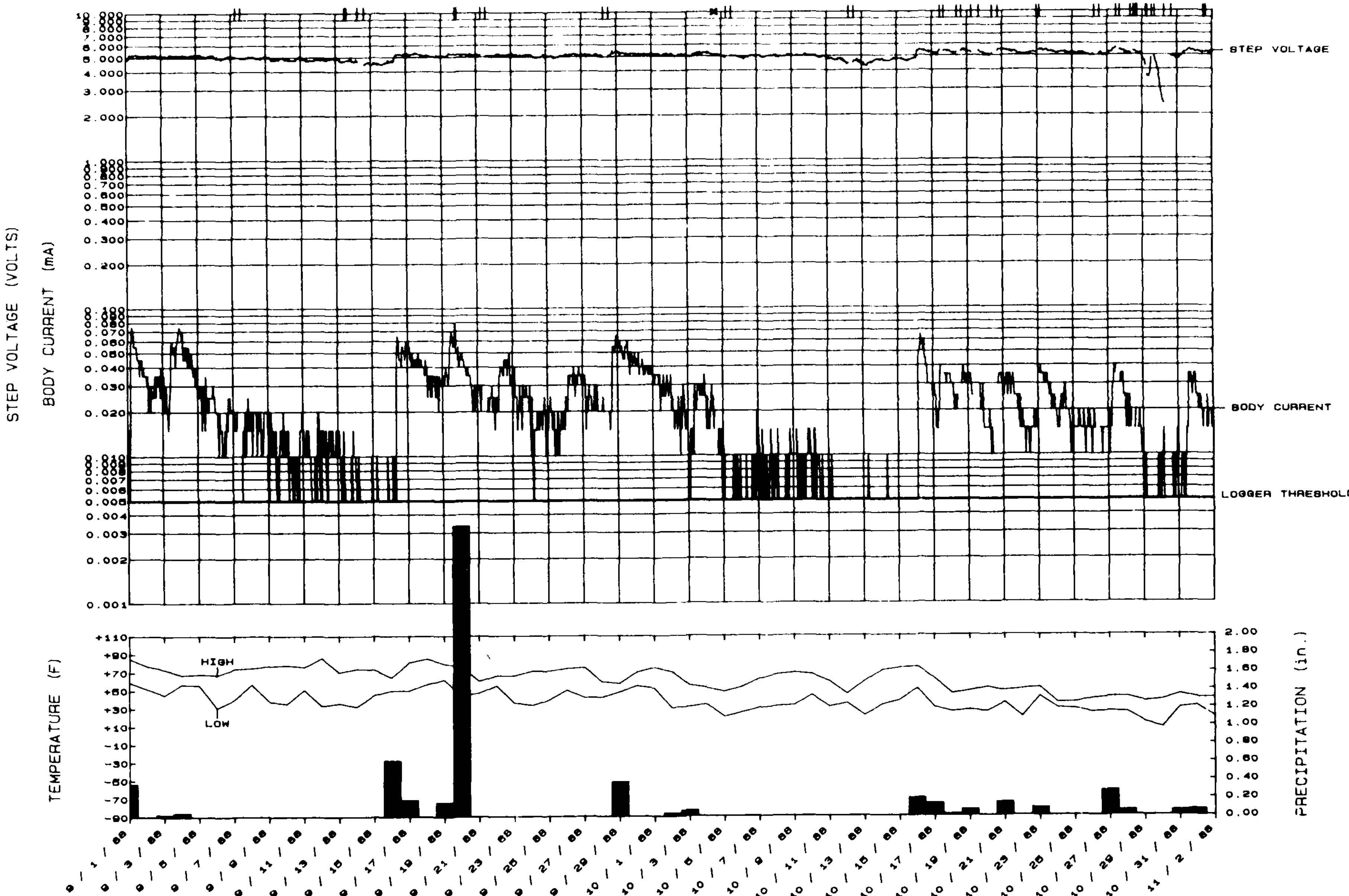


Figure B-9g. Hourly Data Logger Measurements at Site 2 (Gravel Fill)
July - August 1988



— = TEMPERATURE
■ = RAINFALL
□ = SNOWFALL

Figure B-9h. Hourly Data Logger Measurements at Site 2 (Gravel Fill)
September - October 1988

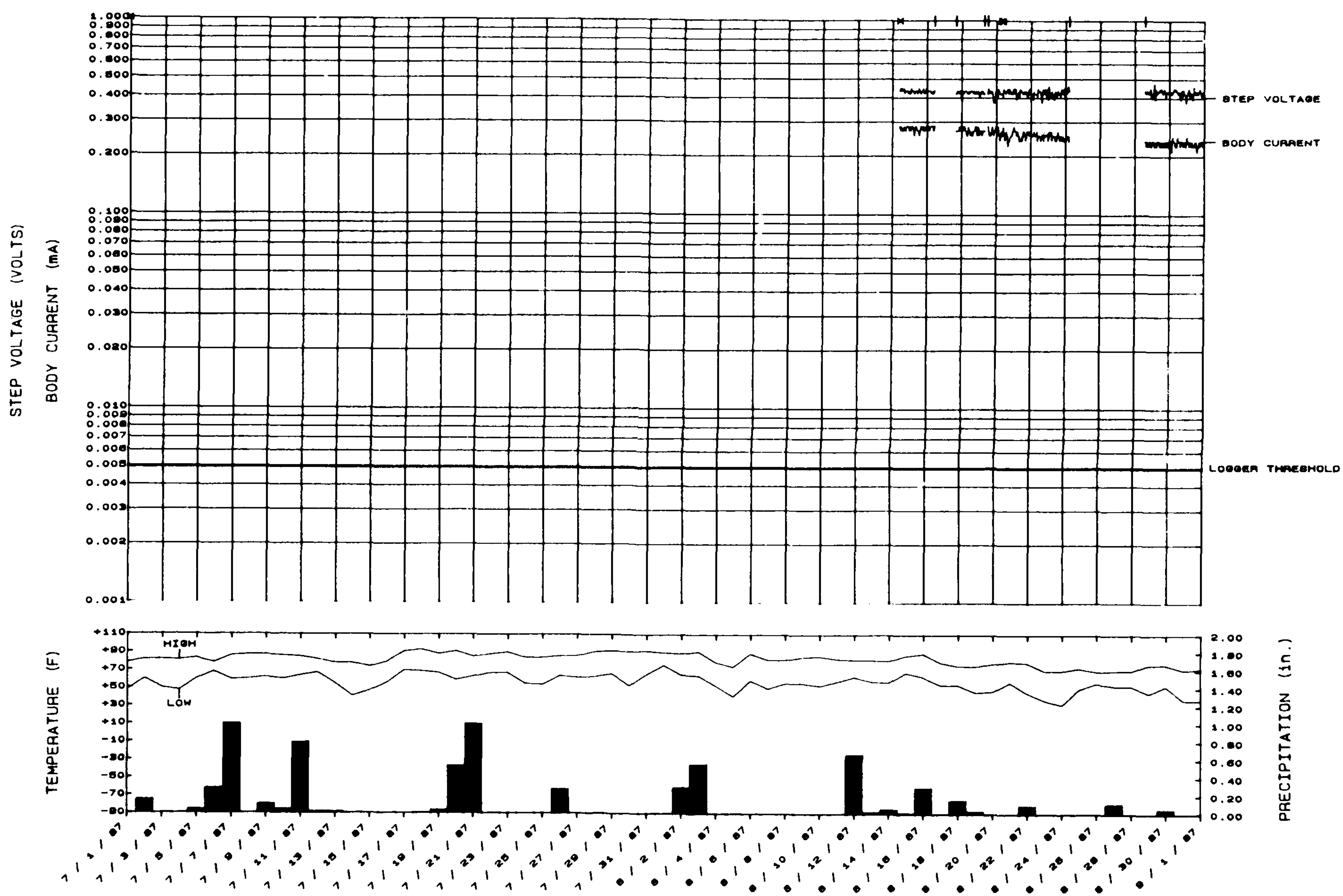


Figure B-10a. Hourly Data Logger Measurements at Site 3 (Bog with Standing Water)
July - August 1987

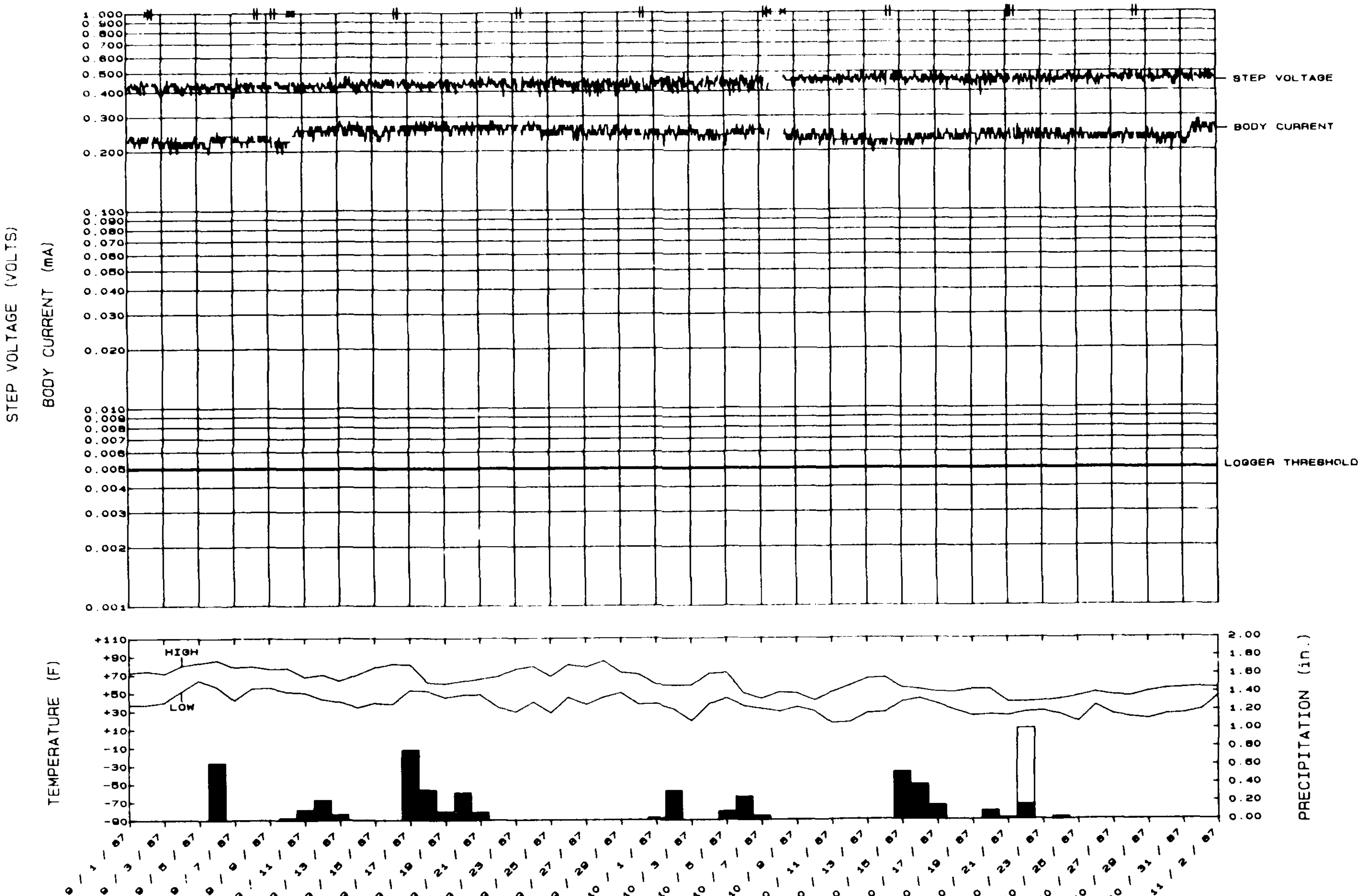


Figure B-10b. Hourly Data Logger Measurements at Site 3 (Bog with Standing Water)
September - October 1987

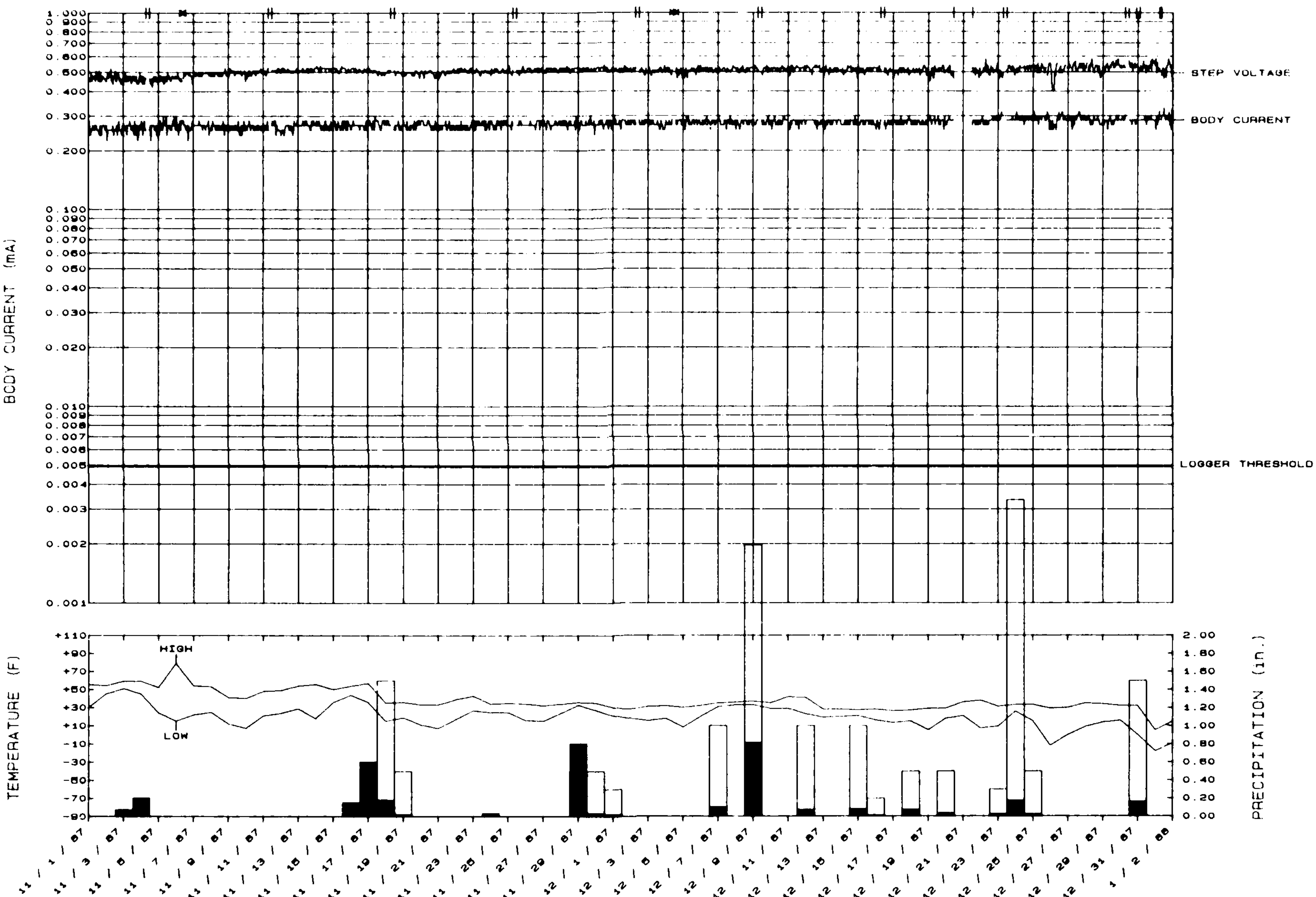


Figure B-10c. Hourly Data Logger Measurements at Site 3 (Bog with Standing Water)
November - December 1987

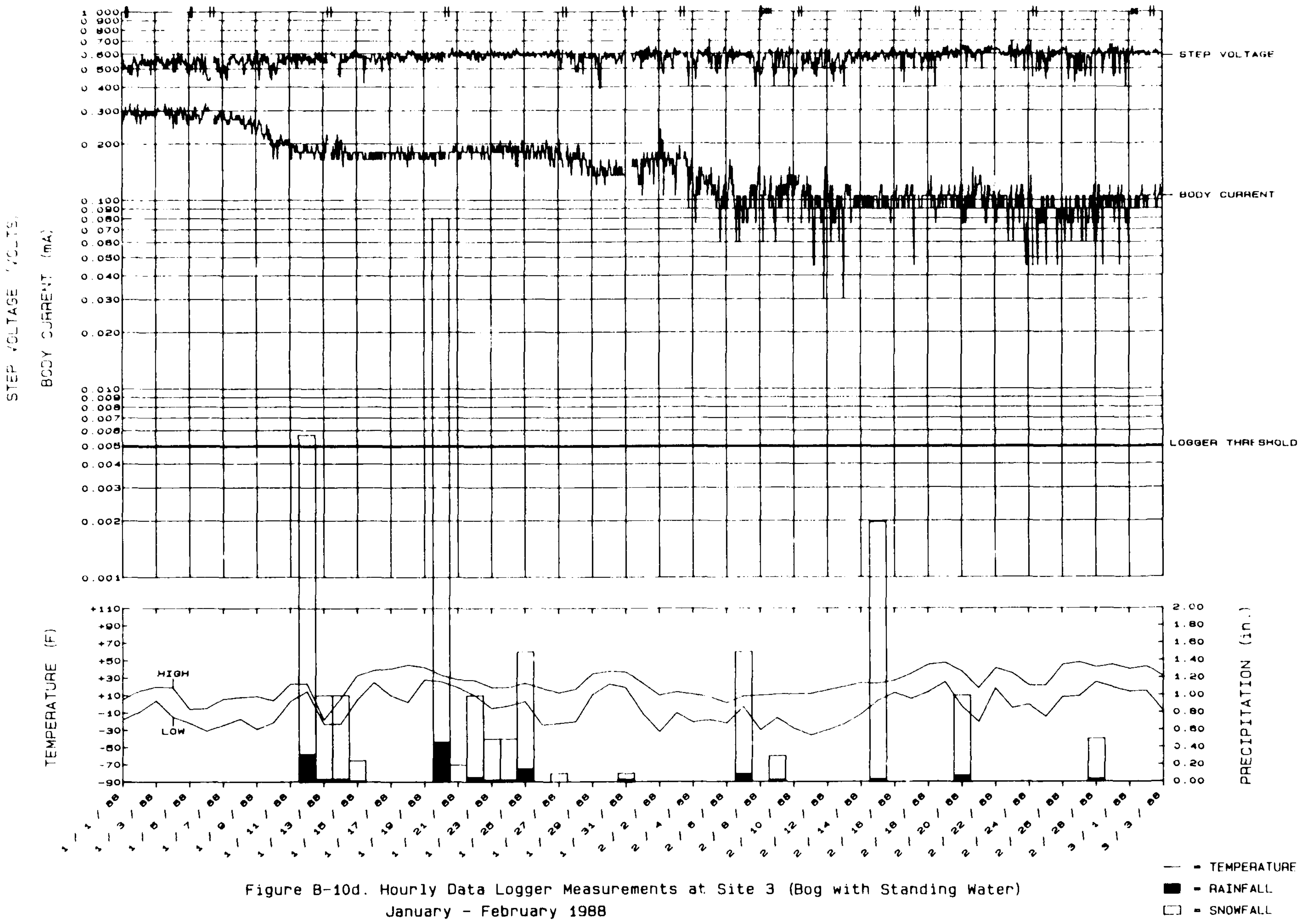


Figure B-10d. Hourly Data Logger Measurements at Site 3 (Bog with Standing Water)
January - February 1988

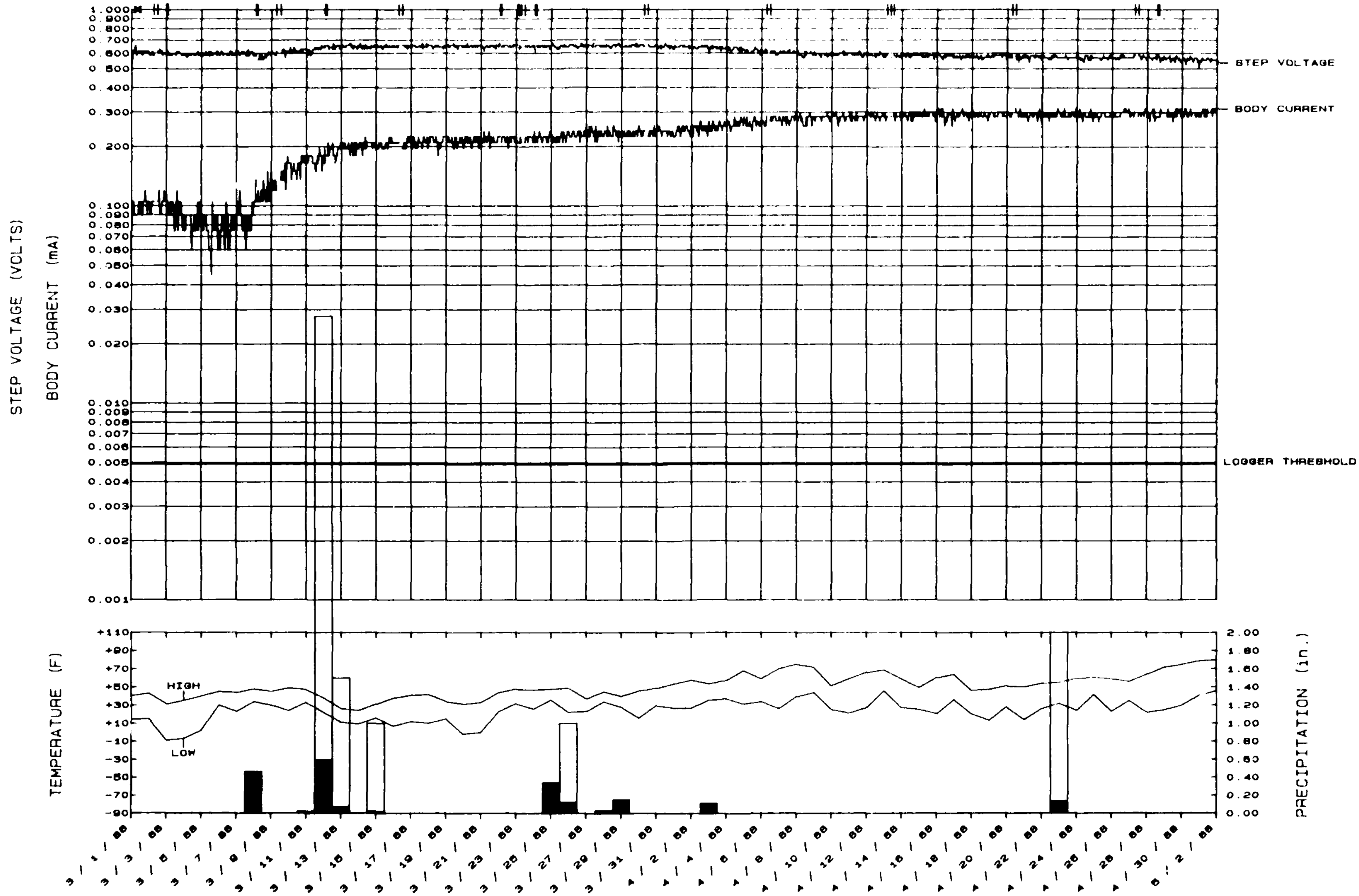


Figure B-10e. Hourly Data Logger Measurements at Site 3 (Bog with Standing Water)
March - April 1988

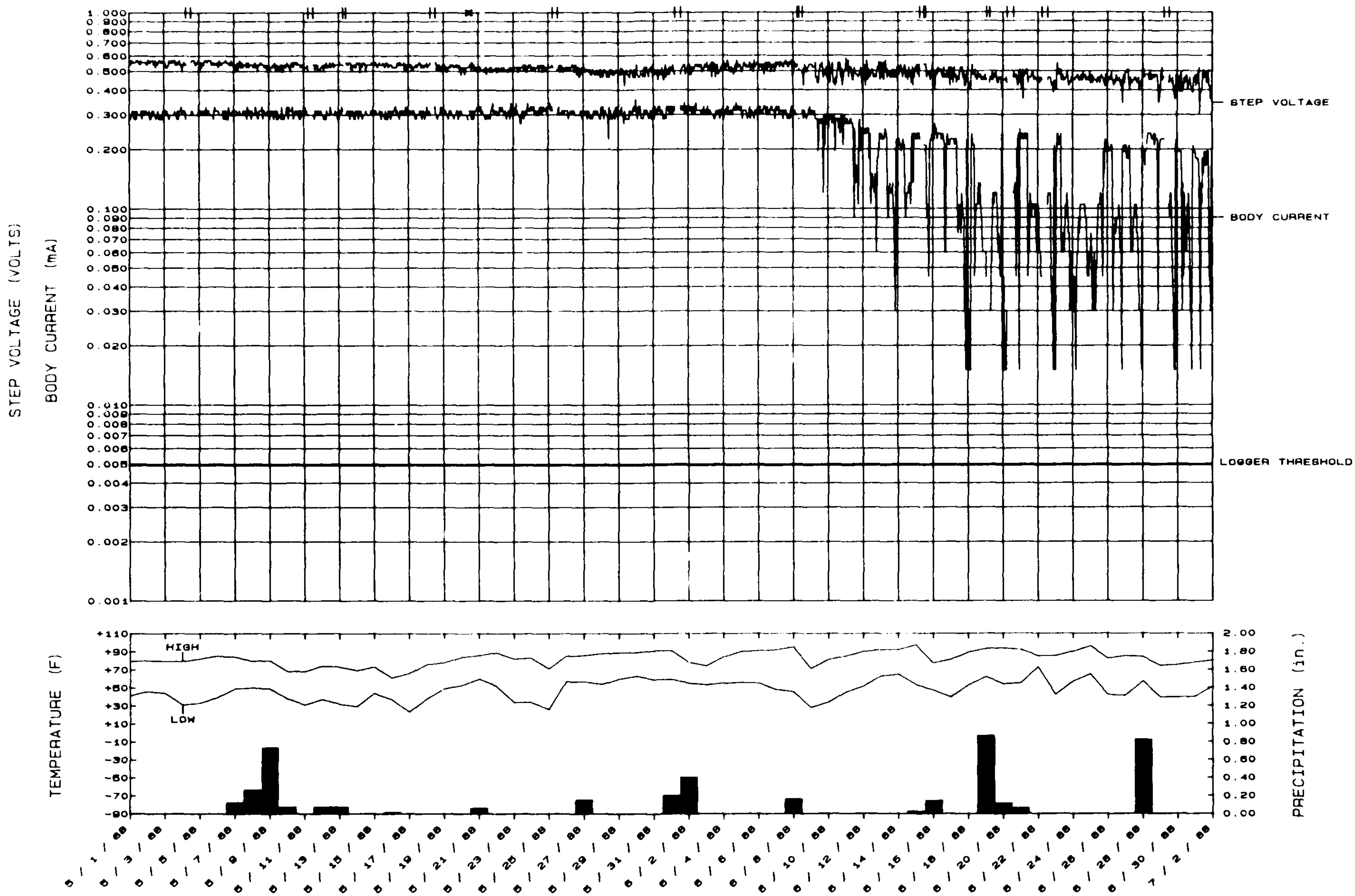


Figure B-10f. Hourly Data Logger Measurements at Site 3 (Bog with Standing Water)
May - June 1988

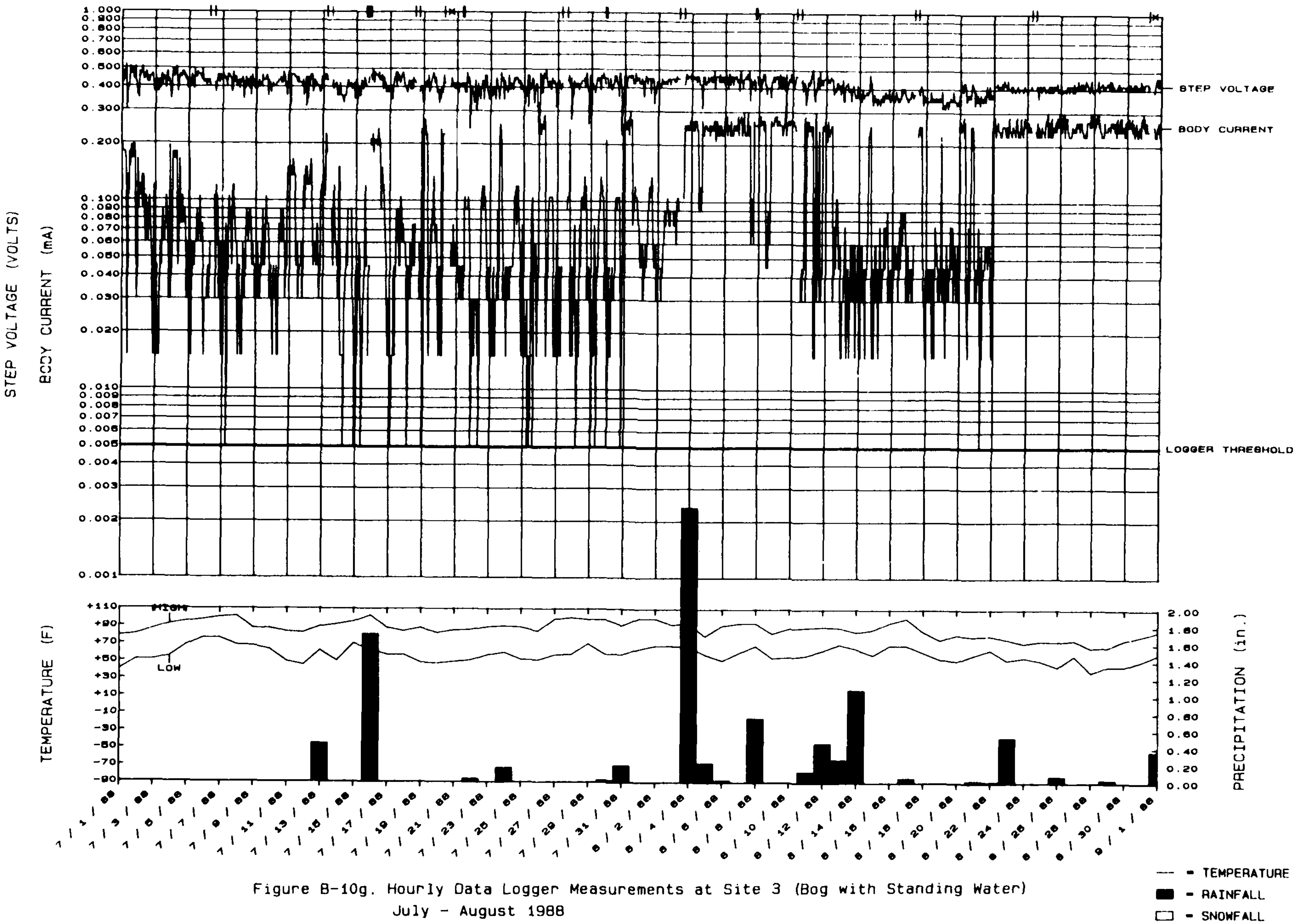


Figure B-10g. Hourly Data Logger Measurements at Site 3 (Bog with Standing Water)
July - August 1988

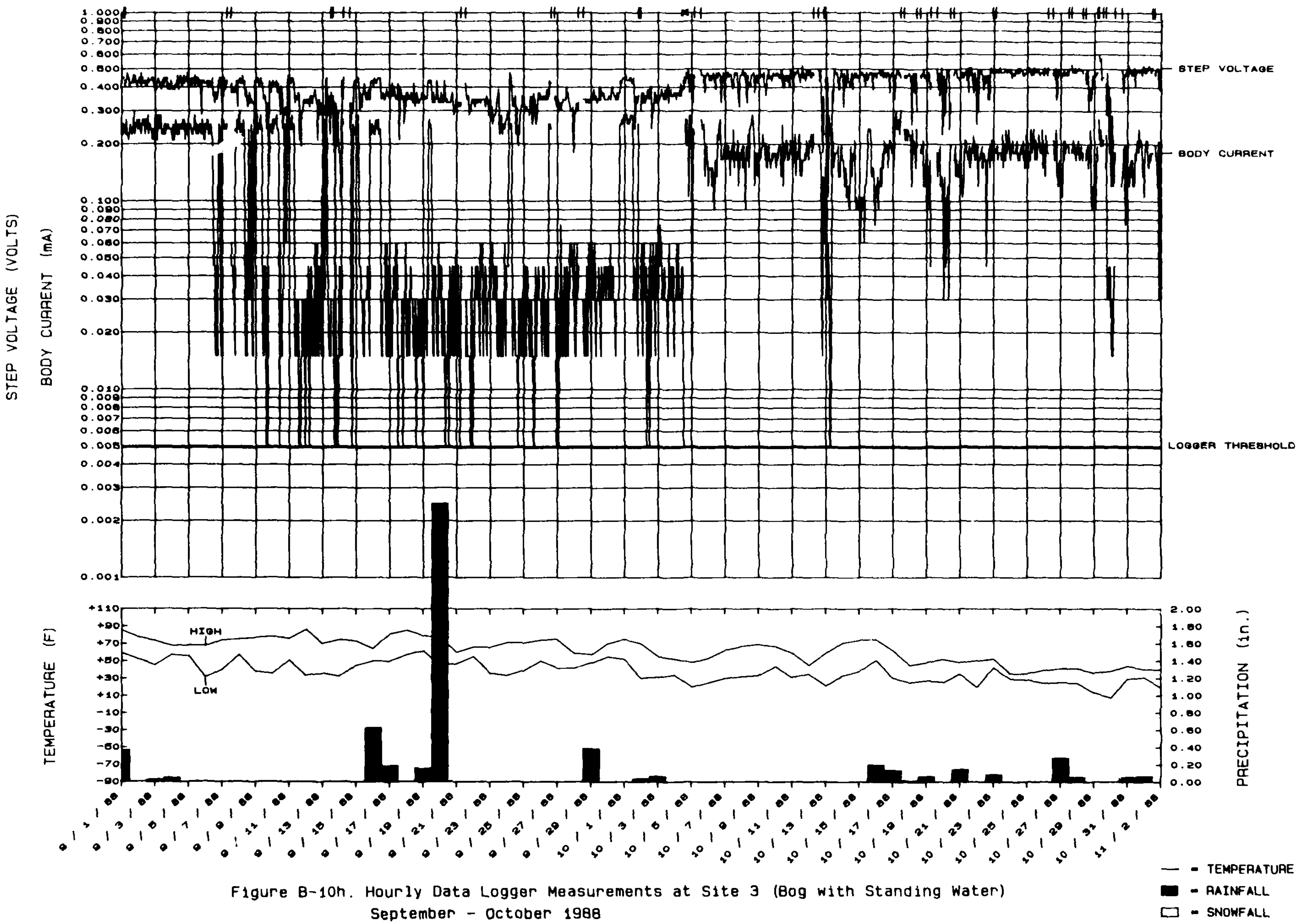


Figure B-10h. Hourly Data Logger Measurements at Site 3 (Bog with Standing Water)
September - October 1988

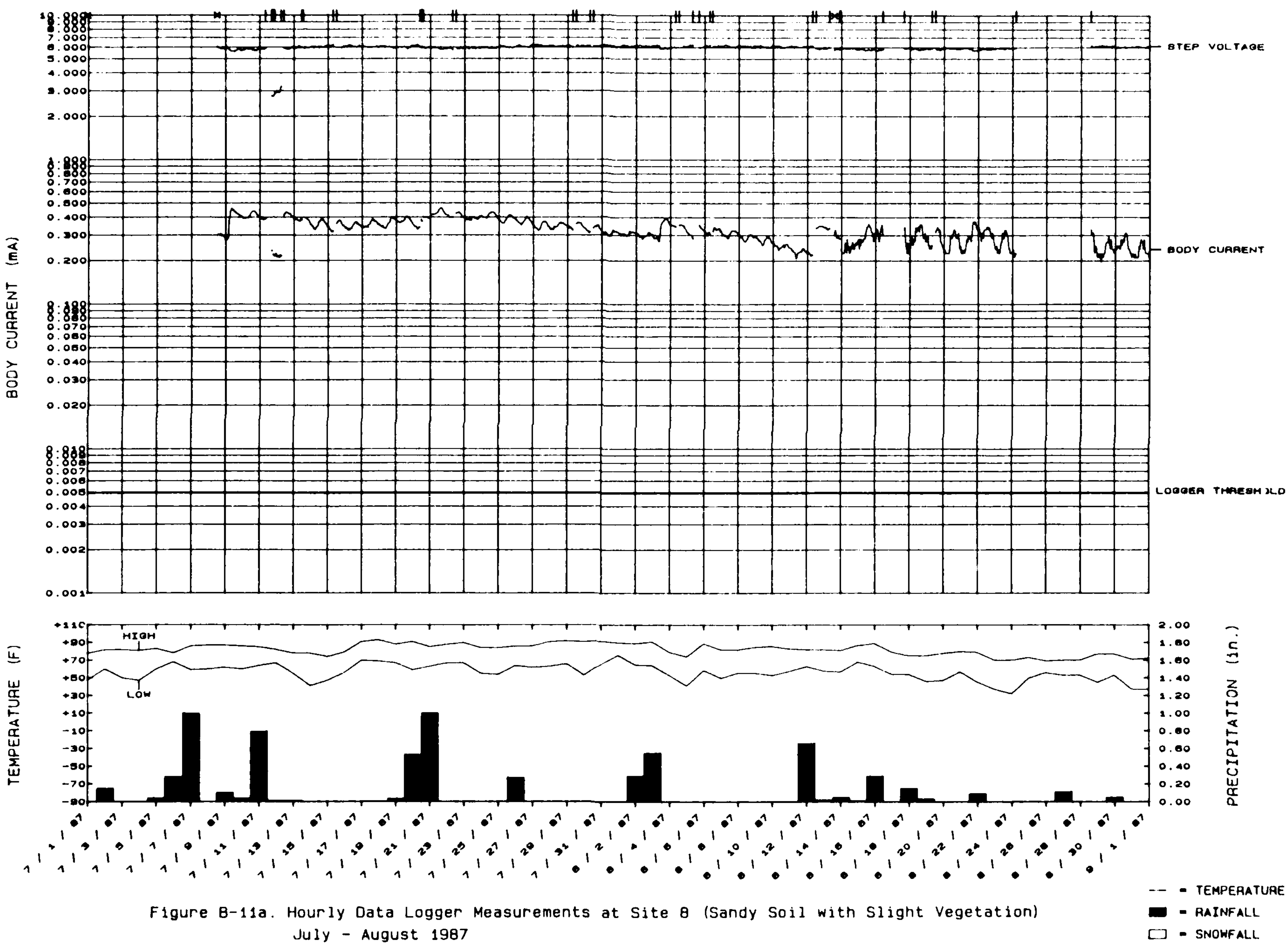


Figure B-11a. Hourly Data Logger Measurements at Site 8 (Sandy Soil with Slight Vegetation)
July - August 1987

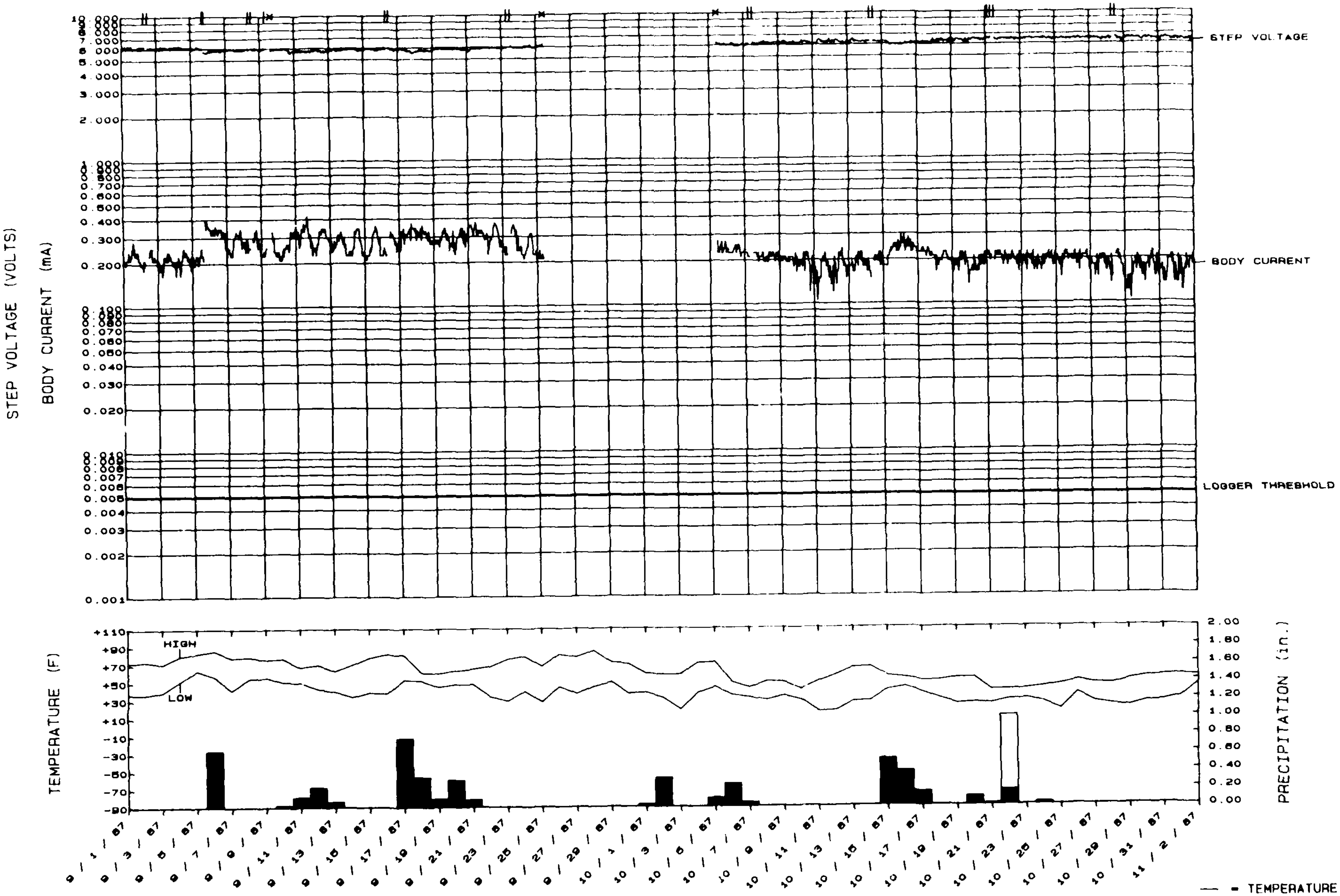


Figure B-11b. Hourly Data Logger Measurements at Site 8 (Sandy Soil with Slight Vegetation)
September - October 1987

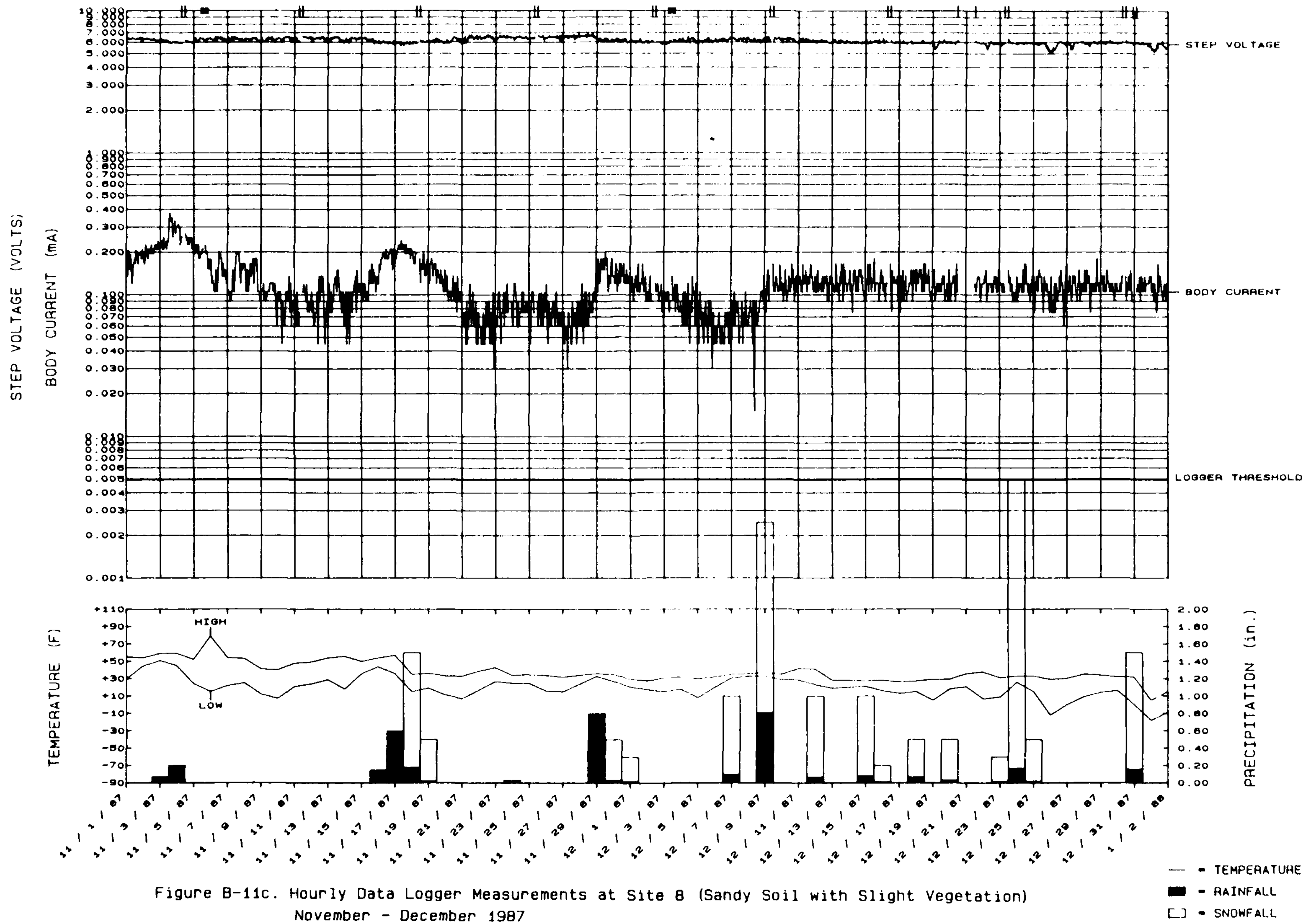


Figure B-11c. Hourly Data Logger Measurements at Site 8 (Sandy Soil with Slight Vegetation)
November - December 1987

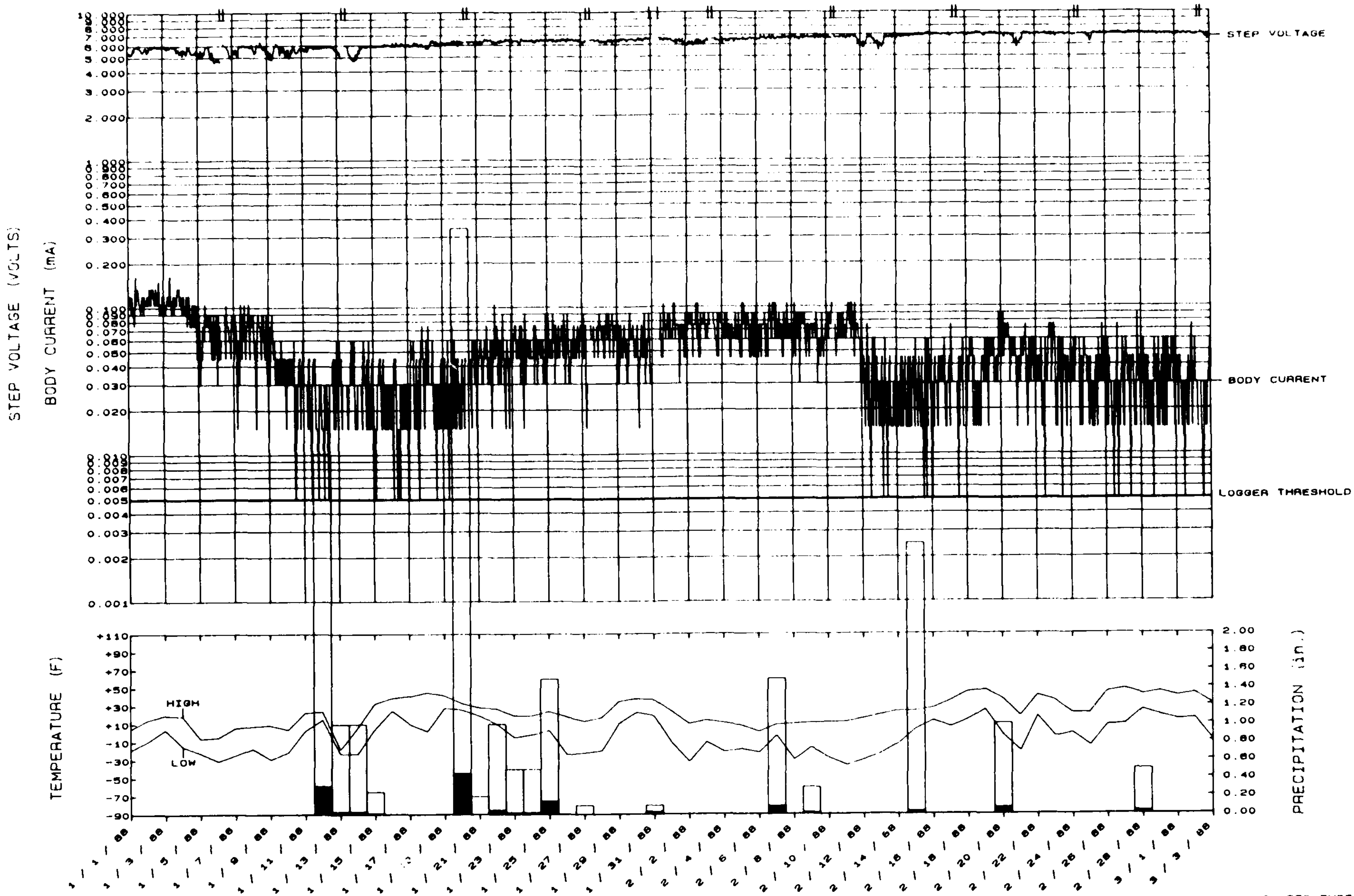


Figure B-11d. Hourly Data Logger Measurements at Site 8 (Sandy Soil with Slight Vegetation)
January - February 1988

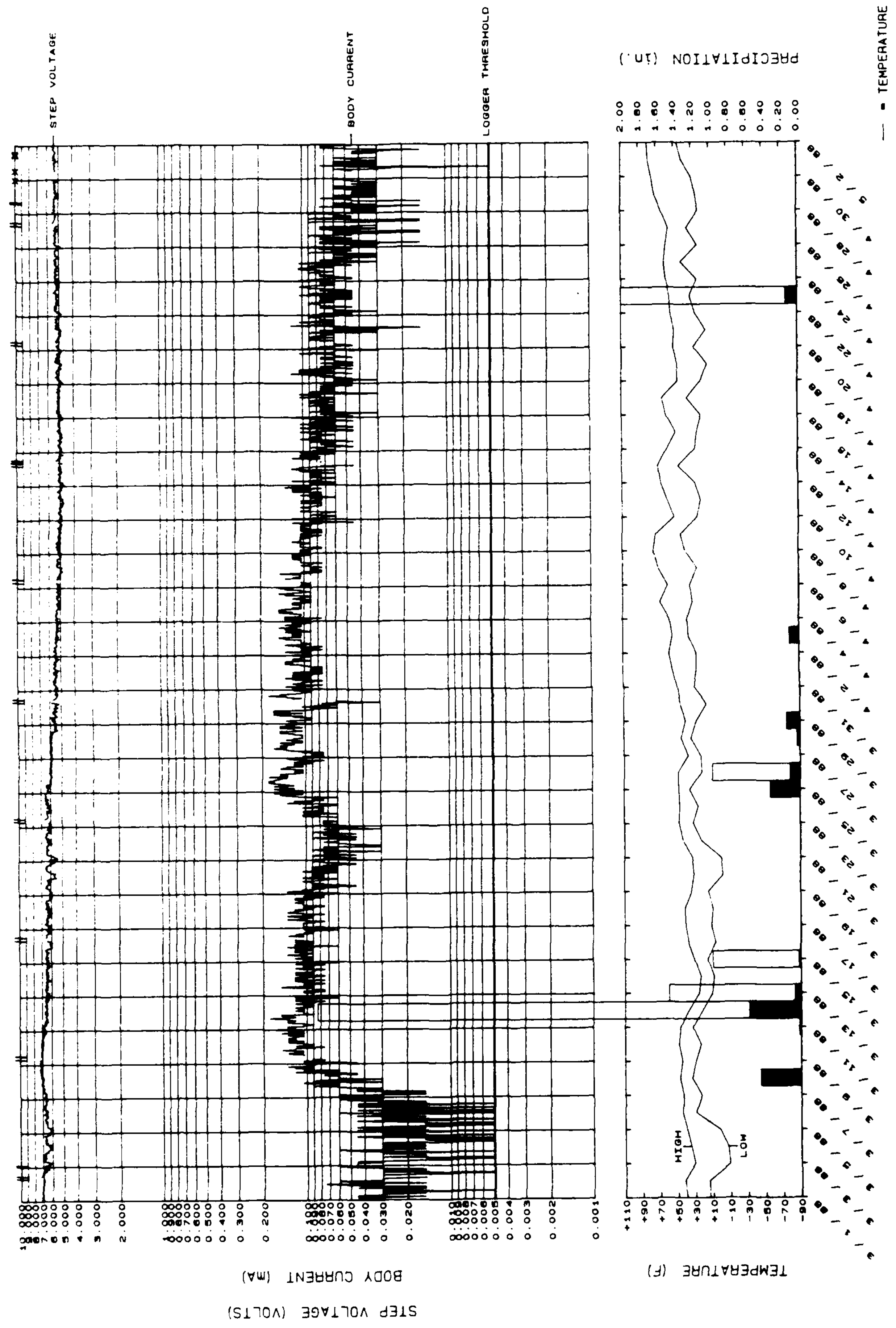


Figure B-11e. Hourly Data Logger Measurements at Site 8 (Sandy Soil with Slight Vegetation)
March - April 1988

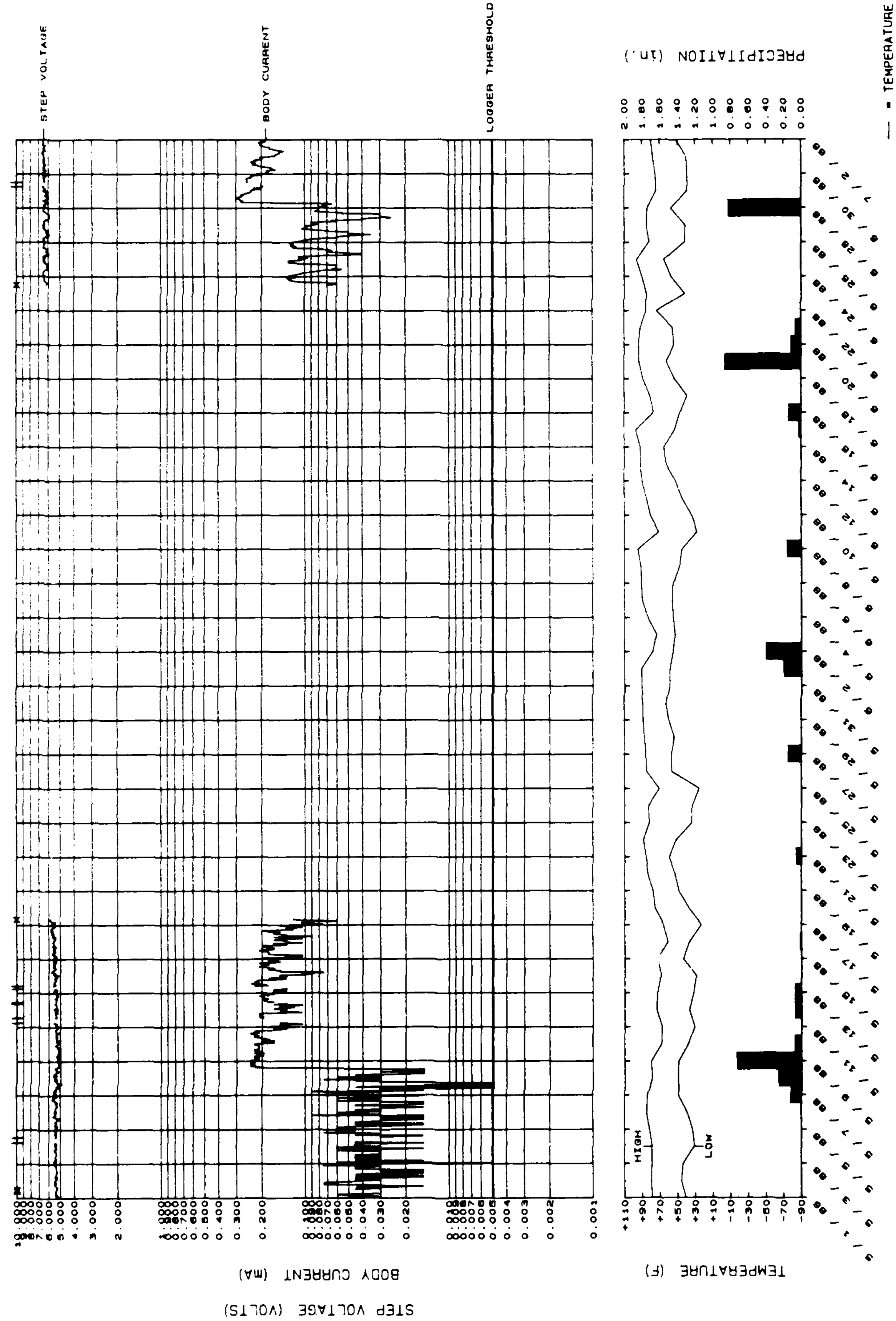


Figure B-11f. Hourly Data Logger Measurements at Site B (Sandy Soil with Slight Vegetation)
May - June 1988

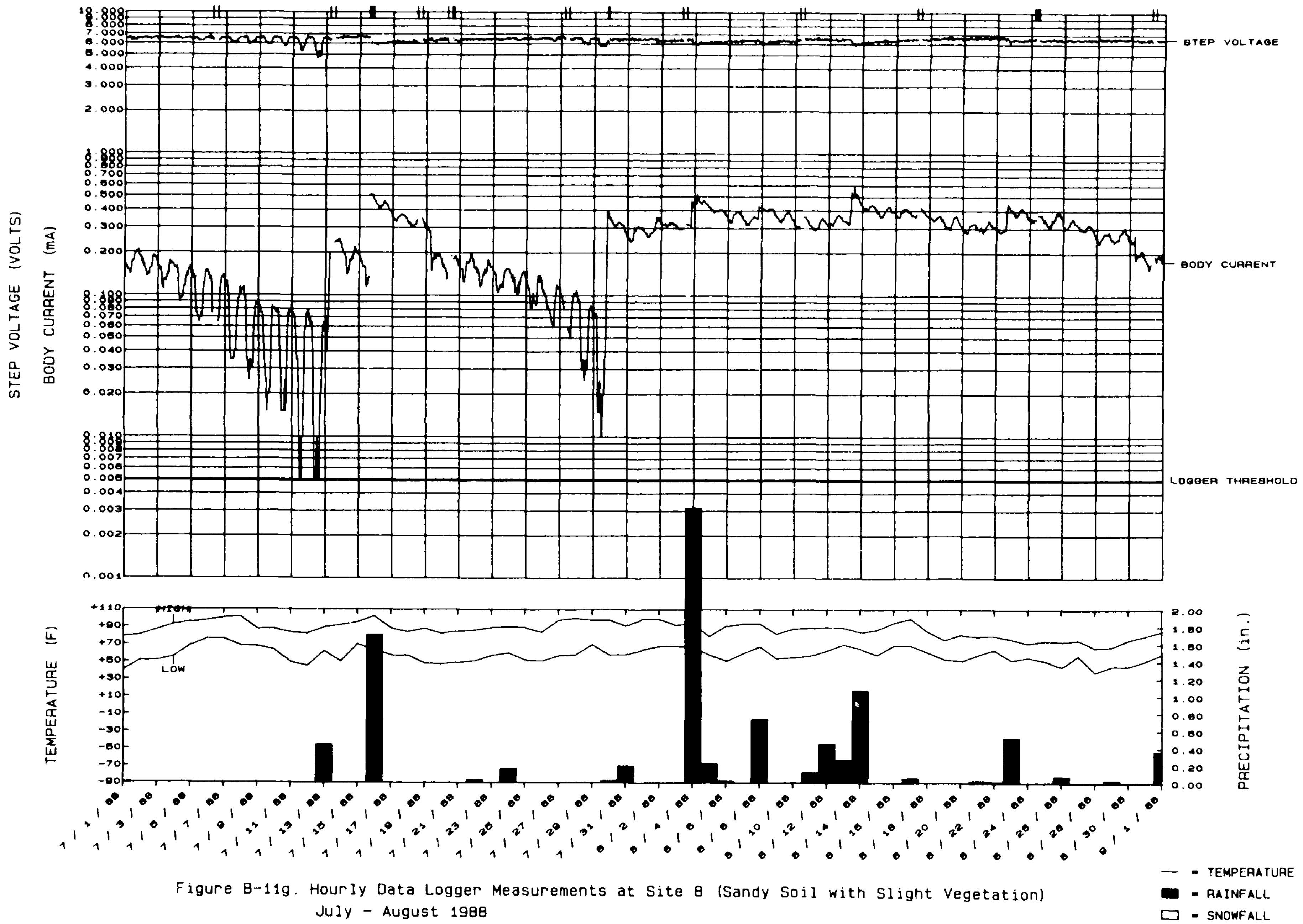


Figure B-11g. Hourly Data Logger Measurements at Site 8 (Sandy Soil with Slight Vegetation)
July - August 1988

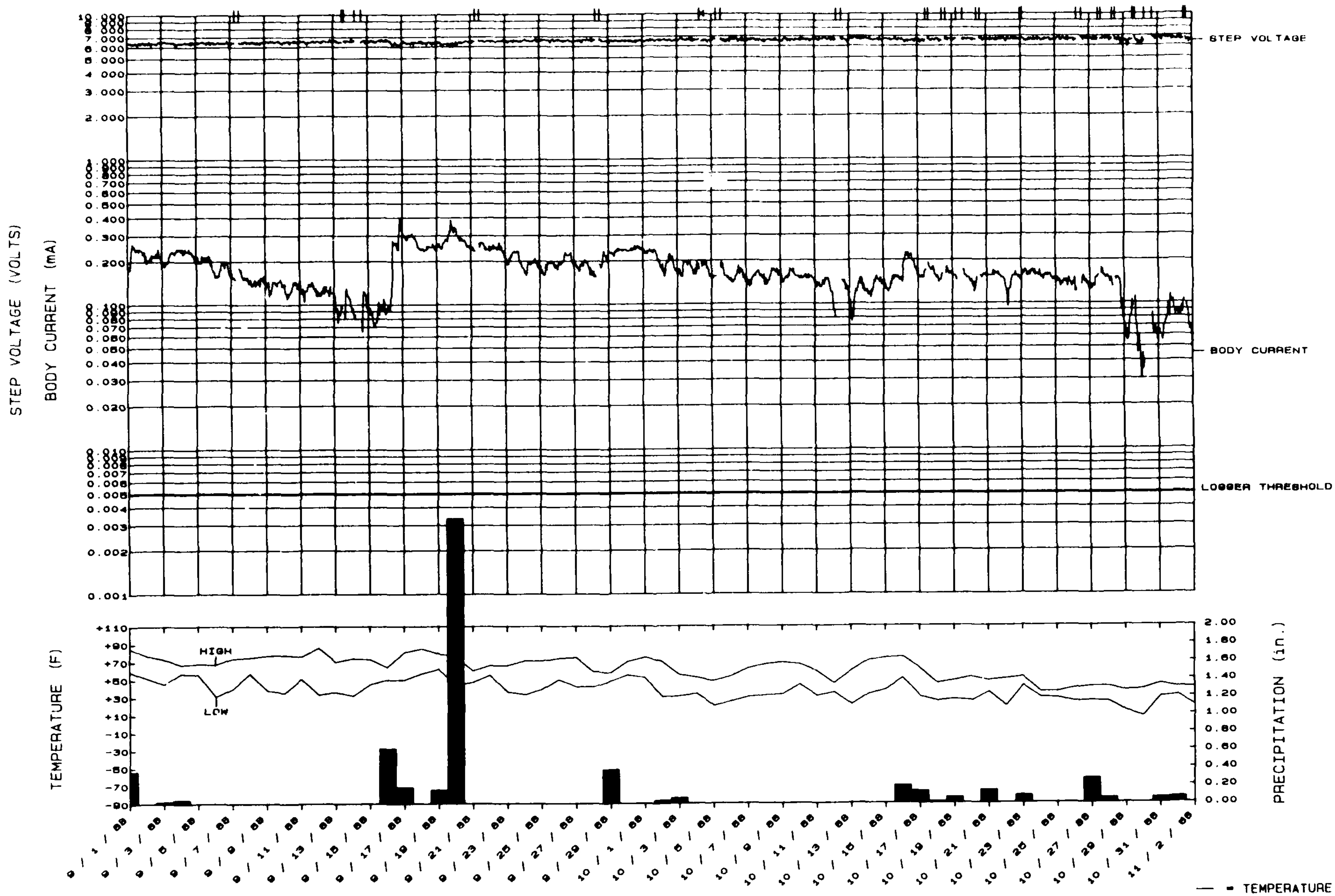


Figure B-11h. Hourly Data Logger Measurements at Site 8 (Sandy Soil with Slight Vegetation)
September - October 1988

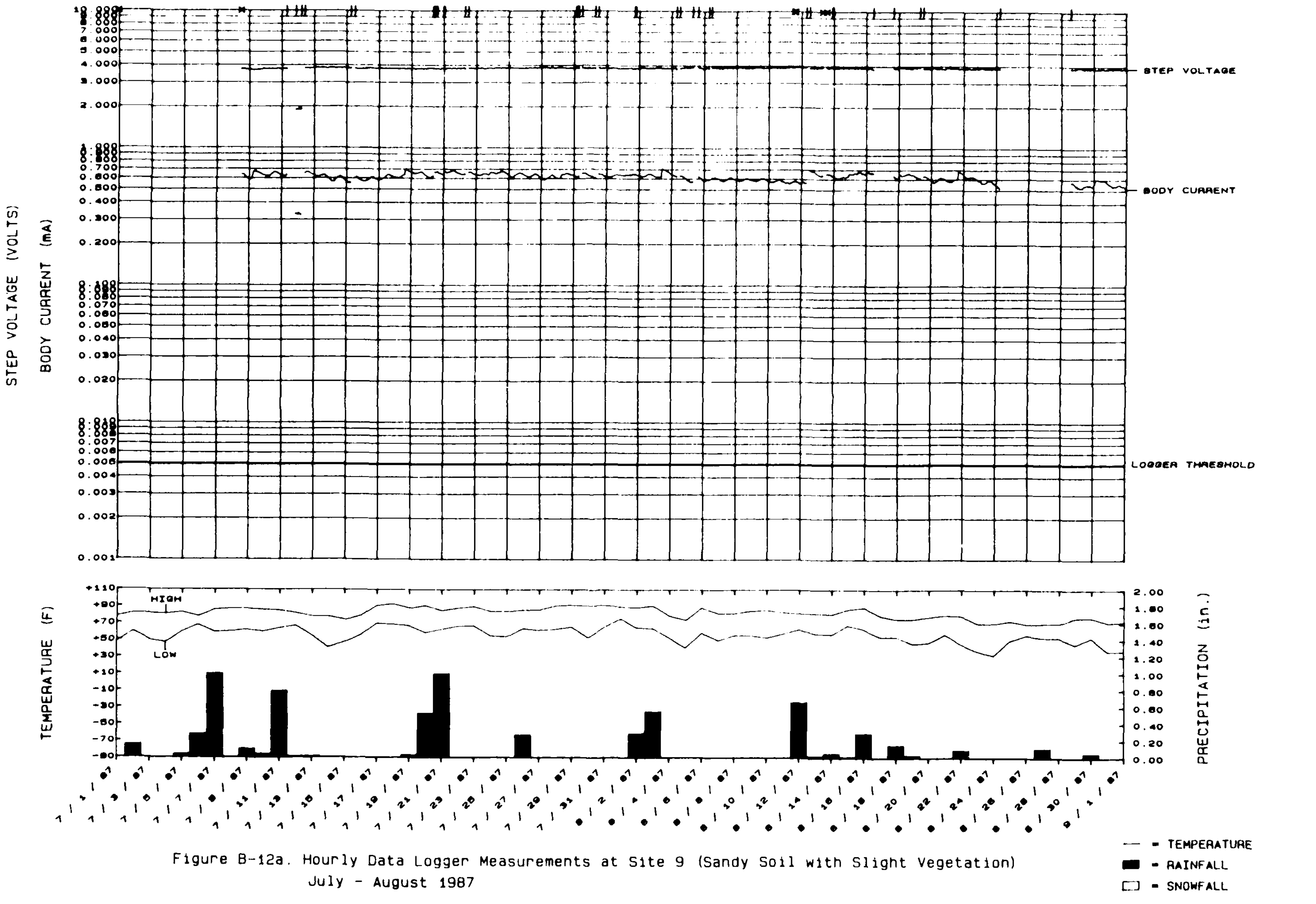


Figure B-12a. Hourly Data Logger Measurements at Site 9 (Sandy Soil with Slight Vegetation)
July - August 1987

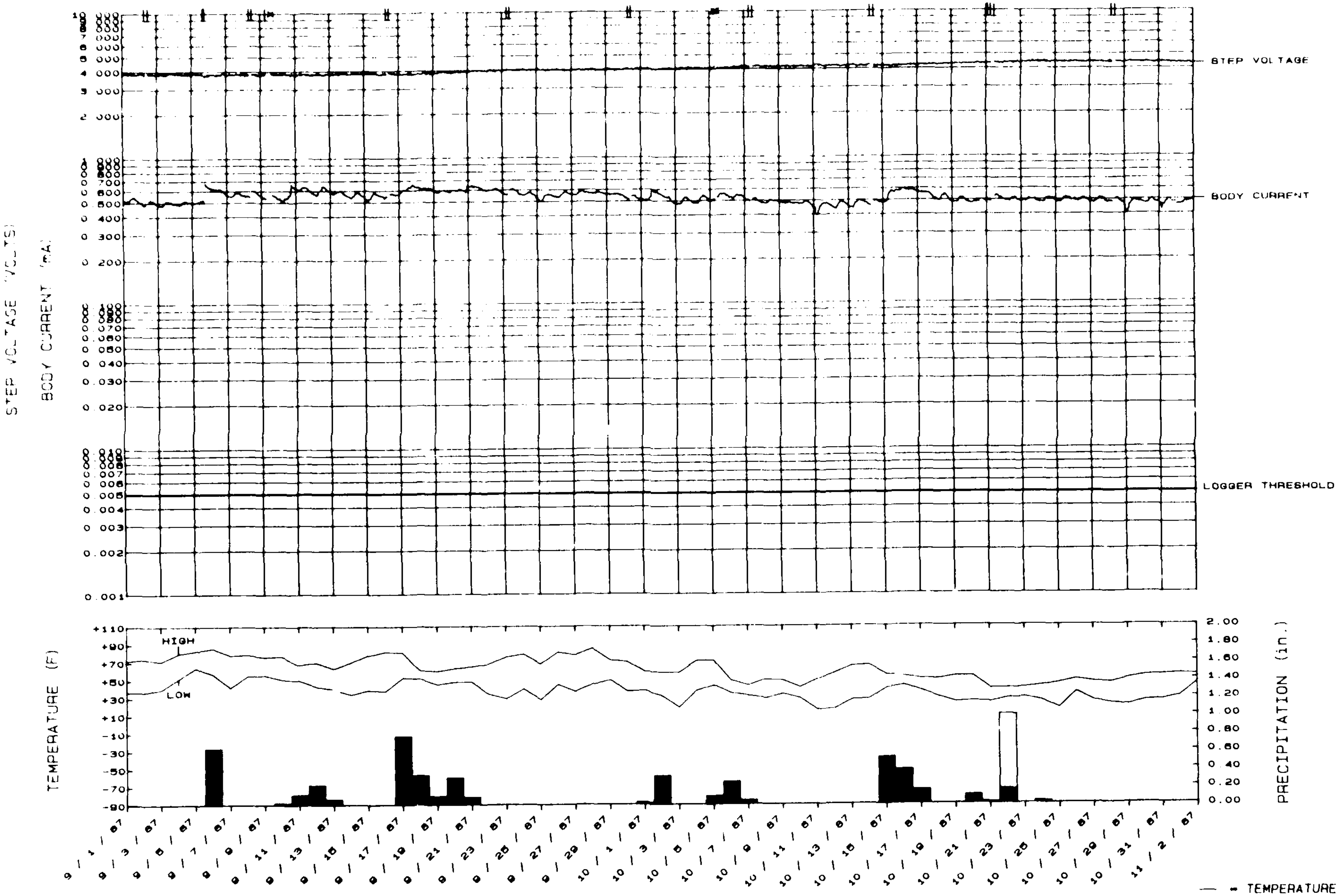


Figure B-12b. Hourly Data Logger Measurements at Site 9 (Sandy Soil with Slight Vegetation)
September - October 1987

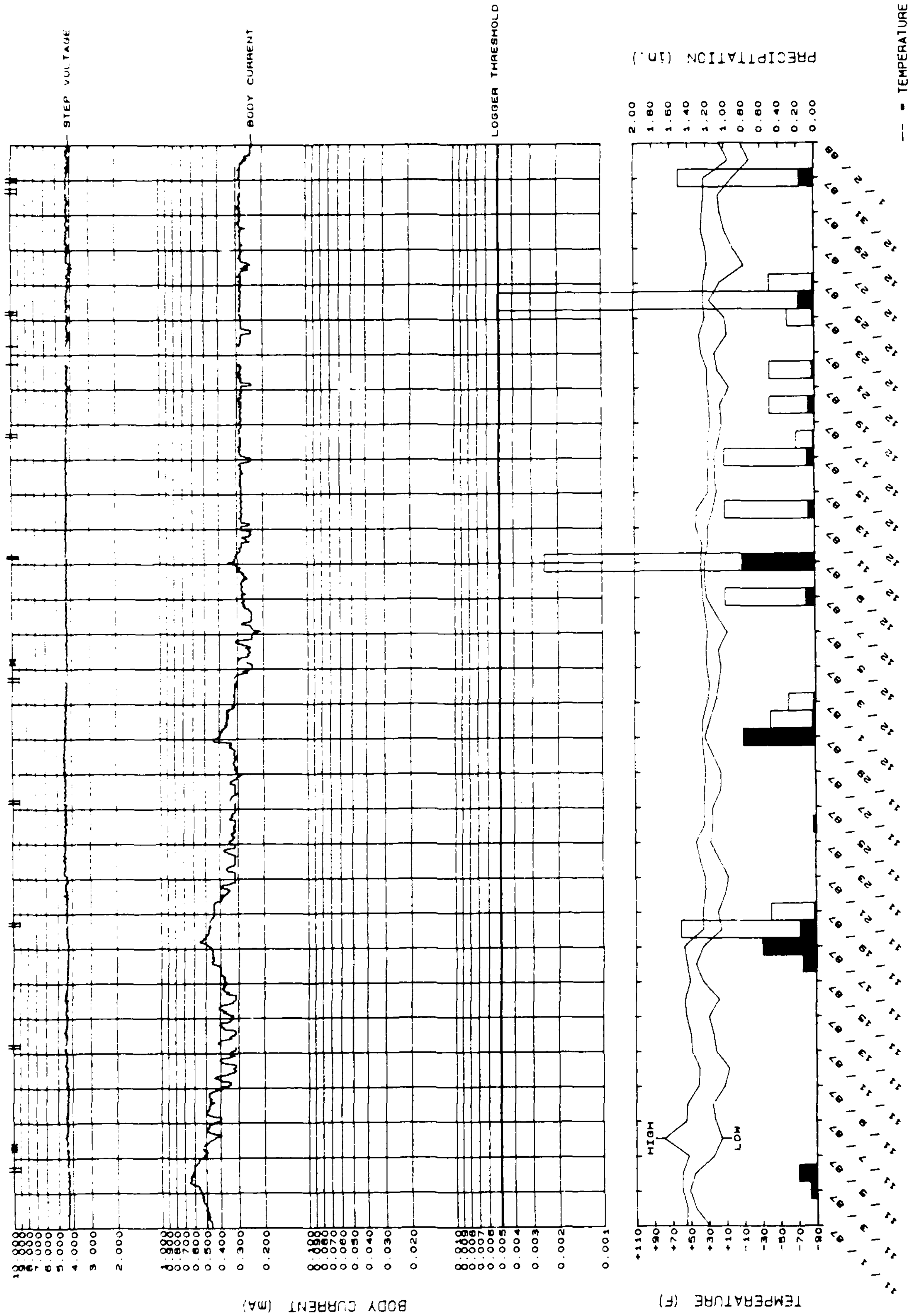


Figure B-12c. Hourly Data Logger Measurements at Site 9 (Sandy Soil with Slight Vegetation)
November - December 1987

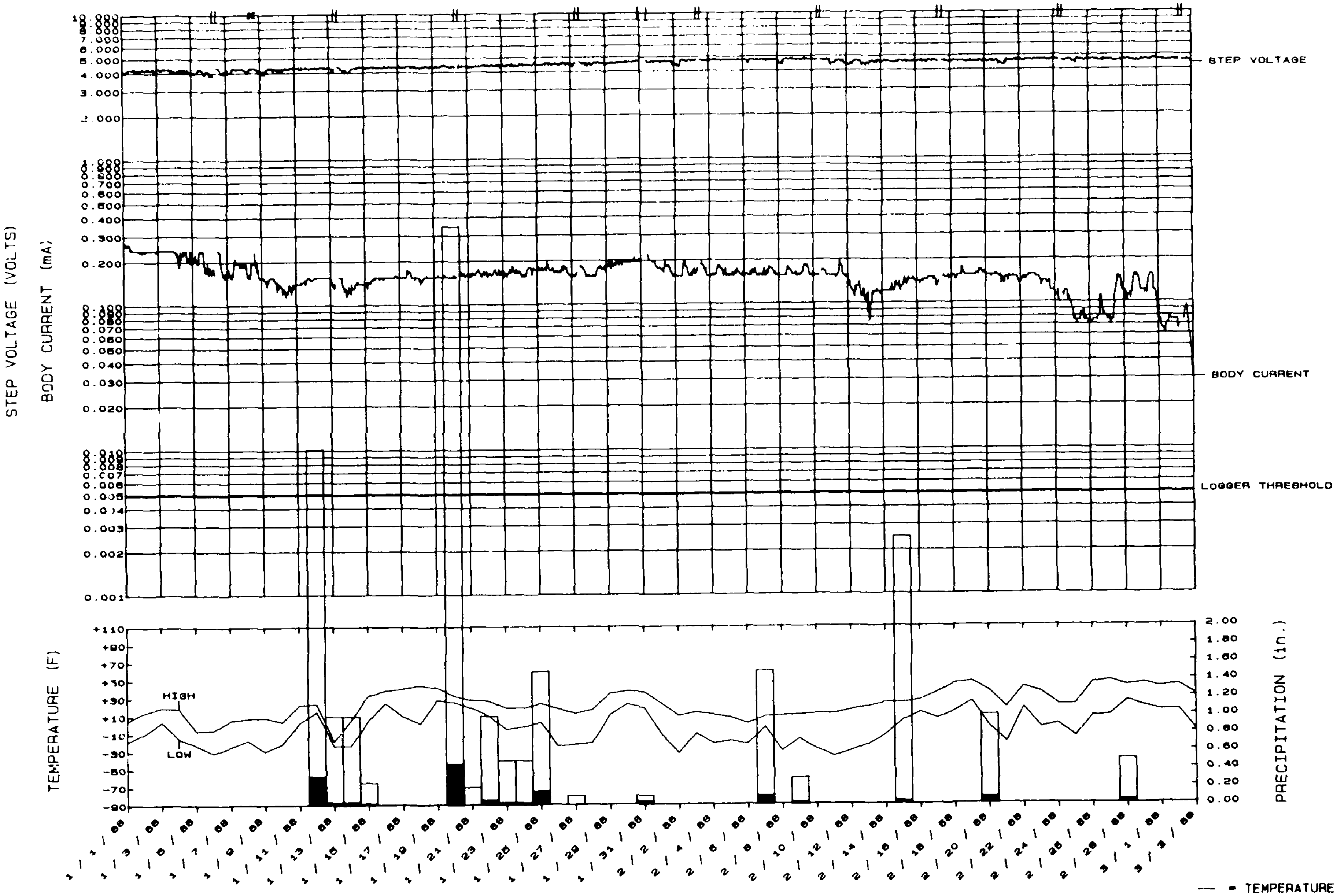


Figure B-12d. Hourly Data Logger Measurements at Site 9 (Sandy Soil with Slight Vegetation)
January - February 1988

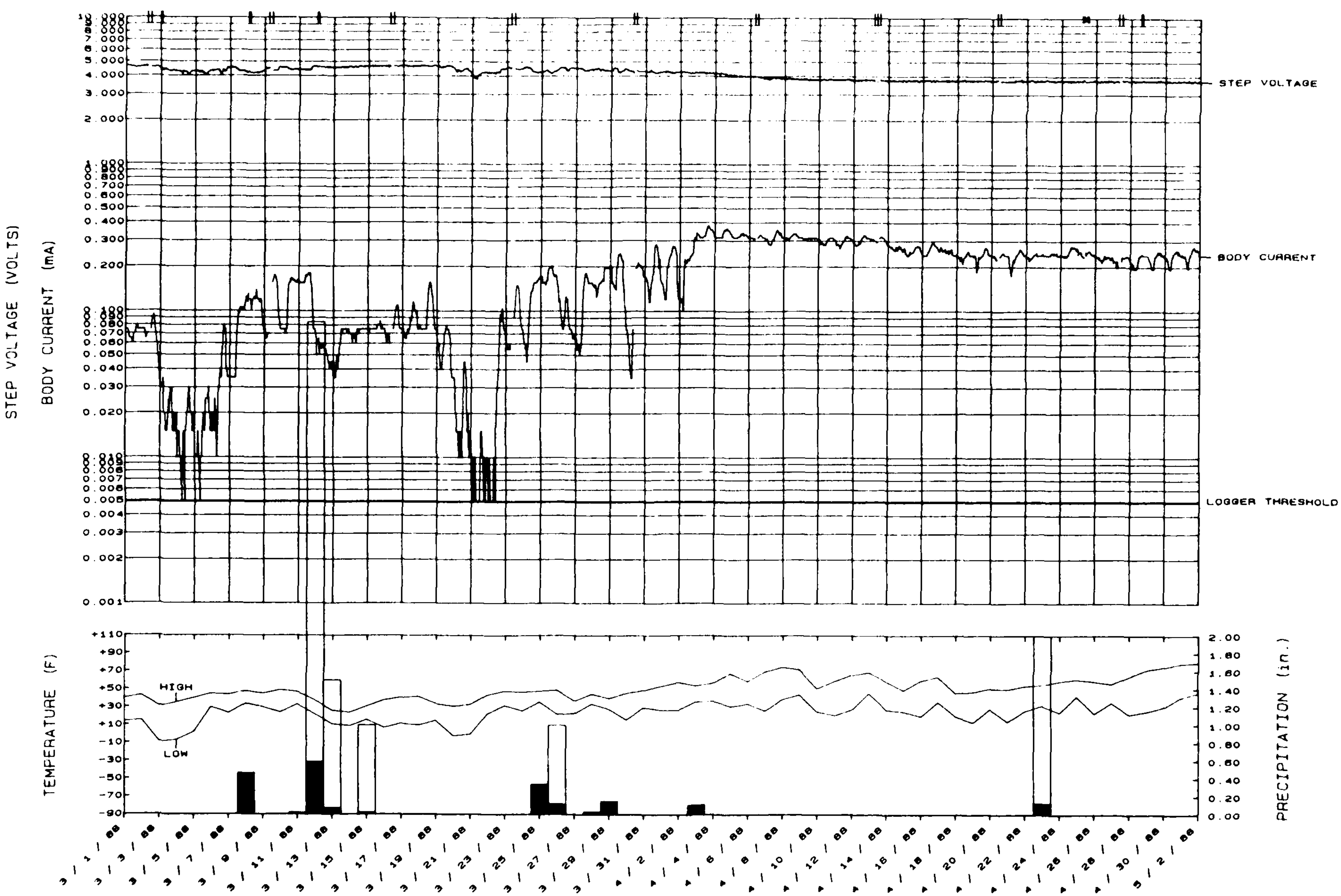


Figure B-12e. Hourly Data Logger Measurements at Site 9 (Sandy Soil with Slight Vegetation)
March - April 1988

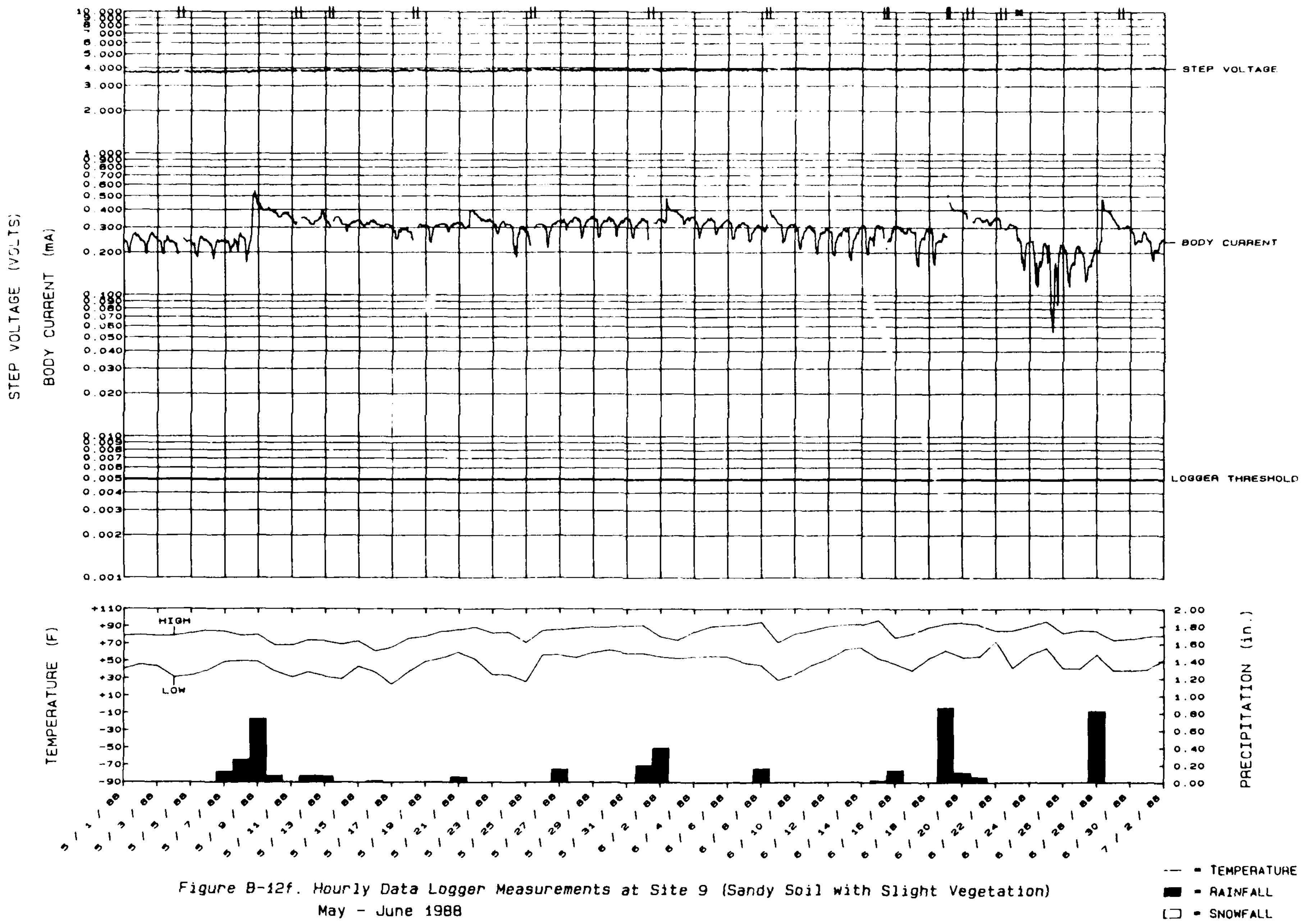


Figure B-12f. Hourly Data Logger Measurements at Site 9 (Sandy Soil with Slight Vegetation)
May - June 1988

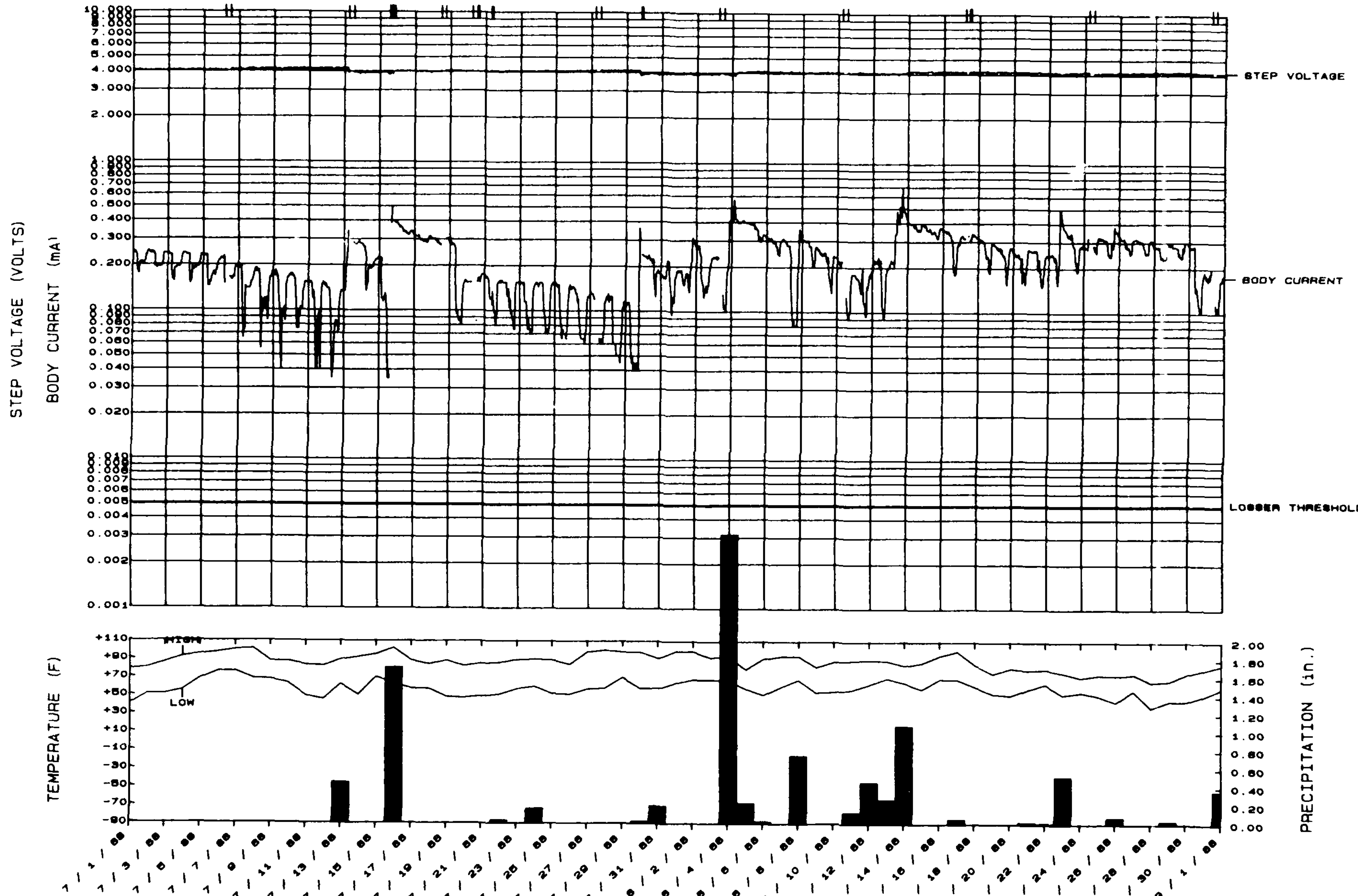


Figure B-12g. Hourly Data Logger Measurements at Site 9 (Sandy Soil with Slight Vegetation)
July - August 1988

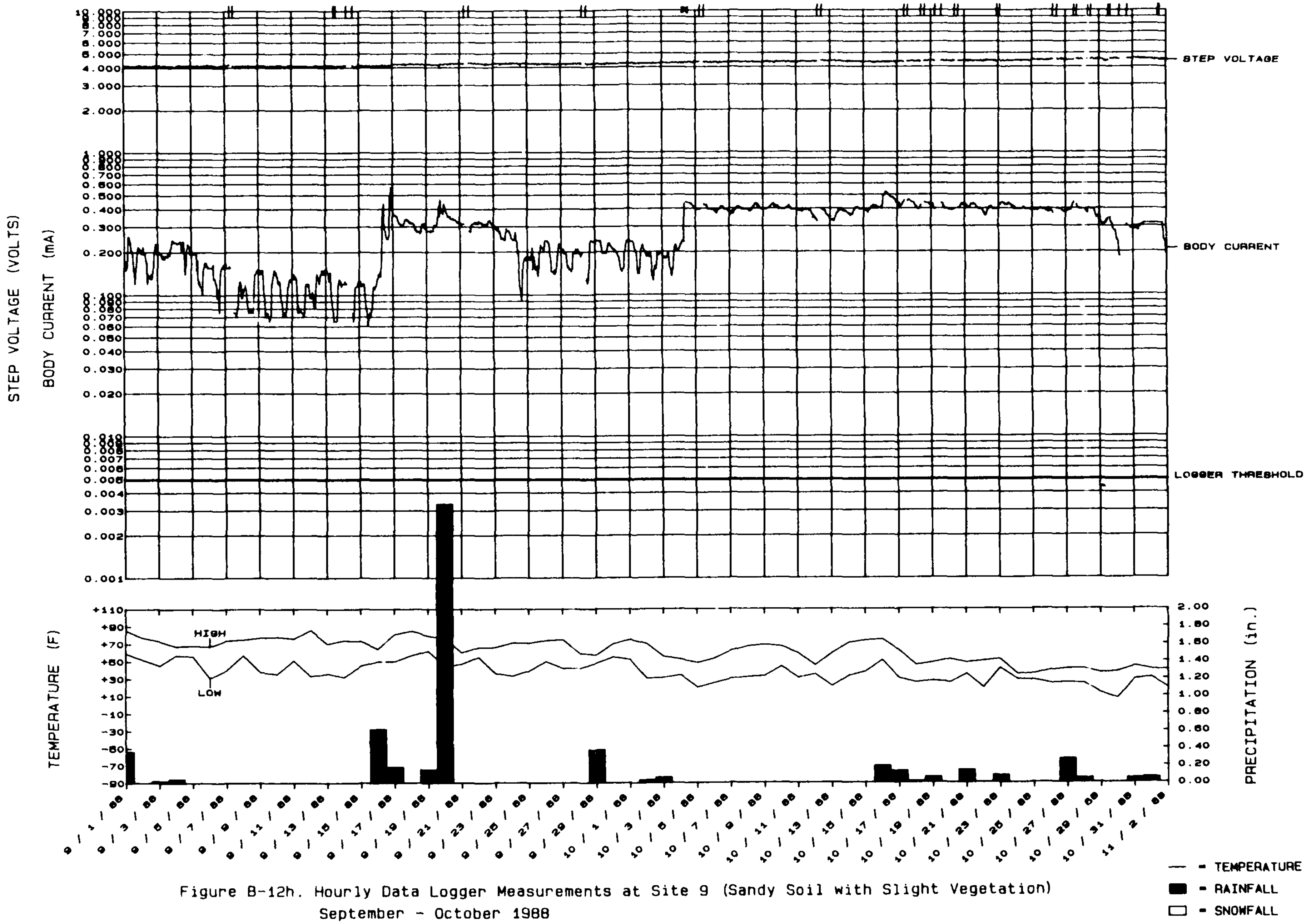


Figure B-12h. Hourly Data Logger Measurements at Site 9 (Sandy Soil with Slight Vegetation)
September - October 1988

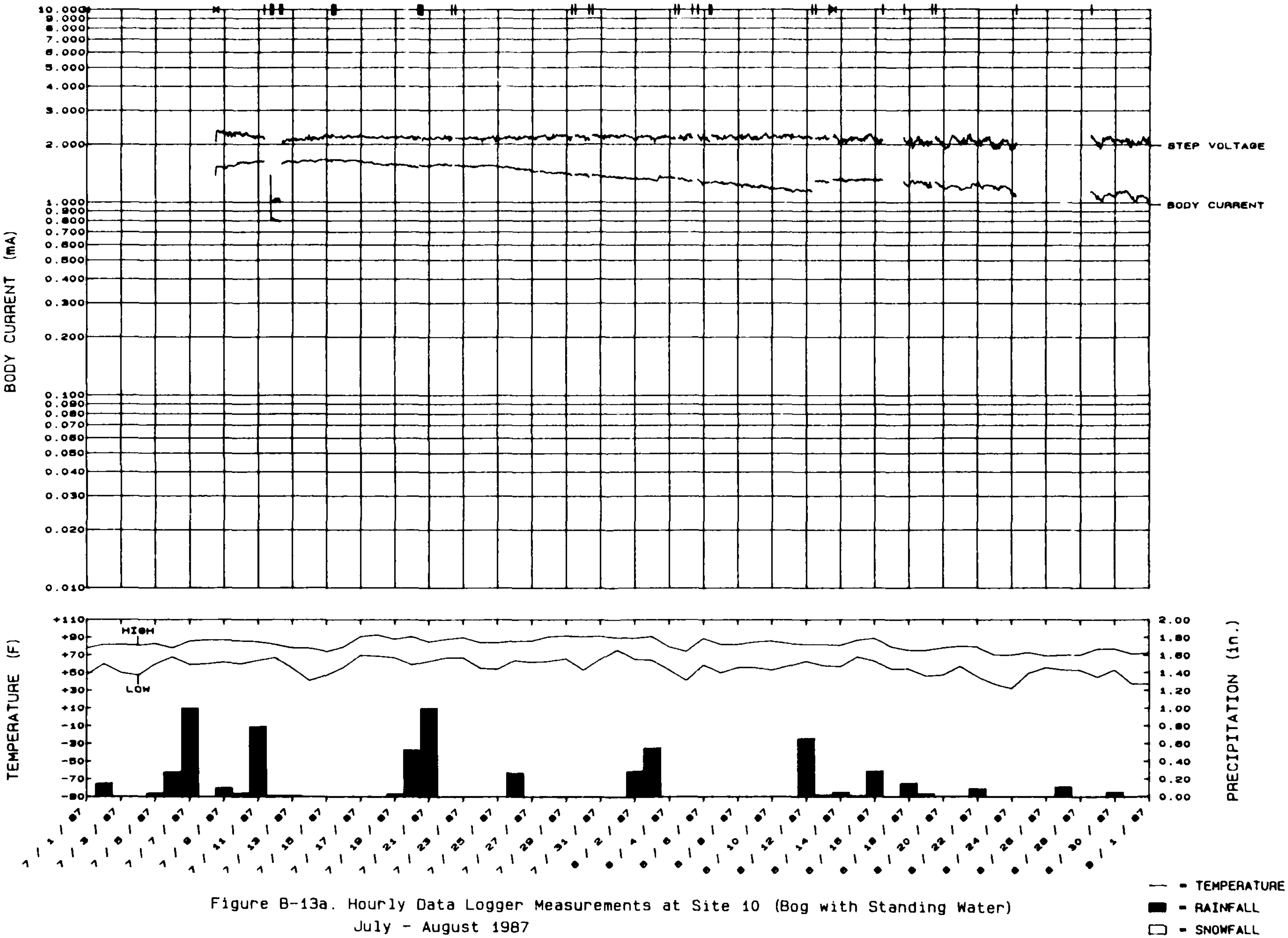


Figure B-13a. Hourly Data Logger Measurements at Site 10 (Bog with Standing Water)
July - August 1987

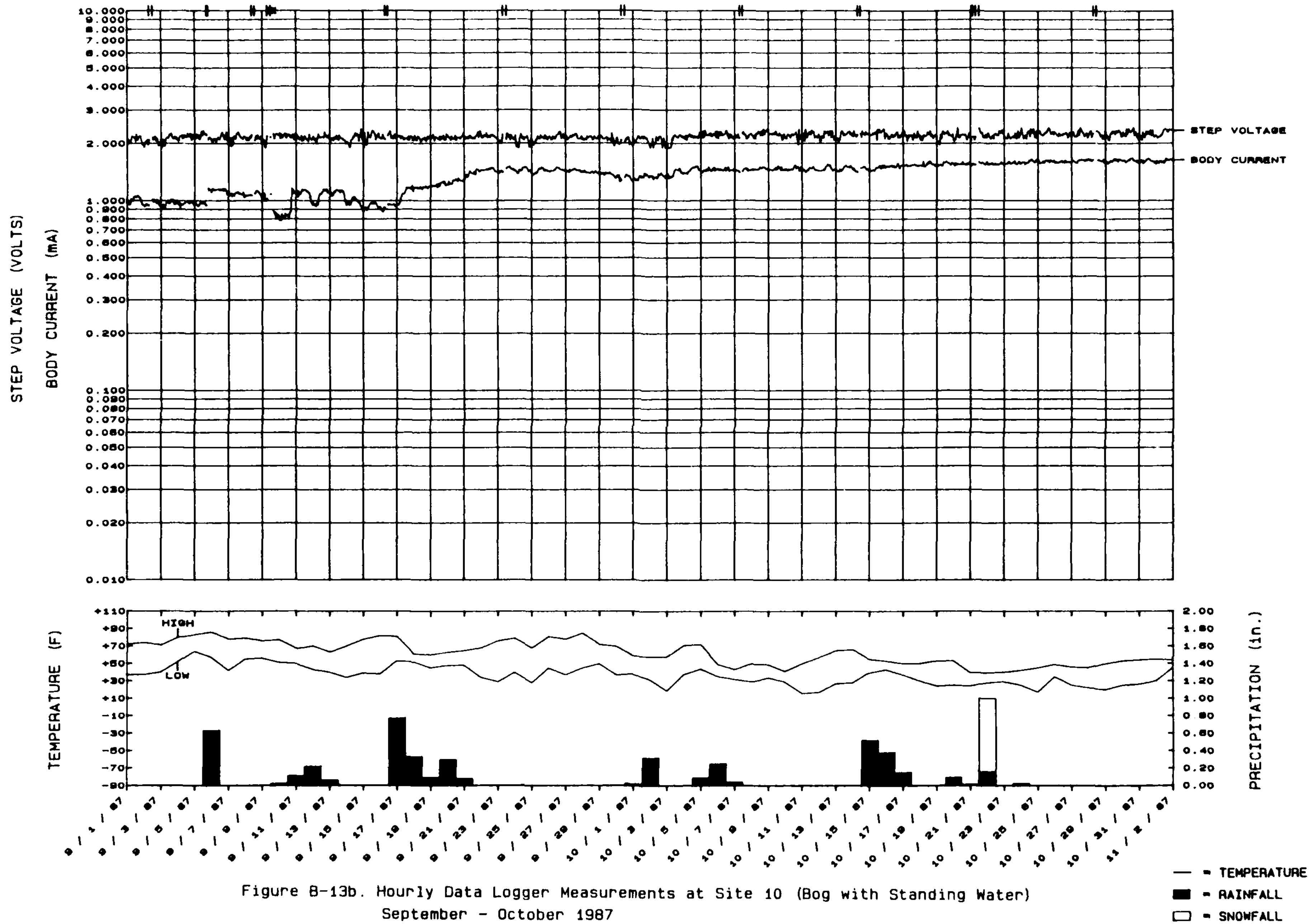


Figure B-13b. Hourly Data Logger Measurements at Site 10 (Bog with Standing Water)
September - October 1987

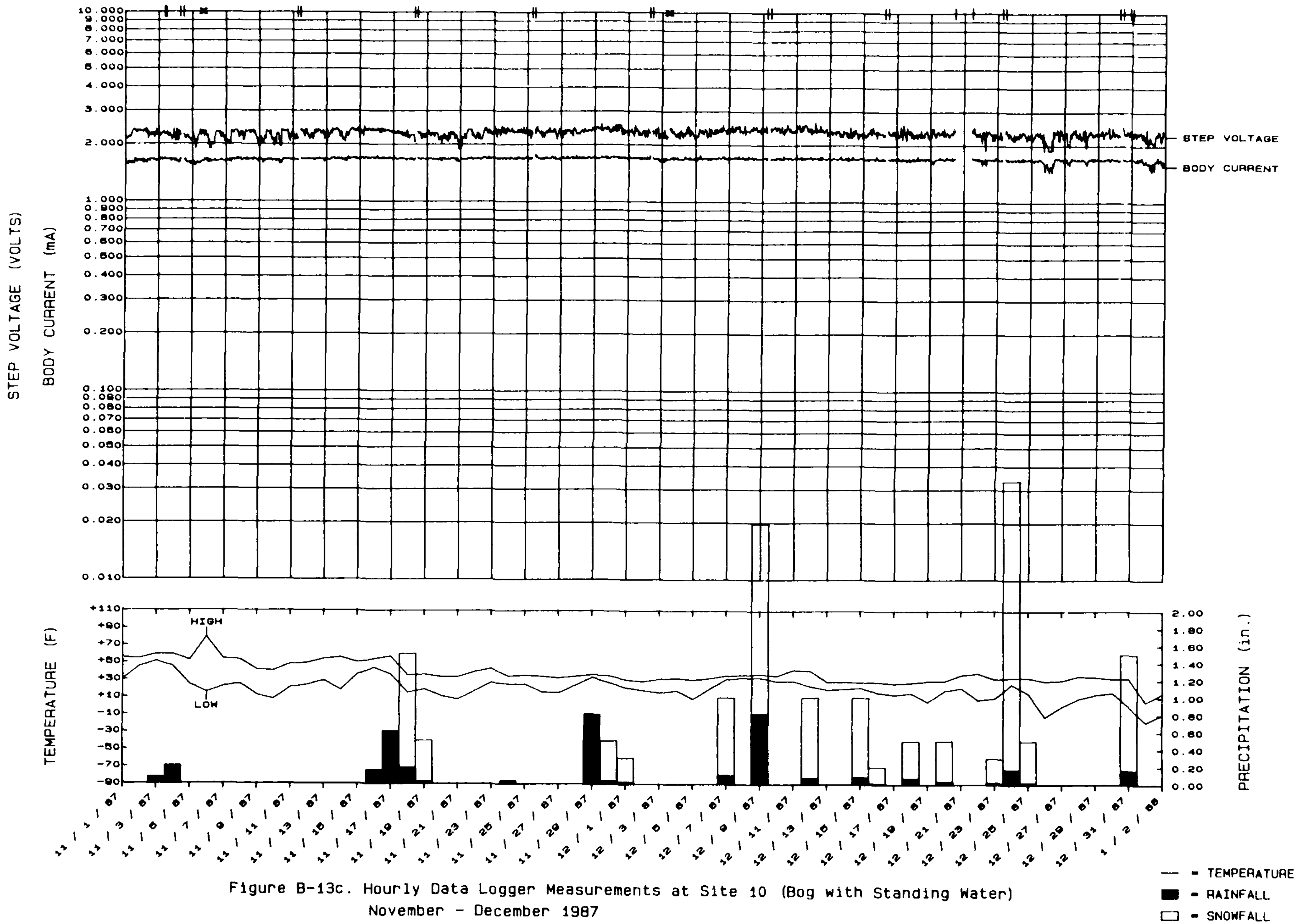


Figure B-13c. Hourly Data Logger Measurements at Site 10 (Bog with Standing Water)
November - December 1987

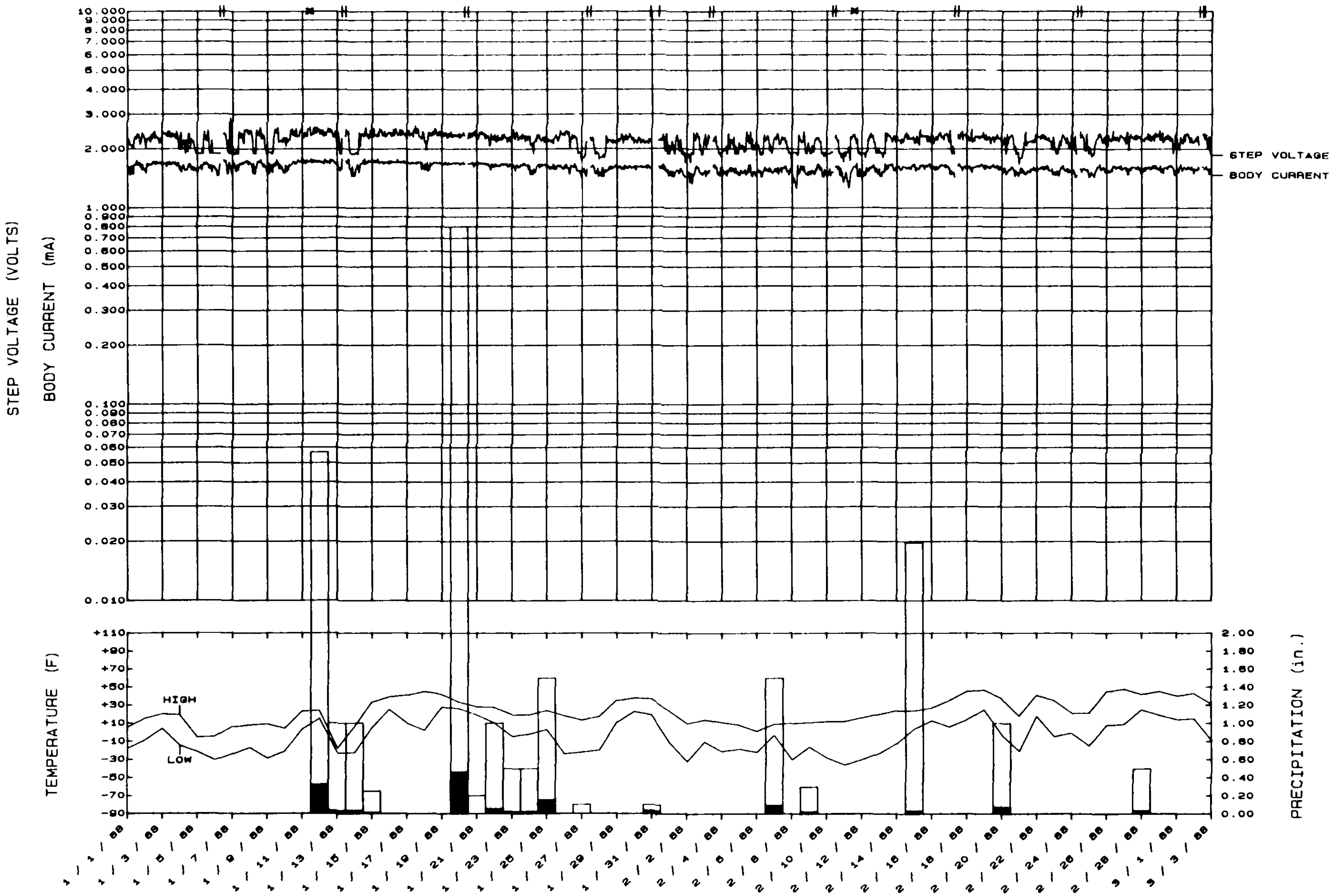


Figure B-13d. Hourly Data Logger Measurements at Site 10 (Bog with Standing Water)
January - February 1988

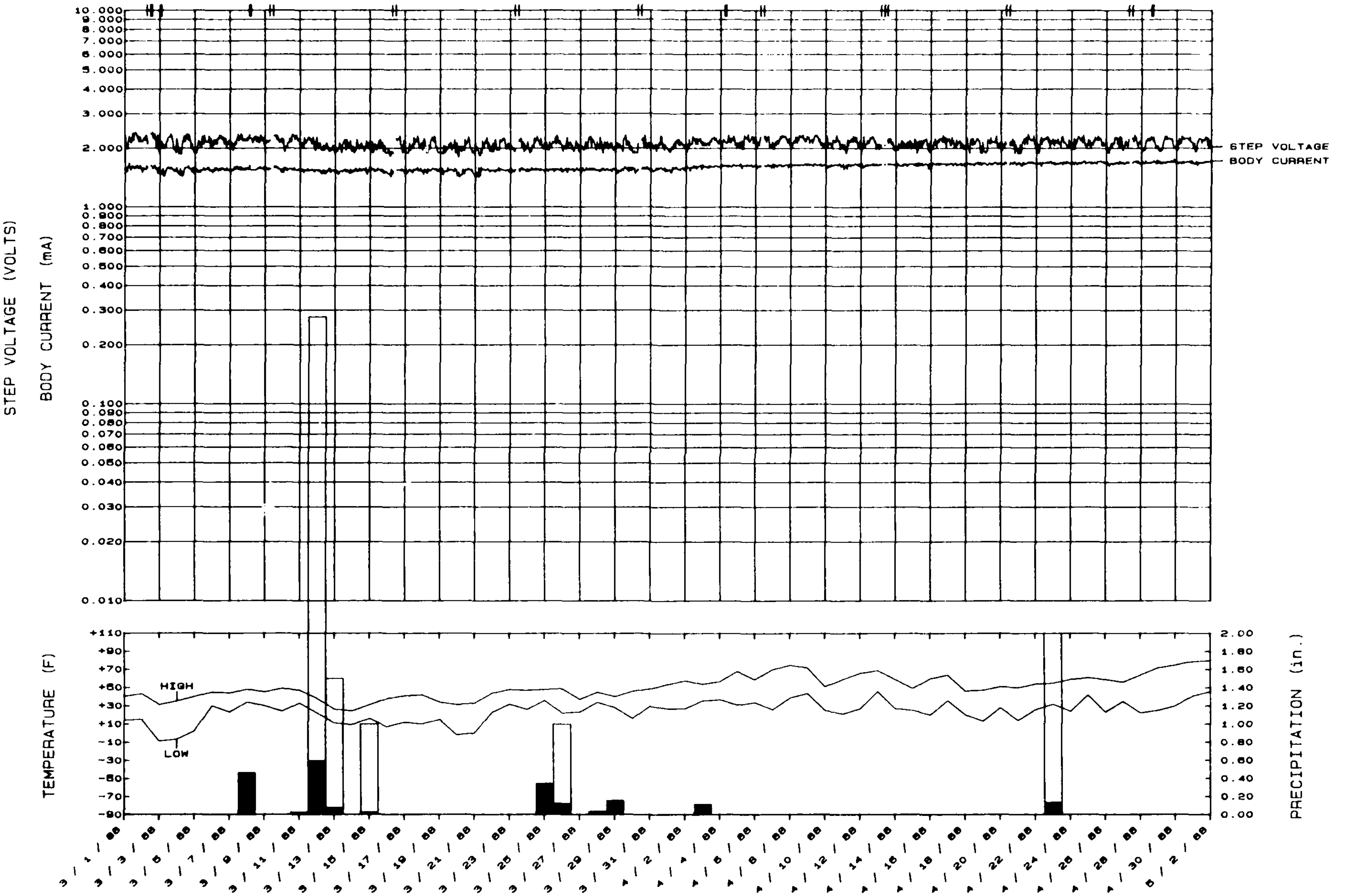


Figure B-13e. Hourly Data Logger Measurements at Site 10 (Bog with Standing Water)
March - April 1988

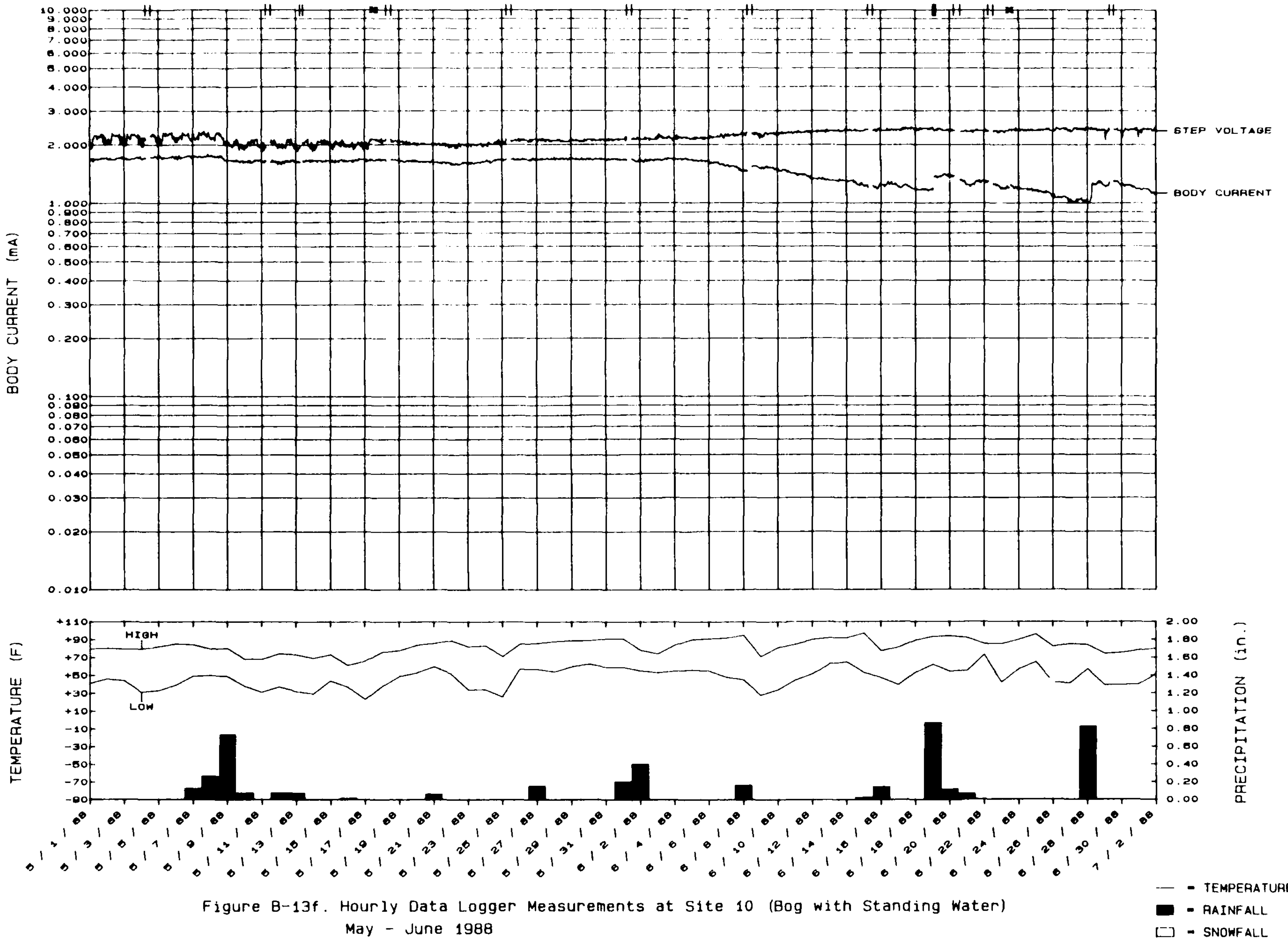


Figure B-13f. Hourly Data Logger Measurements at Site 10 (Bog with Standing Water)
May - June 1988

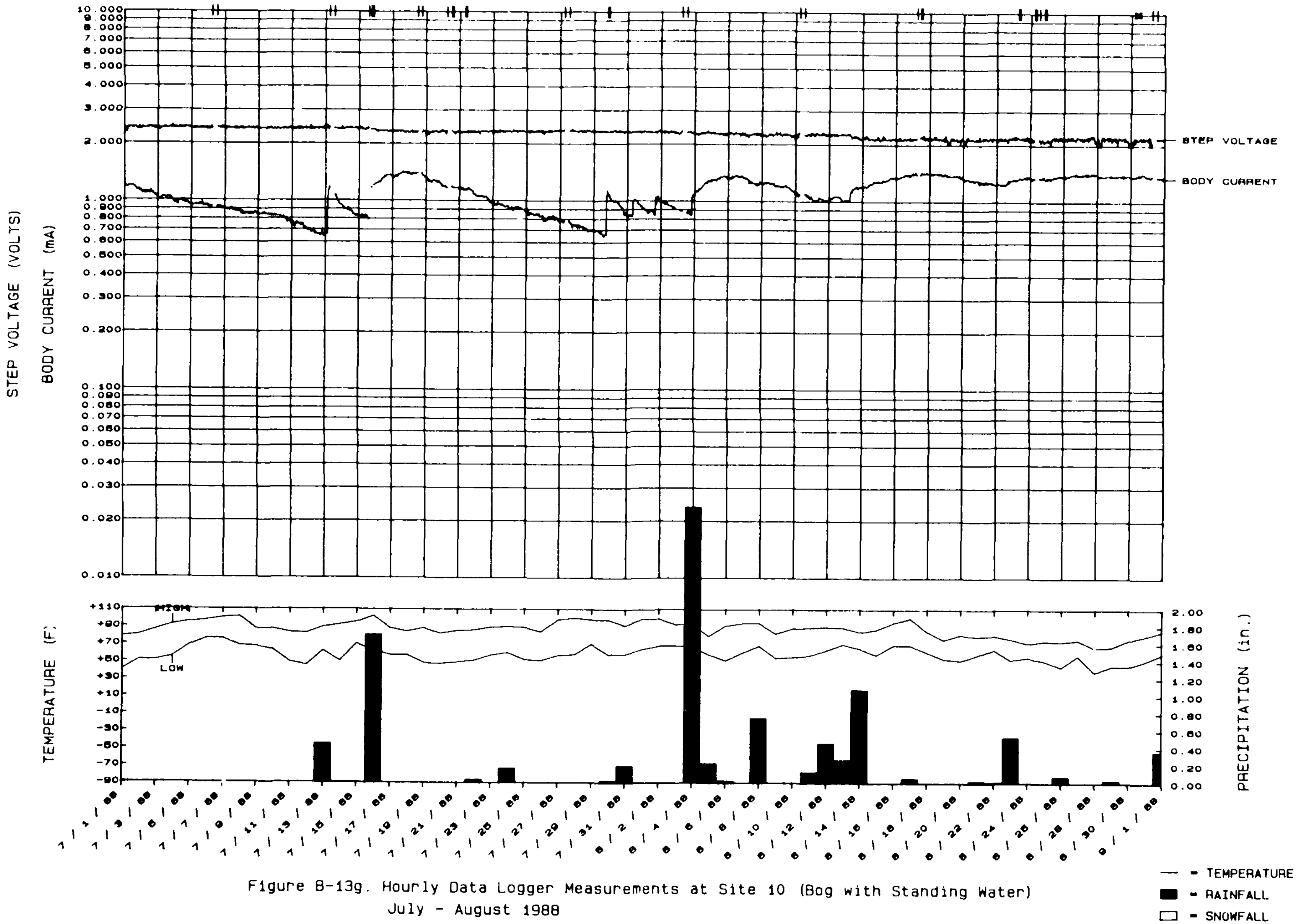


Figure B-13g. Hourly Data Logger Measurements at Site 10 (Bog with Standing Water)
July - August 1988

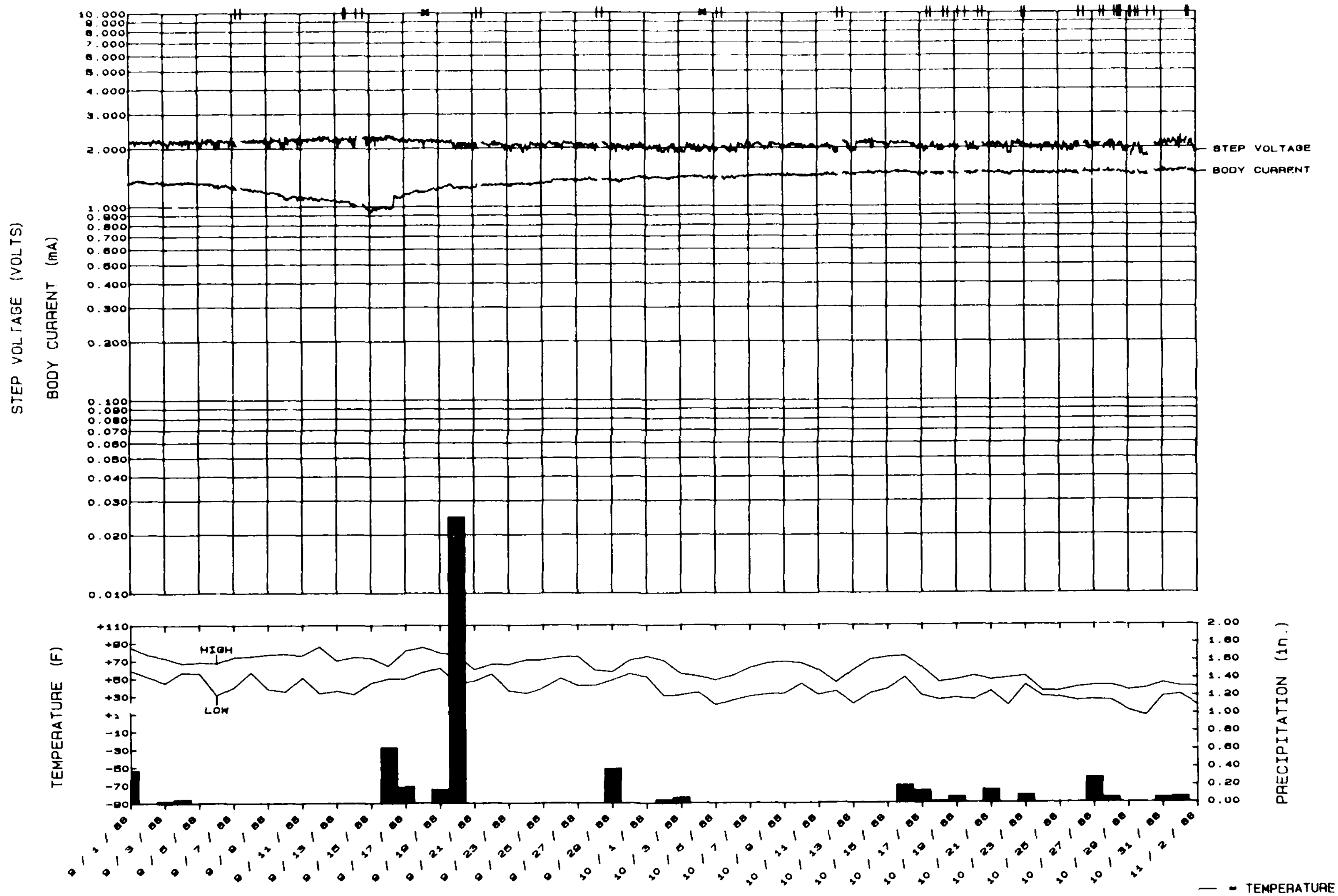


Figure B-13h. Hourly Data Logger Measurements at Site 10 (Bog with Standing Water)
September - October 1988

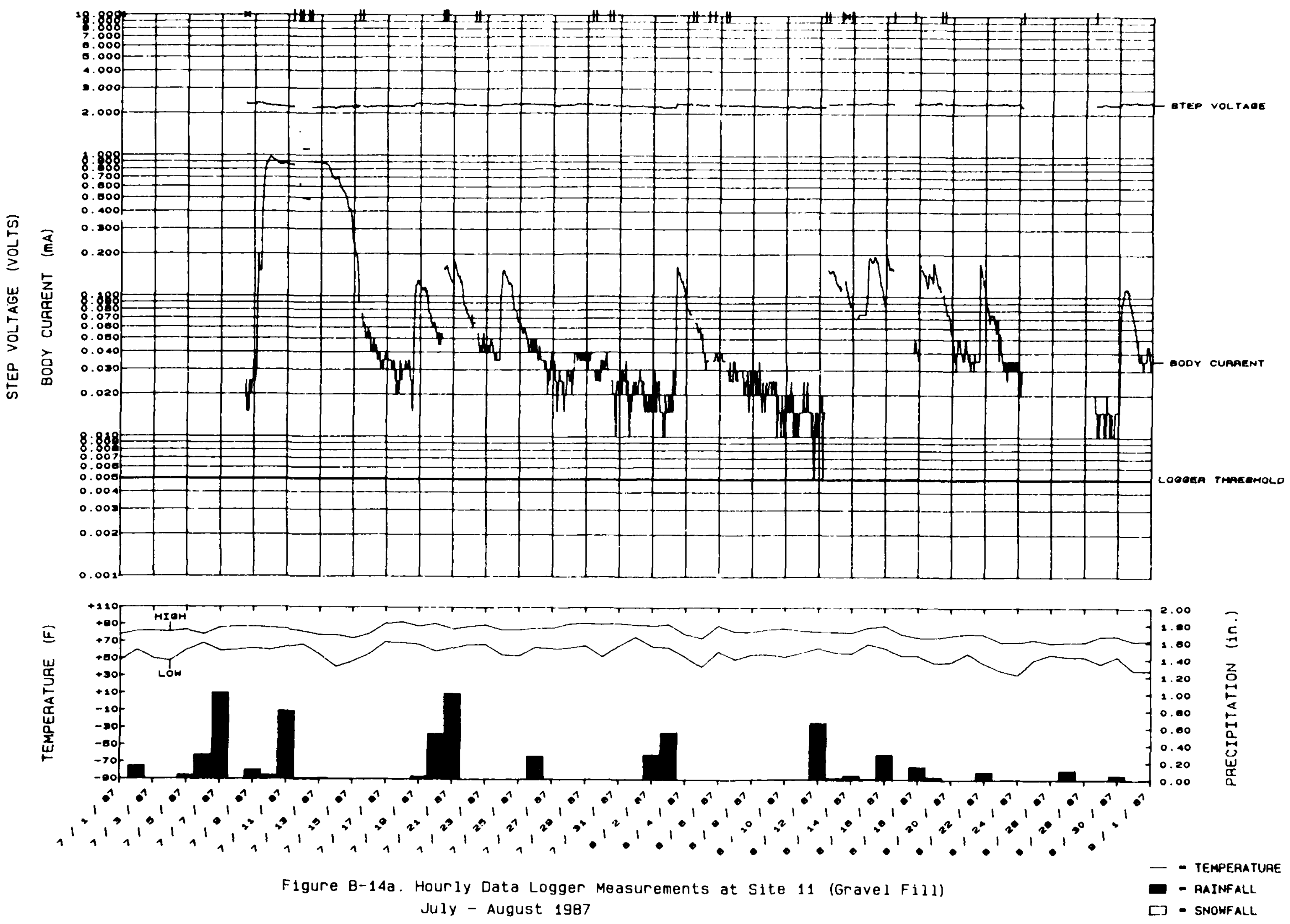


Figure B-14a. Hourly Data Logger Measurements at Site 11 (Gravel Fill)
July - August 1987

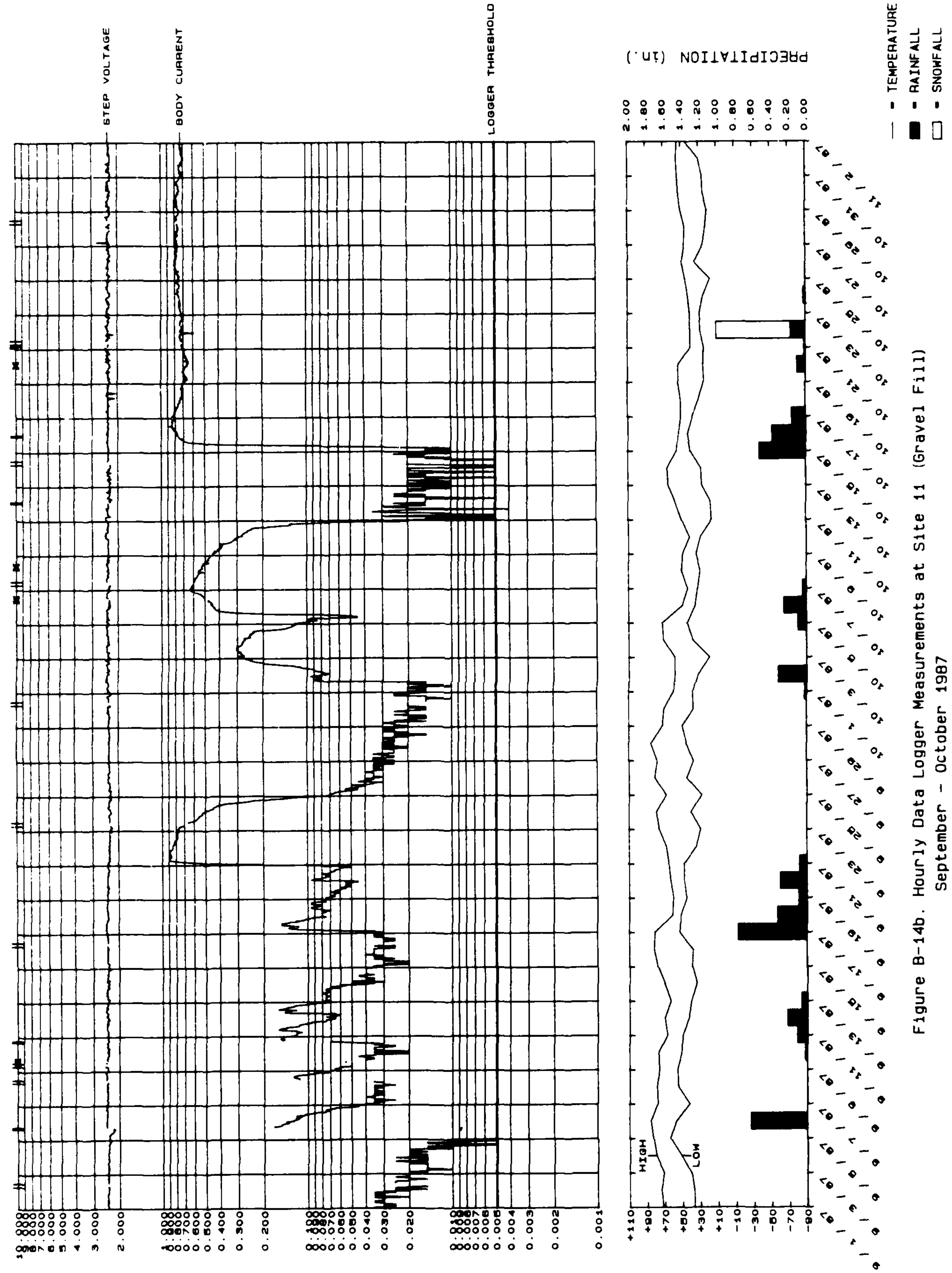


Figure B-14b. Hourly Data Logger Measurements at Site 11 (Gravel Fill)
September - October 1987

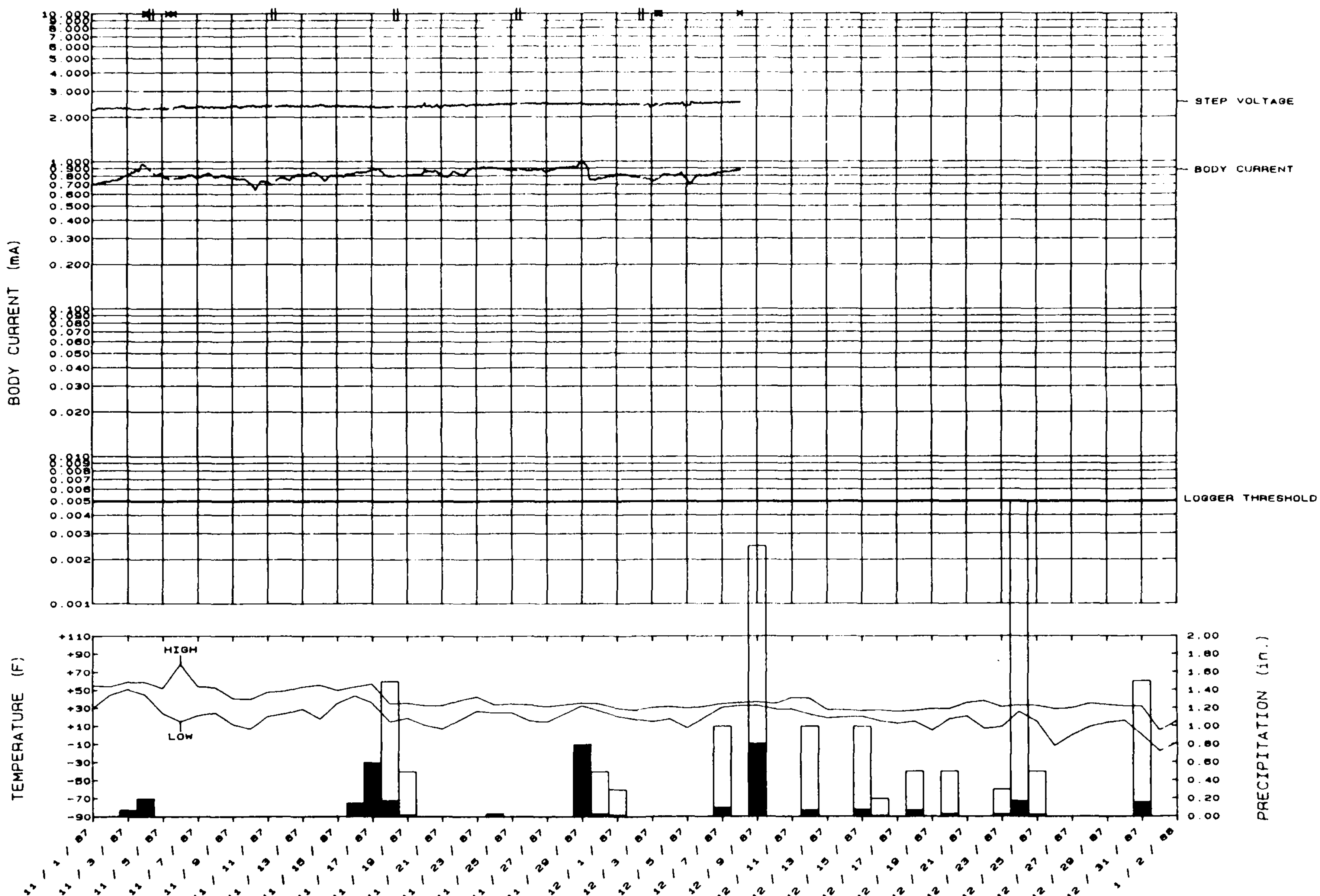


Figure B-14c. Hourly Data Logger Measurements at Site 11 (Gravel Fill)
November - December 1987

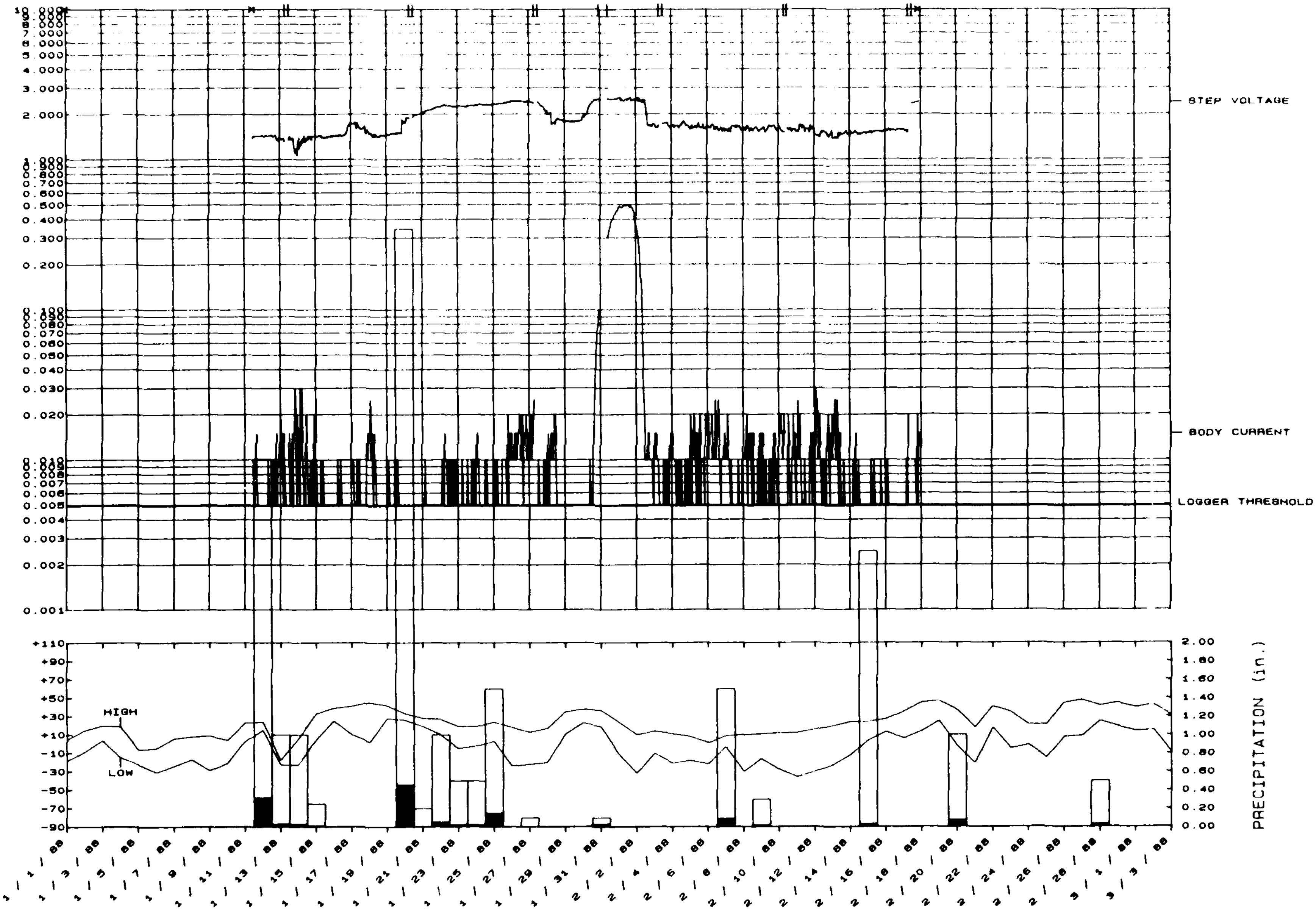


Figure B-14d. Hourly Data Logger Measurements at Site 11 (Gravel Fill)
January - February 1988

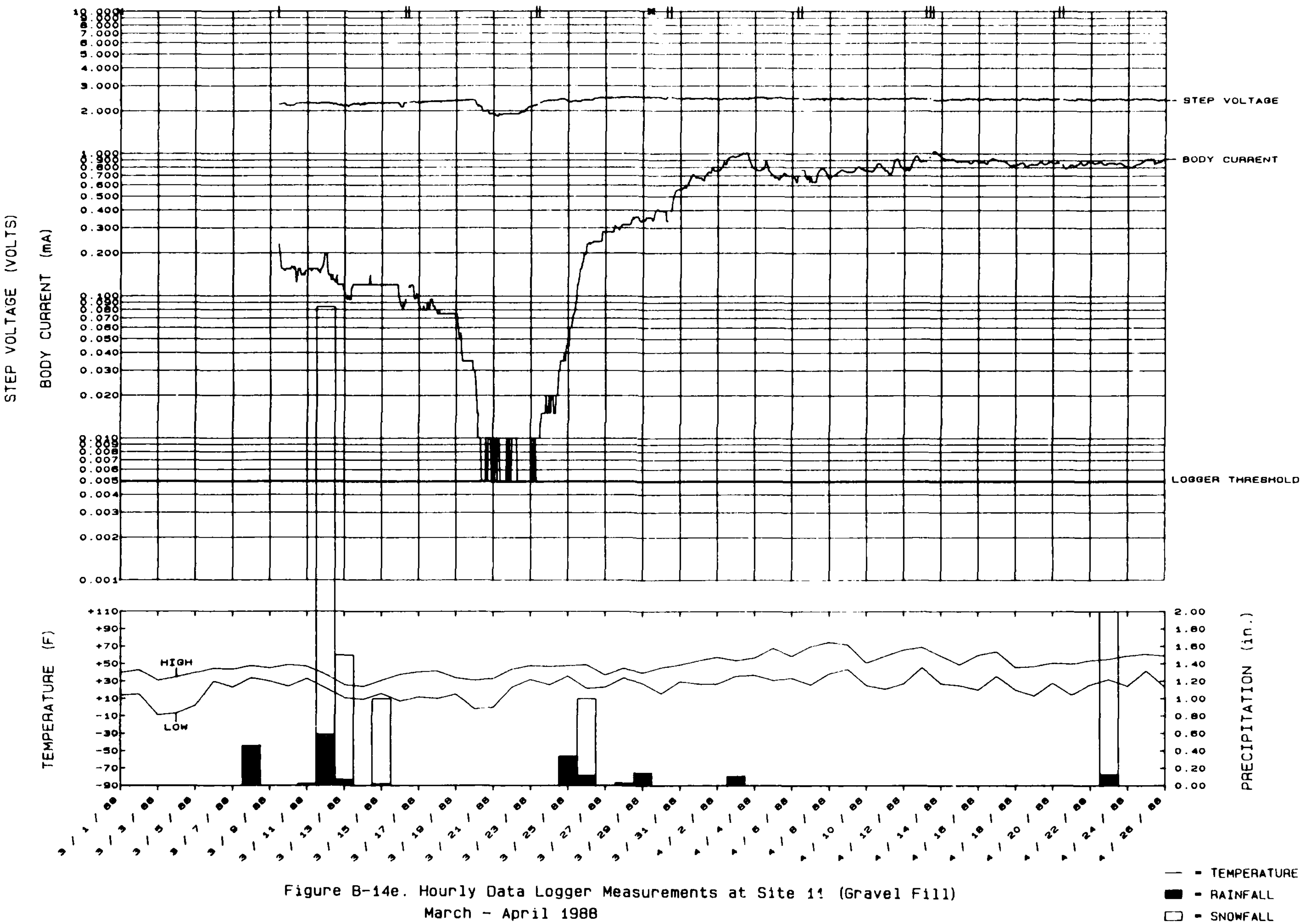


Figure B-14e. Hourly Data Logger Measurements at Site 11 (Gravel Fill)
March - April 1988

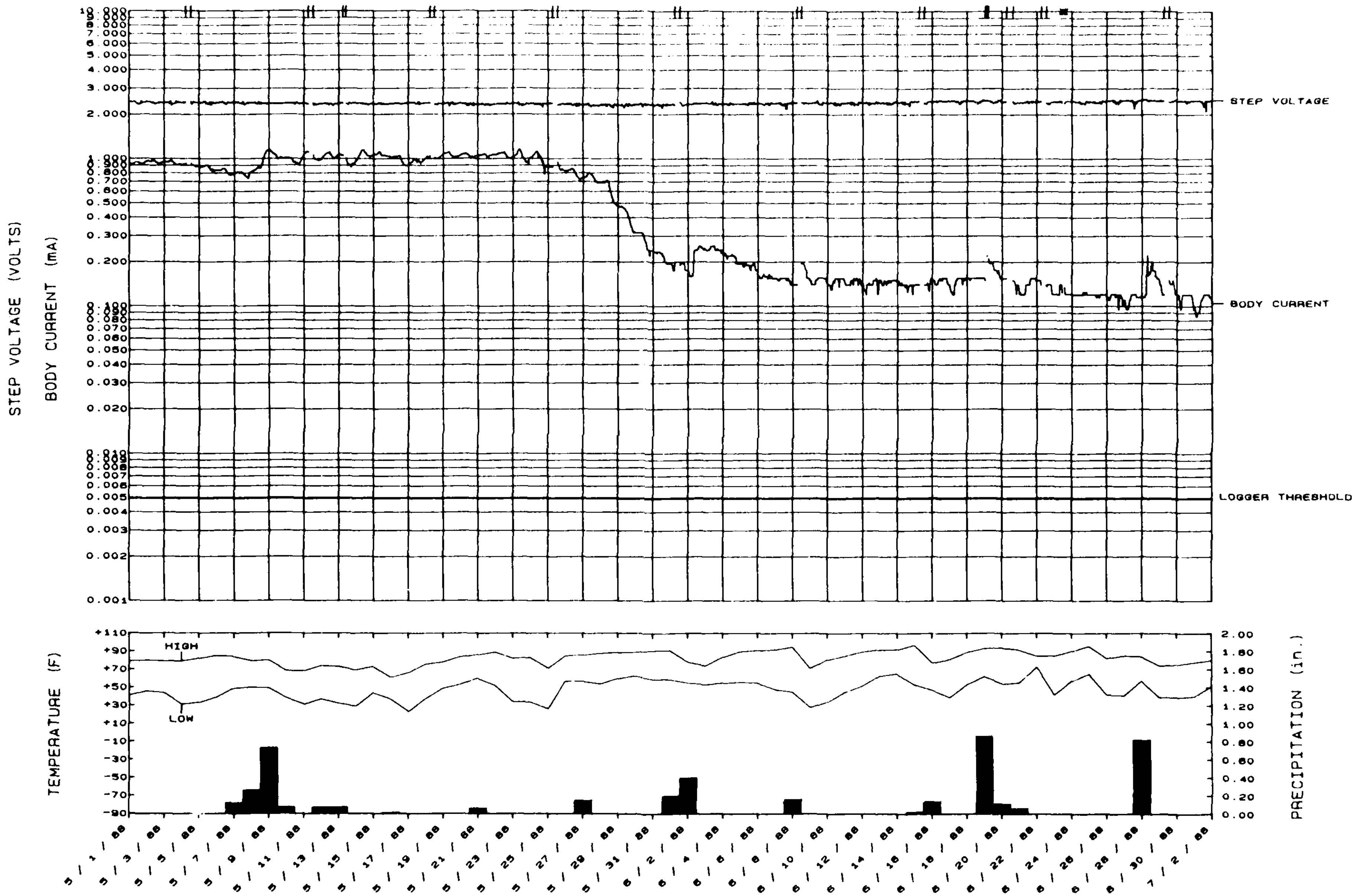


Figure B-14f. Hourly Data Logger Measurements at Site 11 (Gravel Fill)
May - June 1988

— = TEMPERATURE
■ = RAINFALL
☐ = SNOWFALL

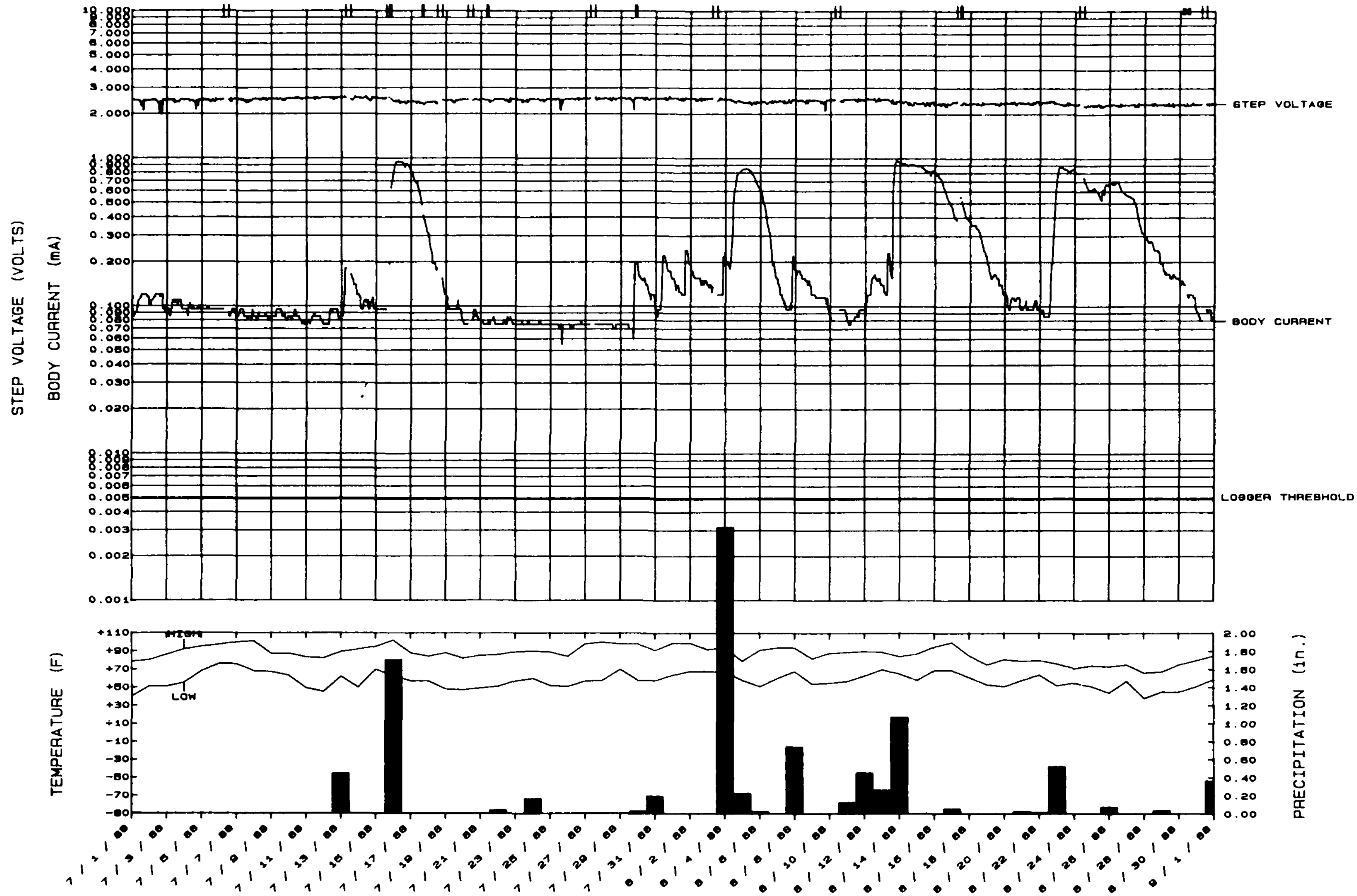
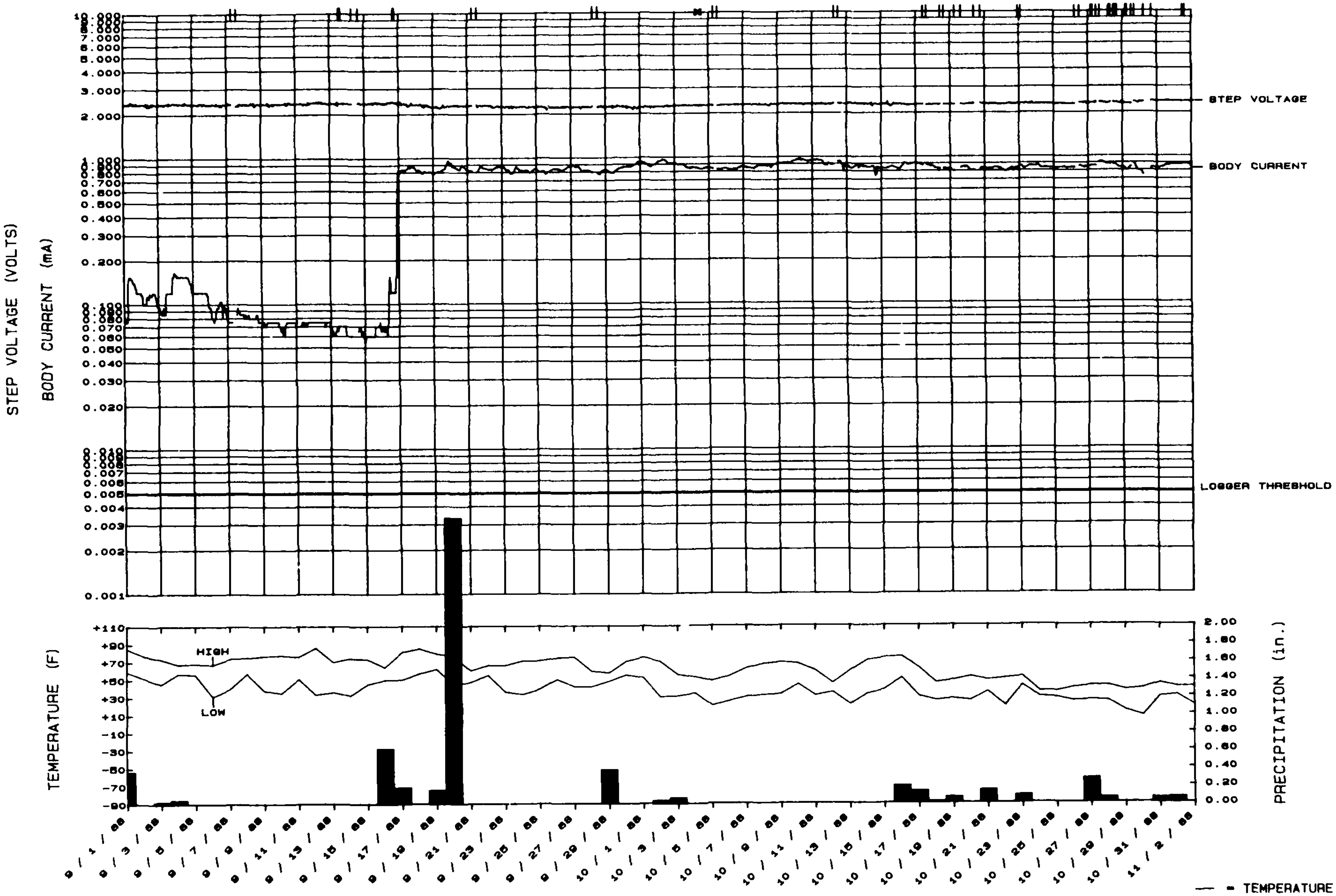


Figure B-14g. Hourly Data Logger Measurements at Site 11 (Gravel Fill)
July - August 1988



— TEMPERATURE
■ RAINFALL
□ SNOWFALL

Figure B-14h. Hourly Data Logger Measurements at Site 11 (Gravel Fill)
September - October 1988