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Hydrologic Controls On The Survival of Water Howellia (Howellia aquatilis) And Implications Of Land Management, Swan Valley, Montana

By

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Water Howellia (*H. aquatilis*) is a rare and endangered wetland plant listed as a threatened species under the Federal Endangered Species Act. 70% of the world population is found in the less than one-hectare, glacially formed, forested Swan Valley wetland systems. Survival of this aquatic species requires emergence during mid-summer, the drying out of occupied portions of the wetlands, a slight refilling of the wetlands in fall, and wetland re-establishment in the spring. This project is designed to determine the wetland source of water and the mechanisms controlling the wetland hydrological cycle in Water Howellia inhabited wetlands. Four representative sites were evaluated using water budgets derived from extensive micro-basin field measurements, methods that define groundwater-surface water interaction, and standard geochemical analyses. Once the dominant hydrological components and seasonal controls on wetland hydrology were resolved, an analysis of how change in vegetative cover in the watersheds alter wetland hydrology. Water balance results indicate that groundwater inflow and plant transpiration components are the dominant hydrological controls in these wetland systems. Vertical hydraulic gradients between the stage of the wetland and shallow groundwater, potentiometric maps, seepage meter flux rates, and the groundwater inflow component of the water balance support the hypothesis that seasonal changes in the wetland are driven by a localized groundwater flow system. The localized groundwater flow system in the wetland micro-watershed basin mitigates wetland stage decline and surface water quality. Snow survey calculations, and low ionic concentrations in the wetland surface water and shallow groundwater surrounding the wetlands suggest that the localized flow system is principally recharged from snow melt. The WRNSHYD model predicts an increase in water yield from the removal of watershed trees by harvesting or a stand replacing fire. If an initial increase in water yield occurred, it may be short lived or last for 25-40 years. However, the degree to which the *H. aquatilis* life cycle would be altered is unknown.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

Acknowledgements

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Bonnie Heidel and the Montana Natural Heritage Program were very instrumental in launching this project. I would also like to acknowledge the enabling support of the U.S. Fish and Wildlife Service. Maria Mantas and Liz Hill with the Flathead National Forest made significant contributions to this project by supplying critical information about Water Howellia and providing access to Forest Service land. Anne Dahl with the Swan Valley Ecosystem helped to recruit volunteers in the Swan Valley to record precipitation data. I also want to thank all of the volunteers.

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CHAPTER 1: INTRODUCTION

Wetlands are unique environments that provide habitat for diverse communities of flora and fauna. Wetlands are also valuable as sources, sinks, and transformers of a multitude of chemical, biological, and genetic materials (Mitsch and Gosselink, 1993). They have the ability to cleanse polluted water, prevent floods, protect shorelines, and recharge groundwater aquifers (Mitch and Gosselink, 1993; Kamp and Hayashi, 1998). Unfortunately, wetlands have been detrimentally affected by human activities. According to Mitsch and Gosselink (1993), an estimated 53 percent of the original wetlands in the lower 48 states has been lost because of drainage and other human activities.

The forested wetlands of the Swan Valley of Missoula and Lake counties, Montana contain a rare plant species, *Howellia aquatilis* (Water Howellia) (Figure 1). It is listed as a threatened species under the Federal Endangered Species Act (U.S. Fish and Wildlife Service, 1994). The highest known concentration of Water Howellia in the world is found in these glacially formed wetland systems of the Swan Valley (Shelly and Gamon, 1996). Other populations of *H. aquatilis* are found in ephermal wetlands or the margins of shallow permanent wetlands located in northern California, western Oregon, Washington, and northern Idaho (Shelly and Gamon, 1996). It is not known how long this species has existed in the wetlands of the Swan River Valley. However, this species has most likely survived since the end of the Pleistocene.

The life-cycle of *H. aquatilis,* as an aquatic annual, is influenced by the

Figure 1. Howellia aquatilis is a rare and endangered wetland plant species. The flowers of this plant are approximately the size of a dime. Photo by Kristi DuBois

seasonal variation in wetland stage (Lesica, 1992). In the spring, Water Howellia occupied wetlands fill with water. During the summer months, Water Howellia matures, flowers at the surface and below water, and produces seeds which are dropped and become incorporated into the wetland sediment. By the end of the summer or early fall, the wetlands dessicate, exposing Howellia seeds to air and the annuals die and decompose. Seeds germinate in October under aerobic conditions and remain as a small seedling beneath the winter snowpack and then are submerged by snow melt in early spring (Shapley and Lesica, 1997). This wetland hydrological cycle of wetting and drying is necessary to maintain *H. aquatilis* populations. It has been suggested that this cycle has been sufficiently continuous since the end of the Pleistocene to maintain the Howellia population, though *H. aquatilis* seeds may remain viable in wetland sediment for several years (Mantas, 2001).

The majority of Water Howellia research in the Swan Valley has focused on *H. aquatilis* habitat from a biological standpoint (Lesica, 1992; Shelly and Gamon, 1996; Mantas, 1998) with only limited characterization of wetland hydrology (Shapley and Lesica, 1997; Shapley, 1998). Shapley (1998) classified *H. aquatilis* wetland morphology into four distinct basin types based on pond geometry, size, and slope. Anderson (1992) studied the hydrology of the Swan River Oxbow preserve, a wetland in the active flood plain of the river that contained a viable population of Water Howellia. He found that the exchange of groundwater between the Swan River, the unconfined alluvial aquifer, and the oxbow wetland was controlled by the difference in seasonal vertical gradients. However, all other *H. aquatilis* occupied wetlands are found within depressions formed in the glacial till deposits located above the main valley floor.

Project Goals and Objectives

This project is designed to determine the wetland source of water and the mechanisms controlling the wetland hydrological cycle. Specific objectives include: 1) identification of the source of water to the wetlands, 2) quantification of controls on the seasonal variation in water input, and 3) analysis of how natural and anthropogenic modification of the wetland watershed have or could alter wetland hydrology. Defining the hydrologic controls on these wetlands is critical to the formulation of land management plans in the Swan Valley that allow conjunctive land use and protection of Water Howellia habitat (Shapley and Lesica, 1997, Shapley, 1998).

Site Descriptions

Physiography:

The Swan valley is a north-south trending glaciated valley that is bound by the Swan and Mission mountain ranges to the east and west. The valley is approximately 50 miles long, 13-28 miles wide, and ranges in elevation from 3060 feet near Swan Lake to 9180 feet in the Swan and Mission mountain ranges (Figure 2). It is located approximately 80 miles northeast of Missoula, Montana.

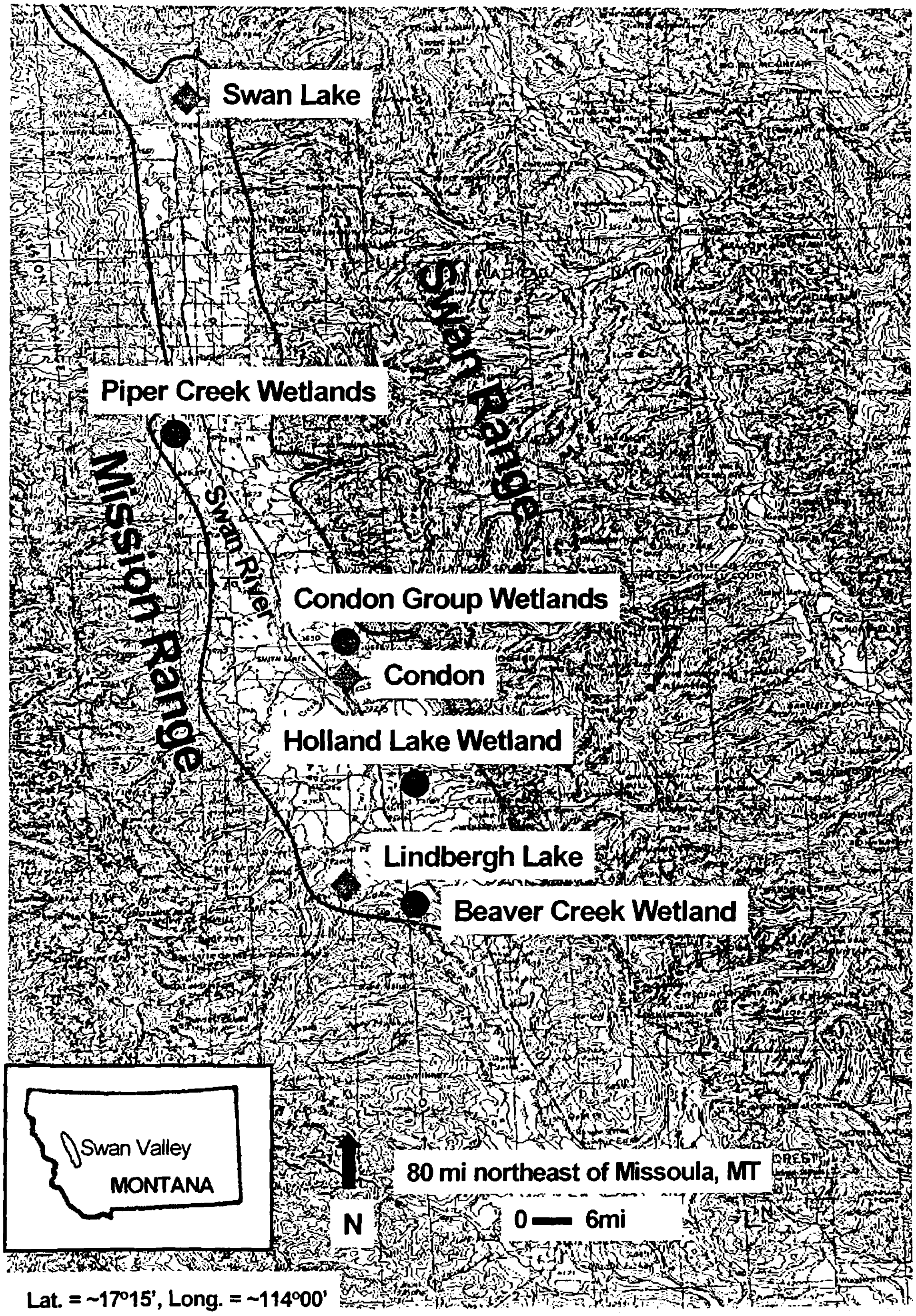


Figure 2. Wetland site locations in the Swan Valley. Solid dots represent wetland study sites. Weather stations are located at Lindbergh Lake and Swan Lake. Condon is the main town in the central valley.

Geology:

The Swan Valley is bordered by two north-south trending normal fault block mountain ranges, the Swan Range to the east and Mission Range to the west (Johns, 1970; Kleinkopf and Mudge, 1972). The Swan and Mission mountain ranges are comprised of slightly metamorphosed (argillites, carbonates, and quartzites) Precambrian sedimentary rocks of the Belt Supergroup, specifically, the Piegan, Grinnell, Missoula, and Appekunny Groups (Ross et al., 1955).

The valley floor is covered by glacial sediments of late Wisconsin age (Witkind and Weber, 1982) and filled to a depth of 2000 to 3000 ft with older Cenozoic deposits (Kleinkopf and Mudge, 1972). Pleistocene lateral moraines, basal moraine and glaciofluvial sediments deposited by one of the two major diverging trunk glaciers occupying the Swan-Clearwater Valley during the late Pleistocene are exposed at the land surface (Shapley and Lesica, 1997). The thickness of the glacial till is unknown. Recent alluvium is associated with stream systems.

Climate:

The Swan Valley has a continental-maritime climate (USEPA, 1980). Active weather stations at Lindbergh Lake and Swan Lake have collected records of precipitation, temperature, and snowfall since 1946 (Western Regional Climate Center, 2001). No evaporation data are collected in the Swan Valley. Mean annual precipitation in the valley ranges from 27 to 29 inches

(Table 1). Higher elevations in the Swan Valley receive over 100 inches of precipitation annually. The Lindbergh Lake weather station averages 26.8 in/yr and an annual mean temperature of 41.4 °F.

Table 1. Regional climate trends in Swan Valley from weather station data

Weather Station Location	**Distance from the southern valley boundary**	**Annual Mean Temperature**	**Annual Mean Snowfall**	**Annual Mean Precip.**
	(mi.)	(°F)	(in.)	(in.)
Lindbergh Lake	20	41.4	152.2	26.8
Swan Lake	60	42.5	136.3	29.3

Hydrology:

The Swan River drainage basin covers 671 square miles (Leathe and Enk, 1985). The Swan River flows northward to Swan Lake and then to Flathead Lake and has a mean annual discharge of 668 cfs near Bigfork, Montana (USGS, 2001). Numerous ungauged tributaries originating in the Swan and Mission mountain ranges flow into the Swan River along its northward course.

The valley is filled with numerous glacially-formed shallow wetlands and valley lakes. There are over a thousand isolated wetlands in the Swan Valley, 126 are Howellia occupied and 86 suitable but unoccupied habitats. The Flathead National Forest District has been monitoring these wetlands over the last 12 years (Mantas, 2001). All *H. aquatilis* occupied wetlands in the Swan Valley are less than 5 acres in size, except for the Swan River Oxbow (Shapley and Lesica, 1997) and found below an elevation of 5,000 feet in elevation (Mantas, 1998).

There has not been any specific regional groundwater studies of the Swan

Valley. It is assumed that the regional groundwater flow system in the Swan Valley is similar to that of the other intermontane basins in the Northern Rockies and generally mirrors the topography (Toth, 1963; Meyboom, 1967; Fetter, 1994; Rosenberry and Winter, 1997).

Wetland Sites:

All Water Howellia wetlands in the Swan Valley occur in a matrix of coniferous forest (Mantas, 1998). The dominant plant species in the watersheds surrounding the wetlands are ponderosa pine, douglas fir, and lodgepole pine. Cottonwood and aspen trees are located in the phyreatophytic fringe surrounding the wetlands.

A subset of four wetlands were chosen to represent the larger population (126 wetlands) of H. aquatilis inhabited wetlands (Mantas, 2001). Criteria for the selection of study sites were based upon:

1) accessibility (USFS land)
2) general lack of land disturbance in watershed basin
3) viable population of H. aquatilis
4) previous research (Shapley, 1998)

The selected wetlands represent northern and southern regions of the valley as well as east and west slope watersheds within the Swan Valley to capture precipitation and groundwater contrasts within the Swan Valley (Figure 2). The elevation of these wetlands varies between 3520 and 4240 feet AMSL.

Beaver Creek, Condon Group, and Piper Creek wetlands are classified as pothole wetlands which are shallow, marsh-like ponds (Mitsch and Gosselink, 1993). The Holland Lake wetland is classified as a "fen", which is a peat accumulating wetland (Mitsch and Gosselink, 1993). Shapley (1998) surveyed a subset of 31 *H. aquatilis* occupied wetlands in the Swan Valley. He described the Condon (P20) and Piper Creek (P90-91) wetlands as small, steep-sided, elongate pond basins, while the Holland Lake (P76) wetland was described as a large, low-gradient, complex pond basin. The Beaver Creek (P45) wetland was not included in this study.

The Beaver Creek wetland (P45) is a single wetland situated in a closed basin that is on the Swan Valley side of the hydrologic divide between the south flowing Clearwater River and north flowing Swan River drainages (Figure 3). Holland Lake wetland (P76) is a single wetland situated in a closed basin, 1000 feet upgradient from Holland Lake (Figure 3). An outlet on the east side exists when this wetland is at full stage. Condon Group wetlands (P20-23) are multiple wetlands in a large basin, with each of the wetlands located in individual, closed micro-watershed basins (Figure 3). There is a surface water connection between the P20 wetland and P21 wetland. Four of the wetlands in this area are included in the research. The Piper Creek wetlands (P90 and P91) are both located in closed watershed basins (Figure 3). P91 is west and upgradient from the P90 wetland. An outlet exists at the northern end of the P90 wetland when at full stage. Additionally, there are 3 to 4 wetlands immediately downgradient to the north from this wetland.

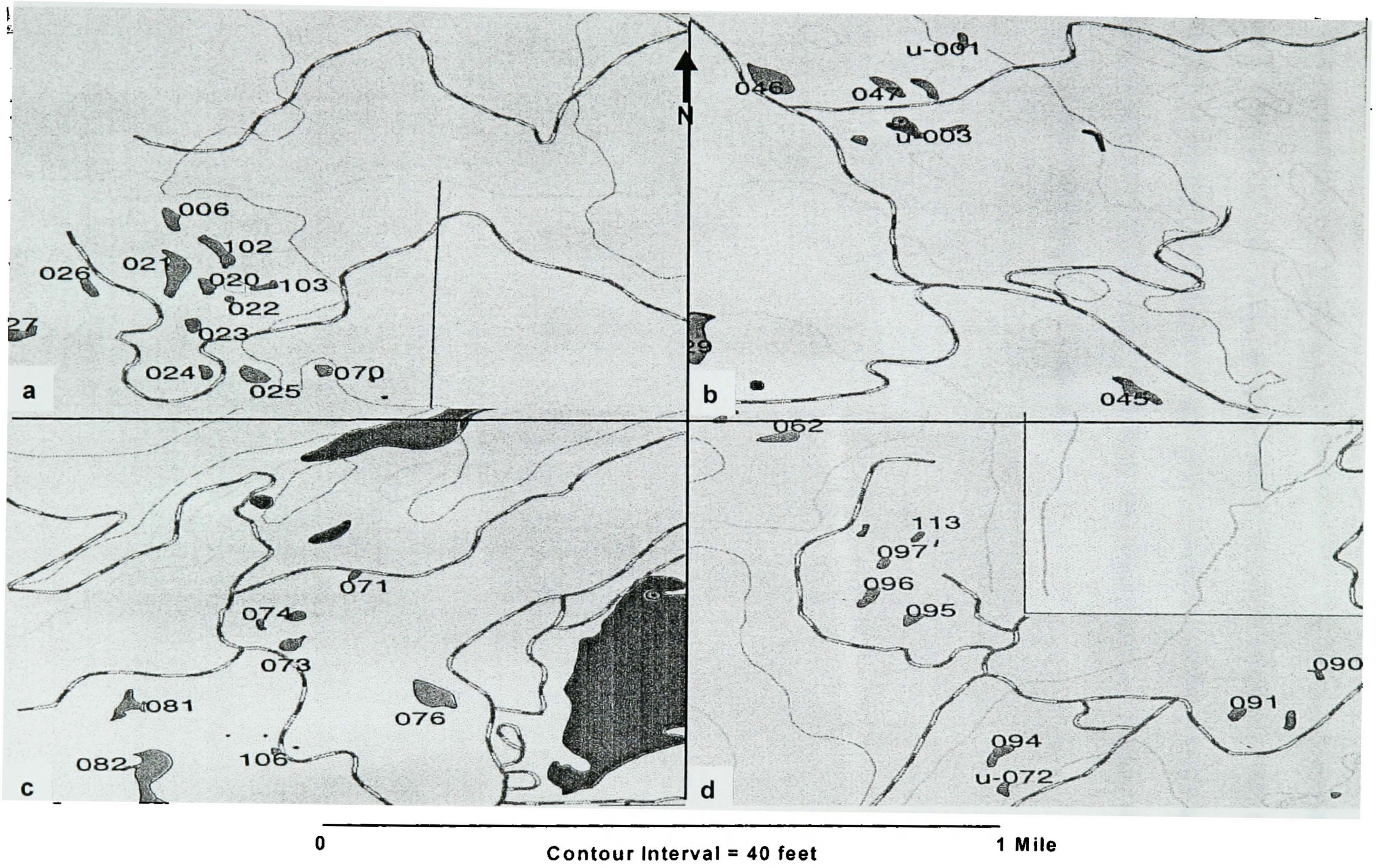


Figure 3 Site maps of individual wetlands. a) Condon Group (P20-23, labeled O20-O23), b) Beaver Creek (P45, labeled O45), c) Holland Lake (P76, labeled O76), and d) Piper Creek (P90-91, labeled O90-O91).

The remainder of this thesis is organized into the following sections: Chapter 2 discusses methodology and instrumentation utilized in this study. Results are presented in Chapter 3 and interpretations of the results and analyses of land use on wetland hydrology are discussed in Chapter 4. Conclusions are presented in Chapter 5.

CHAPTER 2: METHODS AND INSTRUMENTATION

Methods identified the primary source(s) of water to the wetlands, components that drive seasonal variation of water input, and assessed how land use modifications may influence wetland hydrology. Data were collected over two field seasons, 1999 and 2000.

Source and Timing of Water to the Wetlands

Water balances have been a common research tool for hydrologic studies of lakes and prairie-pothole wetlands (e.g. Winter, 1981; Hayashi et. al., 1998; Koerselman, 1989). A water balance approach is extremely useful for identifying the dominant hydrological controls in wetland systems, including their primary source of water (Figure 4).

The measurement of specific water balance components are described once the wetland and watershed morphologies were established. Wetlands were instrumentated with continuous level recorders, staff gauges, precipitation gauges, piezometer nests, monitoring wells in the watershed, floating evaporation pans, seepage meters, and mini-piezometers. A schematic of the Condon (P20) wetland shows the relative locations of instrumentation used to measure water balance components, vertical gradients, and water exchange (Figure 5). Instrument placement for the other three fully instrumented wetlands (P45, P76, and P90) are similar. Contour maps with wetland instrumentation locations are located in Appendix A.

Water Balance for Forested *Howellia* Wetland Systems

Inputs - Outputs +/- Change in Storage (Wetland Volume) = 0

Inputs = Snow Melt, GW Inflow, Precipitation, SW inflow
Outputs = Surface Water Outflow, GW Outflow, Direct Evaporation, Transpiration

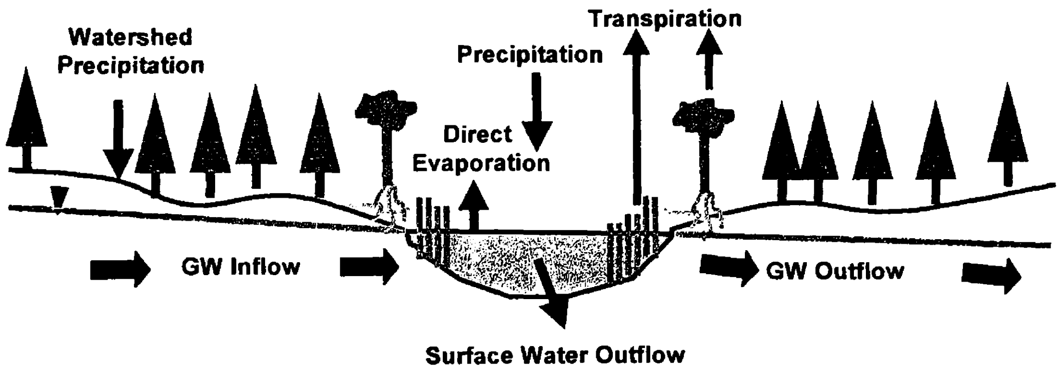


Figure 4. Water balance schematic for *H. aquatilis* inhabited wetlands

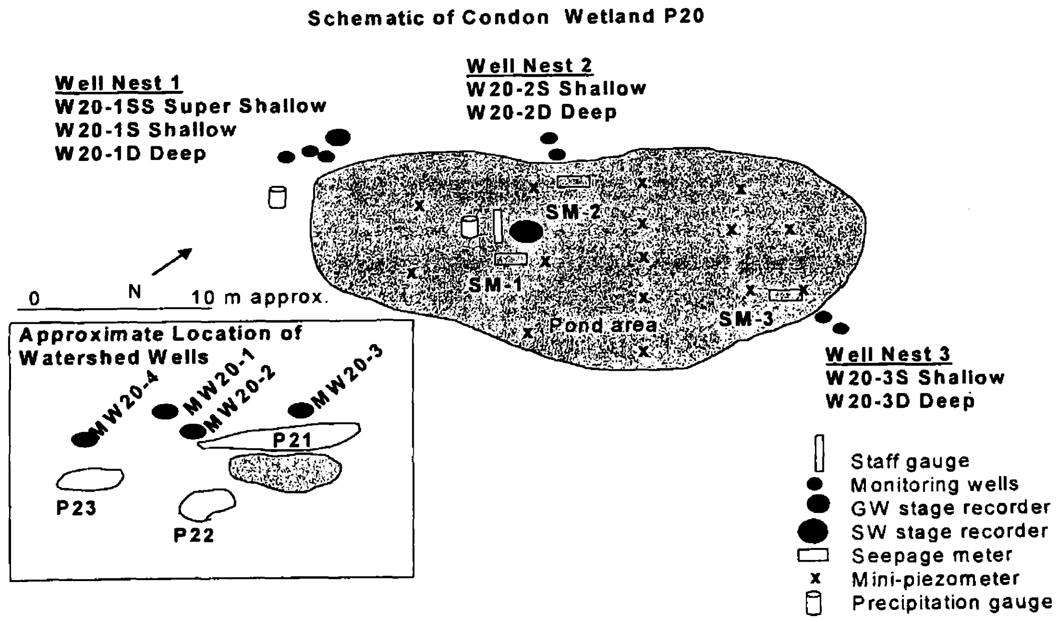


Figure 5. Instrumentation schematic of Condon (P20) wetland

Wetland Morphology:

The morphology of the wetland and the surrounding watershed basin was surveyed using a Leica TC 307 Total Station. These maps were used to compute water volumes associated with the wetland stage and watershed surface area and basin snowpack measurements. The surveying process resulted in at least 200 point measurements within each wetland pond and over 400 point measurements for watershed characterization (Appendix A).

Precipitation Inputs:

Two 8 inch diameter rain gauges, constructed from 1 gallon new paint cans, were used to collect precipitation data. One rain gauge was mounted in the wetland and one was placed in the watershed. A funnel was incorporated into the gauge design to minimize evaporative loss. The direct precipitation inputs for each water balance period were calculated by multiplying the equivalent depth of the precipitation by the area of the wetland. Canopy gauges were used to assess watershed precipitation loading.

In addition to the direct precipitation collected at each of the four wetland research sites, 6 tru-check rain gauges were used by local residents to collect precipitation data from late May 2000 through September 2000. The rain gauges were located throughout the valley, representing east and west slope watersheds and north and south regions of the Swan Valley. Annual mean precipitation and temperature data were also obtained from Lindbergh Lake and Swan Lake weather stations for 1999 and 2000 field seasons (Western Regional

Climate Center, 2001). These data were used to examine precipitation variability in the basin and to compare site specific data with regional precipitation data.

Snow Survey:

In March 2000, a snow survey of watershed snowpack at each of the four wetland watershed basins was performed. The snow water equivalent of the snow pack was converted to be ½ the snow pack depth (Armstrong, 1981). Snow water equivalent was then multiplied by surface area of the wetland basin to determine the available snow melt contribution to the wetlands and their corresponding watersheds (Appendix B).

Wetland Water Volume Changes:

The change in wetland area over time was calculated from wetland stage measurements derived from staff gauge readings and a Stevens Type F continuous level recorder located adjacent to the staff gauge. Volume changes were computed by combining surface area and pond geometry data (Appendix B).

Direct Evaporation:

A floating evaporation pan, constructed from a 14 inch diameter plastic container and located adjacent to the staff gauge, was used to establish direct evaporative loss from the water body. Biweekly, the change in the evaporation pan depth was recorded, adjusted for precipitation input, and combined with surface area data to obtain the volume of water loss to direct evaporation.

Evapotranspiration:

Evapotranspiration was calculated from the continuous surface water hydrographs at each wetland using an equation developed by Meyboom (1967) (Appendix C):

$$ET = Sy(24r +/- \Delta s) \cdot A$$

where Sy = specific yield of wetland, $24r$ = change in wetland stage per day (graphically derived), Δs = difference between wetland stage at the completion of a 24 hour period (graphically derived), and A = surface area of the wetland. Specific yield was assumed to be 1 for the wetland free water surface.

Plant Transpiration:

A plant transpiration component of the water balance was isolated from the evapotranspiration component by subtracting direct evaporation readings from the corresponding evapotranspiration value.

Surface Water Outflow:

No direct overland flow was observed in the wetland watersheds. Thus, direct surface water input was considered to be insignificant as water balance analysis was initiated after snow melt.

Only two wetlands had a surface water outflow component of the water balance, Piper Creek (P90) and Condon (P20). The method of measuring surface water outflow consisted of measuring the width and depth of the outflow channel and multiplying the sum of the width and depth by the water velocity in the channel. The velocity was determined by timing the transport of a floating object over a known distance (Gordon et al., 1992).

Computation of Water Balance

The water balance equation for these forest wetland systems is:

GW inflow + Precipitation - Direct Evaporation - Plant Transpiration - Surface Water Outflow - GW Outflow +/- Δ wetland volume = 0.

Water balances were computed over 2-3 week periods to allow for the separation of dominate hydrological components over time. The calculation of groundwater inflow as a residual from the differences in inputs and outputs in the water balance equation, results in the accumulation of error associated with the quantification of all the other defined water balance components.

Identification of Factors Influencing Seasonal Variation in Water Influx

The use of a water balance approach allows for the gross quantification of the principal sources of water entering and leaving the wetland. However, additional analyses are required to assess how individual watershed and wetland characteristics directly influence wetland response to natural or human induced changes to the watershed basin. Methods for studying groundwater-surface water interaction involve comparing groundwater elevations in shallow wells surrounding the wetland with the stage of the wetland, the determination of in wetland hydraulic vertical gradients using mini-piezometers, and the magnitude, timing, and location of seepage flux.

Groundwater Inflow/Outflow:

Wells in this study were used to establish basin and near pond vertical gradients, to interpret groundwater flow direction, and for collection of water samples for chemical analyses. At each fully instrumented wetland, three well nests consisting of 3/4 inch diameter steel pipe, were driven into the shore. Two of the three nests consisted of two wells completed at depths of approximately 4 and 8 feet, below land surface. The other well nest consisted of three wells finished at depths of approximately 3, 4, and 8 feet (labeled by the well nest number and SS for super shallow, S for shallow, and D for deep). Deeper wells constructed from 3/4 inch diameter PVC, ranging from 8 to 18 feet, were drilled in the watershed at each of the four wetland sites with the use of a truck-mounted Geoprobe unit. For the specifications of all wells, refer to Appendix D.

Geochemistry:

Water samples were collected from the shallow groundwater, wetland surface water, deeper wells in the watershed, and five domestic wells near the Beaver Creek and Holland Lake sites according to standard methods (Appendix E). Samples were analyzed for Al, As, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, S, Si, Sn, Sr, Ti, V, and Zn using an ICP-ES (inductively coupled plasma emission spectroscopy) (Martin et al., 1994) and Cl, F, NO_3, PO_4, and SO_4 using an automated ion chromatograph (Pfaff, 1993). A full round of water samples was taken on September 18, 1999, June 15, June19, and August 16, 2000.

Specific conductance (Hach mini-conductivity meter, model 17250) and pH (Orion model 250A pH meter) of the wetland surface water was measured as part of the bi-weekly data collection process using standard methods.

Additionally, specific conductance and pH was measured for each collected water sample during the 2000 field season. Alkalinity, calculated via volumetric titration, was also determined for each water sample collected during the 2000 field season (Langmuir, 1997). These data were used to examine if a local or regional groundwater source could be identified as well as to examine if ionic constituents were being concentrated due to wetland evaporative losses.

Mini-Piezometers and Seepage Meters:

Vertical hydraulic gradients within the wetland sediment were measured using mini-piezometers constructed from ½ inch diameter electrical conduit (Lee and Cherry, 1978). Seepage meters adjacent to the mini-piezometers constructed from 5 gallon plastic drums were used to measure water exchange through the wetland and to compute vertical hydraulic conductivity values (Lee and Cherry, 1978).

Watershed Hydrogeologic Properties:

To investigate the physical and hydrologic properties of the watershed and wetland sediment, soil pits were dug in the watershed and wetland at all of the research sites. Sediment samples from the watershed were taken from approximately 3-4 feet below land surface. The watershed sediment samples were used for permeameter tests (Fetter, 1995). Cores taken from the wetland were used for permeameter tests and were cut in half for visual inspection. In addition, slug falling-head tests were conducted on selected wells in the field. These data were used to examine the role of local groundwater flow in the supporting the observed wetland cycle.

Land Use Modifications and Influences on Wetland Hydrology

Once the dominant hydrological components and seasonal controls on wetland hydrology are resolved, an analysis of the effects of hypothetical land management alterations on the wetland hydrology was examined.

The watershed of the Swan River is densely forested and has undergone periods of timber harvest and natural modification by fire. The potential affect of timber harvesting on changes in water yield to the local wetland systems was assessed using the WRNSHYD (WReNSs HYDrology) modeling program (Minister of Supply and Services, 1989). The WRNSHYD model carries out all of the graphical lookup and bookkeeping required to use the hydrology section (Chapter 3) of the WRENSS (An Approach to Water Resources Evaluation of Non-point Silvicultural Source) procedural handbook (US EPA, 1980). Input parameters of the model include area of watershed basin, aspect, monthly precipitation averages, tree type, absense/presence of snow scouring, basal area of trees, total area of clearcut, roughness of possible cut, width of cut block, and area of cut block. The modeling will allow examination of the effects of fire and logging on the annual water yield from a typical Swan Valley watershed. Modeling results will then be used to suggest how changes in micro-basin water yield may affect Water Howellia's ability to survive and reproduce.

CHAPTER 3: RESULTS

This section identifies the primary source of water to the wetlands, controls on seasonal variation in water input, and how land management decisions may influence wetland hydrology.

Source and Timing of Water to the Wetlands

Regional Climatic Data:

Annual mean temperature, mean snow fall, and annual mean precipitation from Lindbergh Lake and Swan Lake weather stations are presented in Table 1. These climatic parameters were averaged from historic data, collection of which began in the late 1940's to early 1960's. Precipitation data from the weather stations indicate that total precipitation for 1999 ranged from 83-87% of normal according to historic averages. The annual temperature was slightly higher as the Lindbergh Lake weather station reported a 1.5 °F increase in mean annual temperature for 1999. Complete data were not available for 2000, however, precipitation was reported regionally as below normal.

Precipitation data from the closest volunteer location to each wetland was compared with rain gauge data collected at the nearest wetland (Tables 2-5). Although the precipitation amounts at the volunteer and wetland locations are similar, the differences suggest localized climatic variations occur. Precipitation data for all volunteers are listed in Appendix B.

Table 2. P20 wetland precipitation values versus volunteer precipitation data

Time Period	Swan Ecosystem Center	Condon (P20)
	elev. 3650 ft ppt (in.) 2 mi. SW of P20	elev. 3720 ft. ppt (in.)
6/20-07/07	1.98	1.53
07/07-07/25	0.00	0.00
07/25-08/16	0.15	0.08
08/16-09/21	0.98	1.41
Total PPT	3.10	3.02

Table 3. P45 wetland precipitation values versus volunteer precipitation data

Time Period	Terillion-Pierce Lake	Beaver Creek (P45)
	elev. 4300 ft. ppt (in.) 1.5 mi E of P45	elev. 4240 ft. ppt (in.)
07/19-07/27	0	0
07/27-08/16	0.06	0
08/16-09/21	0.93	1.06

Table 4. P76 wetland precipitation values versus volunteer precipitation data

Time Period	Erickson-Holland Creek	Holland Lake (P76)
	elev. 4000 ft. ppt (in.) ½ mi S of P76	elev. 4080 ft. ppt (in.)
06/23-07/10	0.69	0.78
07/10-08/01	0	0
08/01-08/16	0.09	0
08/16-09/13	0.54	0.61
Total PPT	1.32	1.39

Table 5. P90 wetland precipitation values versus volunteer precipitation data

Time Period	Grant-Salmon Prairie	Piper Creek (P90)
	elev. 3500 ppt (in.) 5 mi. S of P90	elev. 3520 ft. ppt (in.)
06/20-06/29	0.28	0.27
06/29-07/10	0.94	0.8
07/10-07/17	0	0
07/17-07/27	0	0.08
07/27-08/01	0	0
08/01-08/16	0.07	0.12
08/16-09/13	0.985	1.14
Total PPT	2.28	2.41

Water Balance Results:

Water balance measurements were collected during both 1999 and 2000 field seasons. Tables 6 and 7 show water balance results for Condon (P20) and

Table 6. Condon (P20) wetland water balance results

Date	Water Balance Period	Precipitation	Evaporation	Transpiration	SW Outflow	Pond Volume	Net GW Inflow	Net GW Inflow Rate
	(days)	(ft^3)	(ft3)	(ft3)	(ft3)	(ft3)	(ft3)	(ft3/day)
04/30/00-05/16/00	16	500	900	2300	25200	-8300	19600	1200
05/16/00-05/23/00	7	60	800	1700	13000	-1500	12000	1700
05/23/00-06/20/00	28	3600	2400	11400	1300	-3000	16900	600
06/20/00-07/07/00	17	2000	2000	3200	2600	-3000	2400	100
07/07/00-07/25/00	18	0	2600	3000	2800	-7500	900	50
07/25/00-08/16/00	22	0	1800	5400	700	-7600	300	10

Table 7. Beaver Creek (P45) wetland water balance results

	Water Balance				Change in	Net GW	Net GW
Date	Period	Precipitation	Evaporation	Transpiration	Pond Volume	Inflow	Inflow
	(days)	(ft3)	(ft3)	(ft3)	(ft3)	(ft3)	(ft3/day)
06/01/00-06/23/00	22	5900	9100	37500	-15400	25300	1200
06/23/00-07/19/00	26	3200	10600	41500	-28400	20500	800
07/19/00-07/27/00	8	0	3600	14000	-10000	7600	900
07/27/00-08/16/00	20	0	4900	21700	-15600	11000	600

Beaver Creek (P45) wetlands. Water balances for the other two wetlands are similar (Appendix B). Plant transpiration, groundwater inflow and surface water outflow (when present) are the dominant hydrological controls in these wetland systems from spring through early fall. Values for these hydrological controls are an order of magnitude higher than the other water balance components. Groundwater inflow and plant transpiration outputs declined over the water balance period at all wetlands (Tables 8-11). Although plant transpiration rates increased from spring to early fall, total plant transpiration water loss decreased due to the decline in wetland stage and associated water table position. Though discharge estimates of surface water outflow were small (7.3×10^{-4} to 1.8×10^{-2} cfs), total seasonal surface water discharge was significant in wetlands with surface outflow.

Table 8. Groundwater inflow and plant transpiration rates for P20 wetland

Water Balance	GW Inflow	Transpiration
Period	(ft3/day)	(ft3/day)
04/30/00-05/16/00	1200	100
05/16/00-05/23/00	2000	200
05/23/00-06/20/00	300	400
06/20/00-07/07/00	200	200
07/07/00-07/25/00	50	200
07/25/00-08/16/00	10	200

Table 9. Groundwater inflow and plant transpiration rates for P45 wetland

Water Balance	GW Inflow	Transpiration
Period	(ft^3/day)	(ft^3/day)
06/01/00-06/23/00	1100	1700
06/23/00-07/19/00	800	1600
07/19/00-07/27/00	600	1400
07/27/00-08/16/00	600	1100

Table 10. Groundwater inflow and plant transpiration rates for P76 wetland

Water Balance	**GW Inflow**	**Transpiration**
Period	(ft^3/day)	(ft^3/day)
05/16/00-05/23/00	1500	1300
05/23/00-06/23/00	2800	3200
06/23/00-07/10/00	1700	2500
07/10/00-08/01/00	-200	700

Table 11. Groundwater inflow and plant transpiration rates for P90 wetland

Water Balance	**GW Inflow**	**Transpiration**
Period	(ft^3/day)	(ft^3/day)
04/08/00-04/30/00	3100	100
04/30/00-05/14/00	3400	600
05/14/00-05/23/00	500	800
05/23/00-06/20/00	500	700
06/20/00-06/29/00	200	500
06/29/00-07/10/00	300	600
07/10/00-07/17/00	50	400
07/17/00-07/27/00	200	500
07/27/00-08/01/00	100	300
08/01/00-08/16/00	100	300

Water Balance Error Analysis:

Although water balances are a common tool in studying lakes and wetlands, it is important to try to quantify an error in values for each component in the water balance equation. Major influences affecting rain gauges and their precipitation measurements include wind, evaporation, and height above ground. Each rain gauge was approximately 40 inches above ground, and depending on wind patterns, an error of +/- 5 to 15 % can be expected for long term data (Winter, 1981). It is expected that wind patterns did not heavily influence rain gauges due to the forest canopy surrounding the wetlands, minimizing introduced error in precipitation measurements. A +/- 5% error was used in the error analysis.

Floating evaporation pans are considered a direct measurement of evaporation and it is not possible to quantify an error since no other measurements of evaporation were performed. However, literature suggests a range of +/- 10 to 15% error (Winter, 1981). Due to lack of windy conditions, a +/- 10% was used for floating evaporation pan values.

Evapotranspiration calculations using Meyboom's analysis of surface water hydrographs can have significant error (Meyboom, 1967). Although the surface water charts are extremely accurate , +/- 0.01 feet, determining the slope of the diurnal curves has some inherent error resulting from slope placement as the shape and size of the curves vary. Though the slope of the curves was taken near or at 6 am each morning, it was difficult to replicate each hydrograph measurement. The difference in evapotranspiration measurements on the hydrographs due to interpreted slope was typically 0.01 foot or less. Multiplying +/- 0.01 feet to the surface area of each wetland resulted in a mean error of +/- 20%.

Determination of wetland stage involved using the staff gauge to measure to the nearest 1/16 of a foot. The wetland basin was intensively surveyed with state of the art surveying equipment. Error analyses of the survey indicate that instrument elevation error was 0.1 feet at Holland Lake (P76) and 0.002 feet at Condon Group (P20-23), Beaver Creek (P45), and Piper Creek (P90). Due to the difficulty in capturing the exact morphology of the wetland, a 10% error was assigned for the change in wetland volume (storage) component of the water balance.

Significant error could have occurred during measurement of surface water outflow by assuming a constant channel width, depth, and velocity. The surface water outflow was taken at the start of the water balance period and at the end of the water balance period. An average value for surface water outflow was calculated for these two measurements. An average from two periods of time is not as accurate as the mean of several measurements during a water balance period to describe the variability in surface water discharge. Additionally, a float test is not the most accurate way to measure surface water discharge due to velocity differences between the top and bottom of the outlet. Due to these factors, a 50% error was assigned to surface water outflow values.

The determination of groundwater inflow from a difference in water balance components results in the accumulation of error from all of the other water balance components (Table 12). Propagated error assigned to the groundwater inflow component was calculated from the error estimates for all of the other water balance components using the formula $(\Delta\text{groundwater inflow})^2 = (\Delta\text{precipitation})^2 + (\Delta\text{pond volume})^2 + (\Delta\text{evaporation})^2 + (\Delta\text{plant transpiration})^2 + (\Delta\text{surface water outflow})^2$ (Wolfs, 2001). Surface water outflow was assigned the largest error. Surface water outflow only occurred early at the Condon and Piper Creek wetland sites for part of the measurement period. Consequently, error for groundwater inflow is much smaller in the wetland sites that did not experience an outflow of surface water (Beaver Creek and Holland Lake). Examples of water balance component values with associated error estimates are given for Condon and Beaver Creek Creek wetlands (Figures 6 and 7).

Table 12. Error estimates for water balance components

Water Balance Component	**Error**
Precipitation	+/-5%
Change in Wetland Volume	+/-10%
Direct Evaporation	+/-10%
Surface Water Outflow	+/-50%
Plant Transpiration	+/-20%
Groundwater Inflow (no SW outflow)	**+/-25%**
Groundwater Inflow (w/SW outflow)	**+/-55%**

Snow Survey Results:

Snow surveys of the wetland watershed basins were conducted in early March to determine if significant water is available within the local wetland basin to sustain pond hydrology. Results for Beaver Creek (P45) and Condon (P20) indicate that if a minimal infiltration rate of 10% is assumed, localized basin recharge from snow melt is adequate to sustain the seasonal water demands of the localized groundwater flow systems associated with the P20 and P45 wetlands (Tables 13 and 14). Snow survey results for the other wetlands are given in Appendix B.

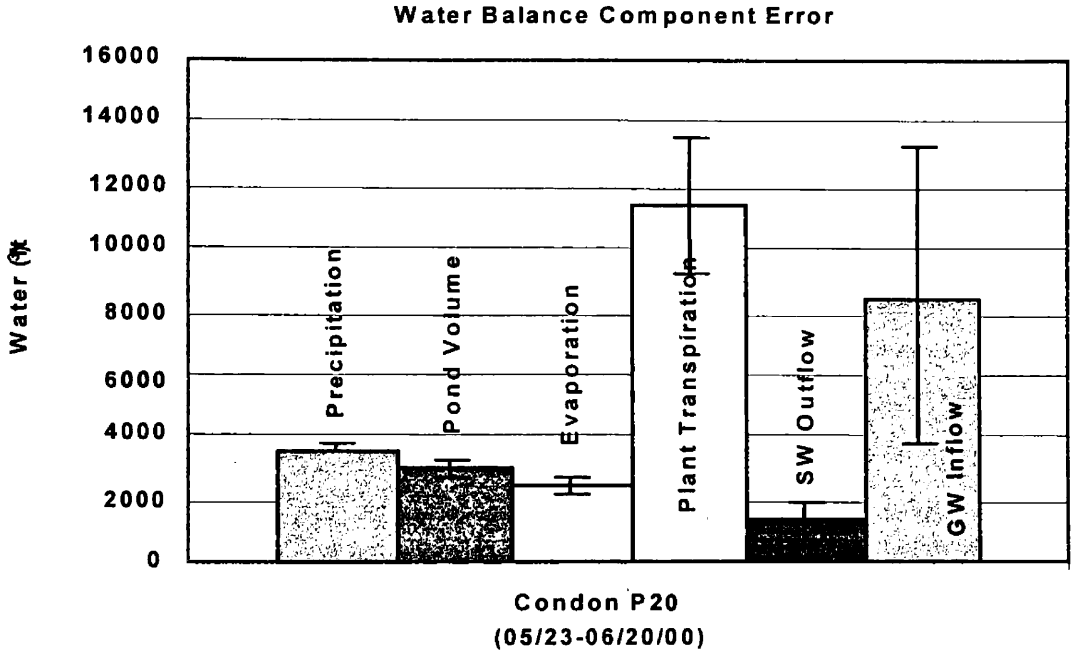


Figure 6. Condon (P20) water balance component values and associated error

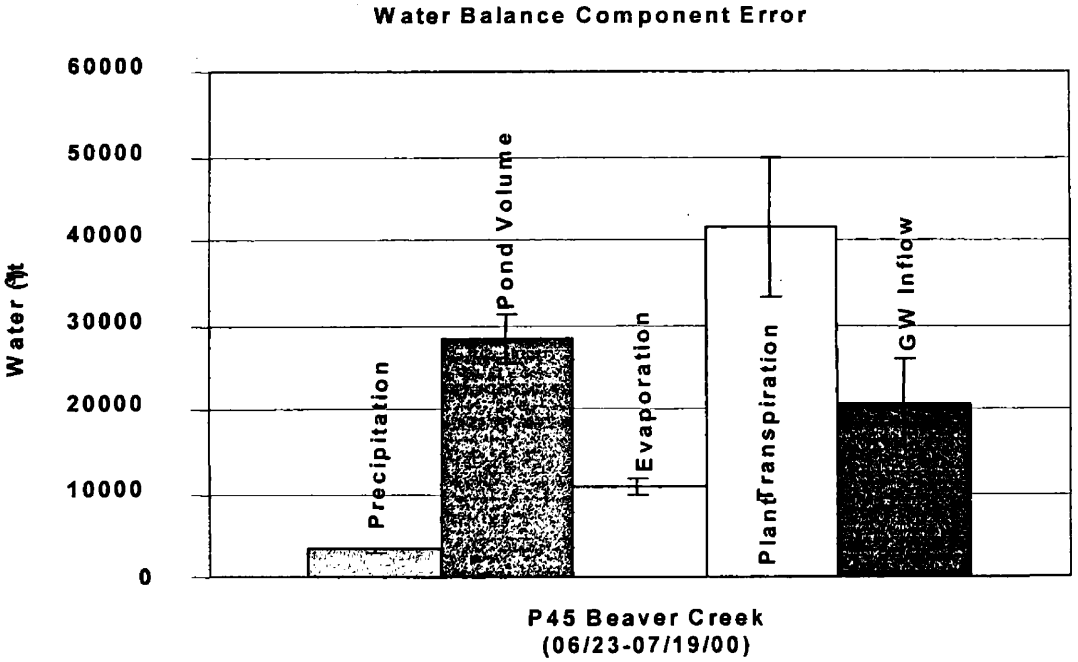


Figure 7. Beaver Creek (P45) water balance component values and associated error

Table 13. Annual water balance for P20 wetland including snow survey

Parameter Assumptions	Snow Input	Precipitation (4/30-8/16)	Net GW Inflow (4/30-8/16)	Evapotranspiration (4/30-8/16)	SW Output (4/30-8/16)	Water Surplus
	ft^3	ft^3	ft^3	ft^3	ft^3	ft^3
10% snow melt infiltration in watershed, 100% in wetland	328100	8000	46300	37500	45900	206500
15% snow melt infiltration in watershed, 100% in wetland	357200	8000	46300	37500	45900	235600
20% snow melt infiltration in watershed, 100% in wetland	386300	8000	46300	37500	45900	264600
30% snow melt infiltration in watershed, 100% in wetland	444400	9800	46300	37500	45900	324600
40% snow melt infiltration in watershed, 100% in wetland	502600	9800	46300	37500	45900	382700

Table 14. Annual water balance for P45 wetland including snow survey

Parameter and Assumptions	Snow Input	Precipitation	Net GW Inflow (6/1-8/16)	Evapotranspiration (6/1-8/16)	Surplus Water
	ft3	ft3	ft3	ft3	ft3
10% snow melt infiltration in watershed, 100% in wetland	754800	117500	61600	37500	773200
15% snow melt infiltration in watershed, 100% in wetland	832200	117500	61600	37500	850600
20% snow melt infiltration in watershed, 100% in wetland	909500	117500	61600	37500	928000
30% snow melt infiltration in watershed, 100% in wetland	1064300	117500	61600	37500	1082700
40% snow melt infiltration in watershed, 100% in wetland	1219000	117500	61600	37500	1237400

Water Chemistry:

Three rounds of water sampling were conducted over the period of this study. Overall, the ionic concentrations in the shallow groundwater and surface water of these wetlands is very low (Tables 15 and 16). The wetland surface chemistry and shallow groundwater is calcium bicarbonate dominated with lesser concentrations of potassium, magnesium, manganese, sodium, and fluoride.

Water chemistry of the wells on the shoreline of the wetlands (i.e. W20-2D) and surface water (i.e. SW20) are similar for all wetland systems (Tables 15 and 16, Appendix E). Calcite was the only mineral that was over-saturated in some of the shallow and deeper groundwater samples. Over-saturated calcite may be precipitated in the wetland, decreasing its concentration in the wetland surface water. An average error of +/-5% was calculated for ionic concentrations from water samples collected from the P20 wetland on 5/23/00. Deeper wells driven into the deeper portion of the watershed groundwater flow system (i.e. MW20-3) have higher ionic concentrations than shallow groundwater and surface water samples. The different chemical signatures from the deeper wells are similar to chemistry results from domestic wells (DW-1), indicating a more regional groundwater source.

Results from bi-weekly measurements of specific conductance and pH for Condon (P20) and Beaver Creek (P45) wetlands are shown in Figures 8 and 9. Values for both pH and specific conductance are seasonally variable. The

Table 15. Water chemistry results for Condon Group wetlands 8/16/00. All concentrations are in mg/l

Sample Name	Depth Below	Ca	K	Mg	Mn	Na	S	F	Cl	SO_4	Alkalinity	Specific	
Practical Quantifiable Limit (mg/L)	***Water Table (ft)***	***0.07***	***0.1***	***0.05***	***0.0003***	***0.18***	***0.007***	***0.1***	***0.1***	***0.5***	**(mg/l)$CaCO_3$**	**Conductance (mcromhos/cm)**	**pH**
Field Blank		<0.05	<0.5	<0.1	0.0014	<0.05	0.0037	<0.1	<1	<0.5			
P20-SW	surface water	9,822	2.626	3.193	0.0277	1.779	0.234	<0.1	1.01444	<0.5	87	92	7.41
P21-SW	surface water	3,603	2.342	2.278	0.0158	1.085	0.2454	<0.1	<1.0	<0.5	31	80	6.41
P22-SW	surface water	4,306	2.446	1.221	0.008	0.9931	0.241	<0.1	<1.0	<0.5	33	50	6.80
W20-1D	3.65	4.521	0.8689	1.438	0.3833	1.143	0.2591	<0.1	<1.0	<0.5	35	110	6.73
W20-2D	3.35	7,144	1.463	1.909	0.635	1.496	0.1946	0.687803	1.42728	<0.5	47	110	6.75
W20-3S	1.12	6,242	1.172	2.322	1.401	1.188	0.2205	0.423977	<1.0	<0.5	47	120	6.36
W20-3D	4.75	8,565	1.092	3.382	0.3192	1.75	0.2614	<0.1	<1.0	<0.5	53	120	5.84
MW20-1	4.13	62.94	11.16	20.01	1.703	8.245	2.264	0.89	4.13	1.93	265	520	7.25
MW20-2	0.20	77.34	7.281	29.25	5.497	13.21	2.671	0.29	4.26	5.07	255	520	7.43
MW20-3	4.68	61.69	10.11	18.25	0.6658	10.62	4.646	0.69	6.18	5.38	317	600	7.35

Table 16. Water chemistry results for Beaver Creek wetland including domestic wells (DW1-DW3). All concentrations are in mg/l

Sample	Depth Below	Ca	K	Mg	Mn	Na	S	F	Cl	SO$_4$	Alkalinity	Specific	
Practical Quantifiable Limit (mg/L)	**Water Table (ft.)**	***0.070***	***0.100***	***0.050***	***0.000***	***0.180***	***0.007***	***0.10***	***0.10***	***0.50***	**(mg/l) CaCO3**	**Conductance (micromhos/cm)**	**pH**
Field Blank		<0.05	<0.5	<0.1	0.0014	<0.05	0.0037	<0.1	<1	<0.5			
P45-SW	surface water	10.770	1.326	3.739	0.007	1.264	0.452	<0.1	<1.0	0.50	47	84	6.96
SM-5	seepage meter	11.06	0.809	3.52	0.0015	1.073	0.2746	<0.1	<1.0	<0.5	64.4	100	6.95
W45-1D	4.7	13.150	<0.5	4.657	0.175	1.725	0.467	0.37	1.07	<0.5	80	180	6.07
W45-2D	3.46	19.77	1.900	7.897	0.7483	2.465	0.3915	0.687803	1.42728	<0.5	100.8	200	6.93
MW45-3	6.49	40.38	0.963	11.45	0.1412	1.378	1.121	0.108576	<1.0	2.53582	152.4	300	7.55
MW45-4	7.58	46.24	1.512	13.67	0.0749	1.827	1.194	0.263664	<1.0	2.64688	184.4	320	7.53
MW45-5	7.67	75.01	2.336	22.39	0.7841	3.821	0.919	0.328295	1.63801	0.813396	268.8	500	7.04
MW45-6	6.74	19.250	4.475	5.479	0.402	2.182	2.187	<0.1	1.68272	5.4503	103.2	240	6.95
DW-1	unknown	11.88	2.126	19.92	0.0007	3.784	0.6782	0.300514	1.1613	2.04692	125	240	7.55
DW-2	unknown	37	1.102	15.39	0.0114	7.344	0.7454	0.163704	<1	1.74313	185	350	7.52
DW-3	unknown	40.38	1.571	24.95	0.0004	5.853	1.122	0.170114	1.09961	2.95155	245	420	7.45

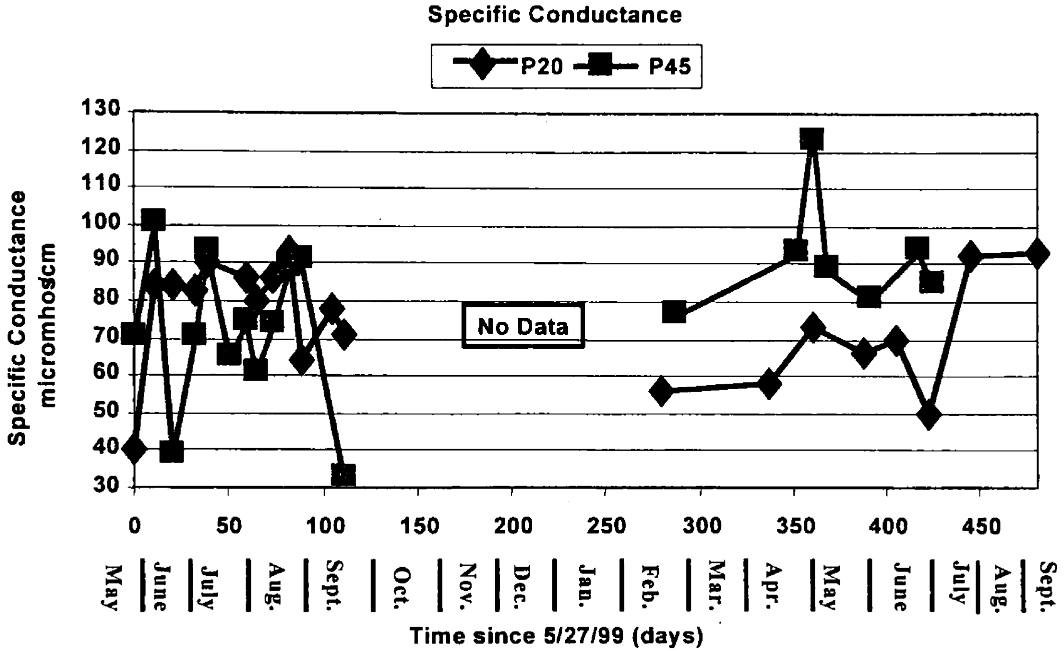


Figure 8. Specific conductance values for Condon Group wetlands

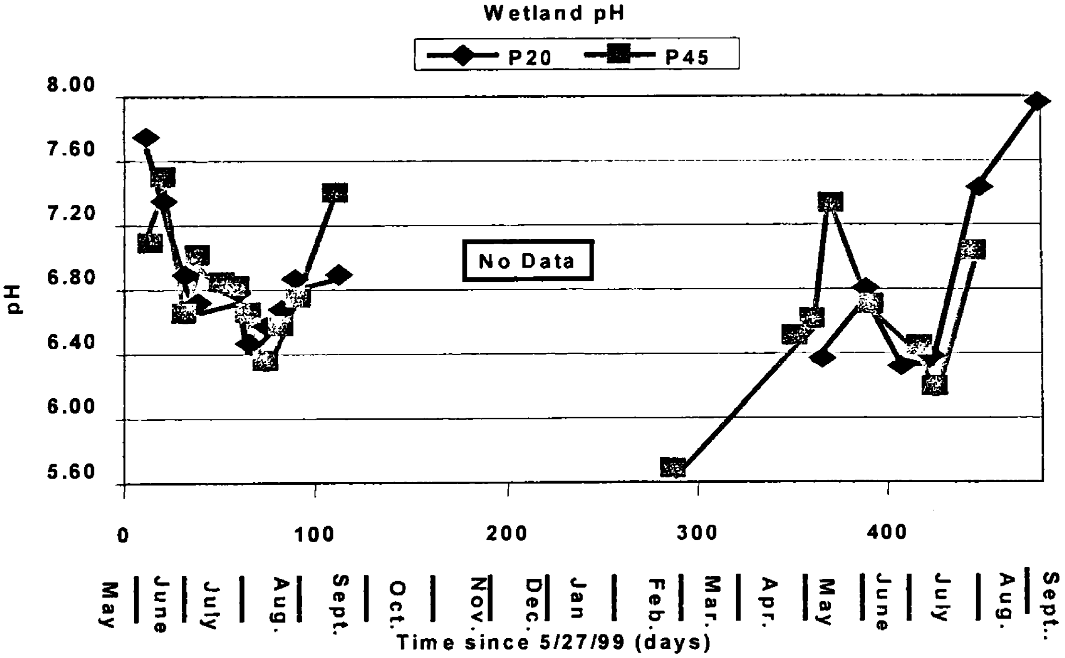


Figure 9. pH trends for Condon Group wetlands

lowest specific conductance values for all wetlands were generally measured in the early spring, during snow melt inputs. Specific conductance values were variable during the summer period, with a slight increase measured during periods just prior to total wetland dessication. Though wetland pH values for all wetlands were seasonally variable, ranging from 5.62 to 7.97, no distinct trends were observed.

Hydrological Controls of Wetland Sediment and Watershed Till:

Physical and hydrological properties of the wetland sediment and watershed till matrix control the amount and rate of groundwater recharge, and the rate and quantity of groundwater/surface water exchange in the wetlands. Many of the Howellia inhabited wetland depressions are shallow, undrained, and are probably kettles formed from ablation till. Shapley and Lesica (1997) estimate that in the Swan Valley about 60% of the H. aquatilis sites are underlain by valley-facies till deposited by the northward-flowing Swan Valley Glacier, 5% are underlain by valley-facies till of the south-flowing Clearwater Glacier, and about 25% by deposits of tributary alpine glaciers. The remainder of the Howellia sites are underlain by discontinuous or lesser known lithologies.

Grain-size analyses of the watershed till matrix suggest that the sediment is coarse-grained as the gravel and coarse sand fraction ranges from 75-87% by weight (Table 17). These numbers are misleading as the degree of sorting and its influence on water movement is not presented. The glacial till of the watershed basins is a diamicton, representing poorly sorted sediment that contains a coarse-grained fraction in a fine-grained matrix. The fine-grained matrix limits hydrologic flow and the gravel size fraction creates locations in the till that are impermeable to water, reducing hydraulic conductivity.

Table 17. Grain-size distribution of watershed sediment

Grain Size	P20	P45	P76	P90
	% by wt	% by wt	% by wt	% by wt
gravel	45.78	41.27	47.48	43.87
coarse sand	36.37	45.83	28.77	39.92
fine sand	3.65	4.88	2.49	0.41
silt	14.00	7.93	20.98	15.66
clay	0.19	0.09	0.28	0.13

Hydraulic conductivity of the wetland sediment and watershed till was estimated from permeability tests using wetland sediment cores and surrounding watershed till samples (Fetter, 1995), falling-head slug tests, seepage meter flux data coupled with vertical gradients from mini-piezometers (Lee and Cherry 1978), and published values (Fetter, 1995) (Tables 18 and 19). Specifics on all site characterization tests are in Appendix G. Hydraulic conductivity estimates for the watershed till matrix range from 1 x 10^{-06} to 5 ft/d Tables (18-20). Permeameter tests of the watershed till indicate that the till in Condon, Holland Lake and Piper Creek wetlands have similar hydraulic conductivity values ranging from 1 x 10^{-2} to 8 x 10^{-3} ft/d. A higher sand fraction percentage in the top layer of till at the Beaver Creek wetland resulted in higher hydraulic conductivity estimates (3 to 5 ft/d) from permeameter tests. However, falling head slug tests for the Beaver Creek wetland resulted in low hydraulic conductivity values (1 x 10^{-4} to 1 x 10^{-6} ft/d), indicating the presence of low permeability layers below the top sandy-silt layer.

Physical properties of the wetland sediment including description and depth of sediment zones and organic carbon content are listed in Table 20. Wetland sediment in wetlands, P20, P45, and P90 contain an organic horizon ranging from 10-12 inches in thickness underlain by a silty-sand or clayey zone. The organic layer in the P76 wetland was continuous to 40 inches. Permeameter tests of the wetland sediment cores (Table 19) indicate low vertical hydraulic conductivity values for all wetland sites (1.8×10^{-01} to 5.9×10^{-02} ft/d). The clayey layer present in the Condon, Holland Lake, and Piper Creek wetlands probably limits groundwater exchange rates in the wetlands. Shapley and Lesica (1997) have also described a clayey layer in other *H. aquatilis* wetlands in the Swan Valley.

Hydraulic conductivity estimates were also estimated using groundwater flux from the water balance, vertical gradients, and wetland surface areas for P20 and P45 wetlands (Table 21). The hydraulic conductivity estimates based on groundwater flux are 1 to 4 orders of magnitude higher than hydraulic conductivity estimates from permeameter and falling-head tests, indicating the presence of zones of higher hydraulic conductivity and/or secondary permeability (fractures) in the watershed till. Although fractures were not observed in shallow pits dug into the watershed till, fractures have been commonly observed in glacial till (Grisak et. al., 1975; Grisak et al., 1976; Hendry, 1982; Keller and Kamp, 1988). If fractures or higher hydraulic conductivity zones are present in these low permeability wetland systems, they would control groundwater/surface water exchange and the amount and rate of groundwater recharge.

Other evidence of zones of higher hydraulic conductivity or secondary

Table 18. Published hydraulic conductivity estimates for geologic materials (Fetter, 1994)

Geologic Material	**k (ft^3/d)**	**k (ft^3/d)**
clay	3.40E-05	3.40E-02
silt, sandy silts, clayey sands, glacial till	3.40E-02	3.40E+00
silty sands, fine sands	3.40E-01	3.40E+01

Table 19. Hydraulic conductivity estimates of the watershed and wetland sediment for all sites

Method	**P20**		**P45**		**P76**		**P90**	
	min (ft/d)	max (ft/d)	min (ft/d)	max (ft/d)	min (ft/d)	max (ft/d)	min (ft/d)	max (ft/d)
Permeameter Test-Wetland Sediment (k_v)	no data	no data	5.00E-02	1.80E-01	2.79E-02	5.90E-02	2.72E-02	4.29E-02
Permeameter Test-Watershed Sediment (k_v)	7.82E-03	8.63E-03	3.70E+00	5.37E+00	1.06E-02	2.79E-02	7.02E-03	1.20E-02
Slug Falling-Head Tests (k_v)	7.40E-05	2.17E-03	1.33E-06	1.43E-04	4.89E-06	7.05E+00	7.82E-04	1.08E-03
Seepage Meter Flux/Grad. (k_v)	9.22E-03	1.93E-01	9.59E-04	1.49E-02	5.32E-02	1.50E-01	7.69E-04	1.38E+01

Table 20. Physical properties of wetland sediment

Wetland	**Zone**	**Depth**	**Bulk Density**	**Organic Carbon**
		(in.)	g/cm3	%
P20	Organic	0 to 12	0.36	19
	Clay	12 to 20	0.55	11
	Gravel/Clay Matrix	20+	na	na
P45	Organic	0 to 10	0.11	69
	Sand	10 to 30	0.92	4
	Gravel/Sand Matrix	30+	na	na
P76	Organic 1	0-18	0.15	na
	Organic 2	18+	0.16	na
P90	Organic	0 to 11	0.15	74
	Clay	11 to 20	0.45	20
	Gravel/Clay Matrix	20+	na	na

permeability are higher hydraulic conductivity values estimated from seepage flux and falling-head tests. Seepage meters in Piper Creek during the 2000 field season, specifically SM90-2 and SM90-11, had high hydraulic flux values ranging from 1 x 10^{-01} to 12 $ft^3/d/ft^2$. During slug falling-head tests in the field, W76-2D had a hydraulic conductivity estimate of 7 ft/d, which was 3-4 orders of magnitude higher than any other k estimates using falling-head tests. Additionally, during chemistry sampling results, wells W76-2D and W20-3D, were the only wells that it was not possible to pump dry.

Table 21. Hydraulic conductivity estimates from groundwater flux

Wetland	Time Period	Days	Area	GW Inflow	Hydraulic Flux	Gradient	Hydraulic Conductivity
			ft2	ft3	ft3/d/ft2		ft/d
P20	05/16/00-05/23/00	7	17200	14400	1.E-01	0.3	4.E-01
P20	05/23/00-06/20/00	28	16700	8500	2.E-02	0.2	9.E-02
P20	06/20/00-07/07/00	17	16100	2800	1.E-02	0.15	7.E-02
P45	06/01/00-06/23/00	22	57600	25200	2.E-02	0.15	1.E-01
P45	06/23/00-07/19/00	26	52800	20500	1.E-02	0.05	3.E-01
P45	07/19/00-07/27/00	8	41500	5000	2.E-02	0.03	5.E-01

Controls on Seasonal Variation in Water Input

It has been observed over two field seasons that at *H. aquatilis* occupied wetland re-establishment begins in the spring and dessication occurs in the fall. The size of each wetland, specifically surface area and volume, at full-stage is given in Table 22. The four wetlands did not have a higher stage in 2000 than in 1999, even though the 2000 stage readings were measured earlier in the year (March) than the stage readings in 1999 (May). At full stage, surface water outflow exists at Holland Lake, Piper Creek and Condon wetlands, such outlet would limit maximum stage.

Table 22. Wetland surface area and volume at full stage for 1999 and 2000 field seasons

Wetland	Field Season	Surface Area	Volume
		(ft^2)	(ft^3)
Condon (P20)	1999	18,200	35,000
	2000	18,400	39,500
Beaver CreeK (P45)	1999	57,100	72,700
	2000	60,100	82,300
Holland Lake (P76)	1999	96,100	73,600
	2000	103,800	106,600
Piper Creek (P90)	1999	15,700	20,600
	2000	22,400	32,800

Potentiometric maps of the Condon Group (P20-23) were constructed from water level data collected on 6/20/00 and 8/16/00 (Figures 10 and 11). Unlike the Condon Group wetlands, the other three wetlands are located in closed watershed basins that only contain a single wetland. Consequently, a

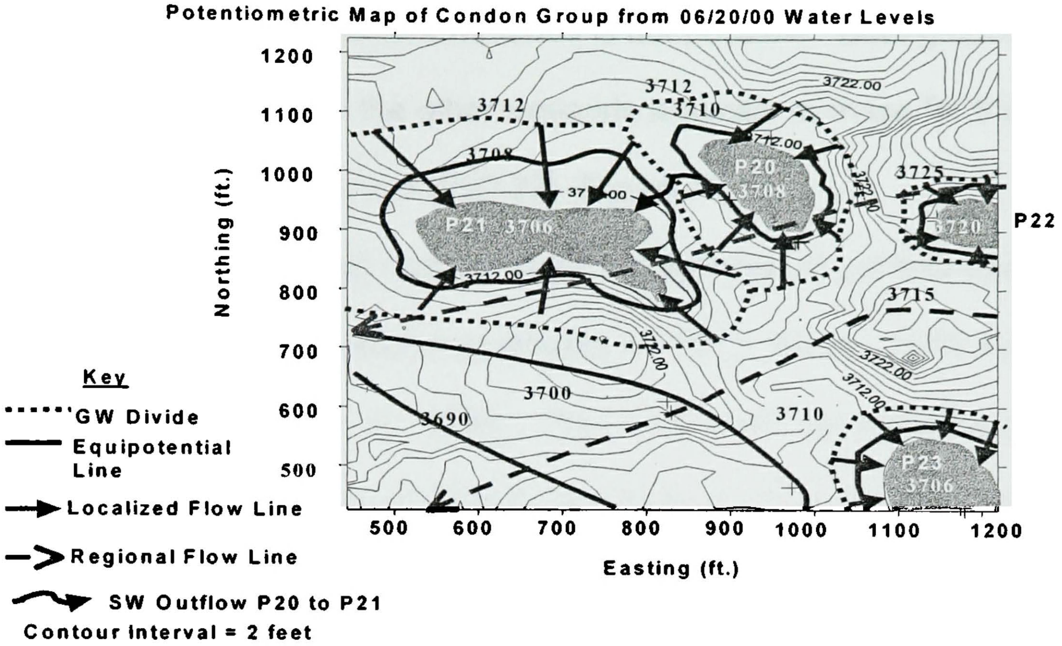


Figure 10. Potentiometric map for Condon Group wetlands 06/12/00

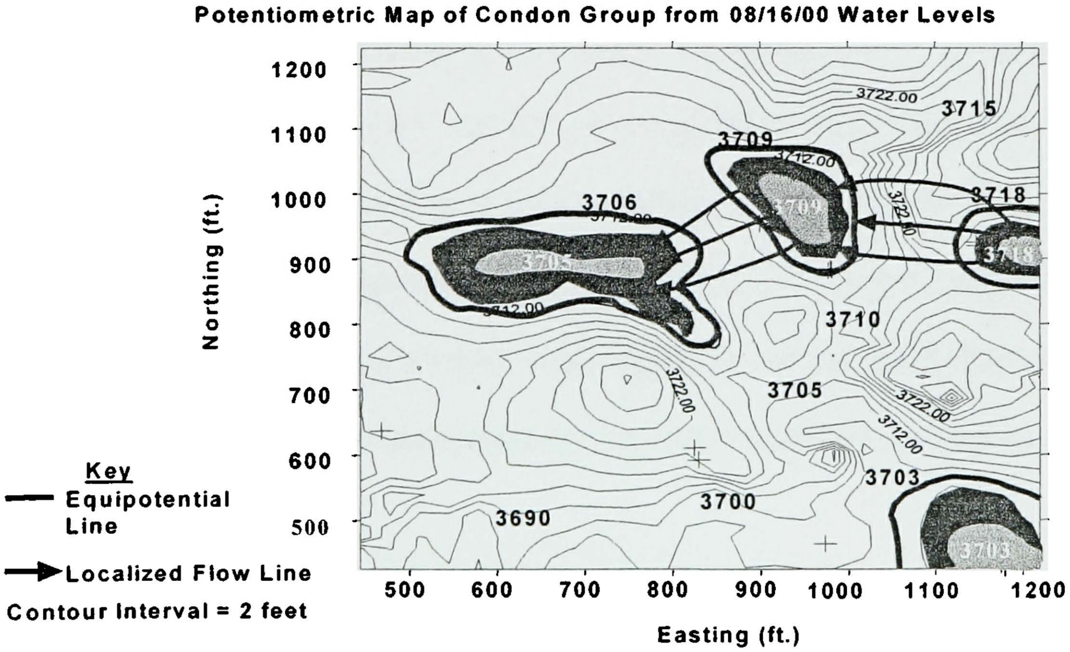


Figure 11. Potentiometric map for Condon Group wetlands 08/16/00

source of water from upgradient wetlands is not possible. Both groundwater and surface water behavior for the other wetlands is similar to those for the individual wetlands in the Condon Group (P20-23) (Figure 10).

Several studies have described the complexities of the flow systems associated with lakes and wetlands (Meyboom 1967; Winter, 1978; Kamp and Hayashi 1998; Hayashi et. al., 1998). They have observed seasonal gradient reversals in the flow system (Anderson and Munter, 1981; Rosenberry and Winter, 1997). Cross sections constructed from data for the Condon Group (P20-23) and Beaver Creek (P45) wetlands demonstrate seasonal gradient reversals (Figures 12 and 13). The trends in seasonal hydraulic gradient reversals correlate with water level data from the other wetland systems, as the trend of positive vertical gradients (groundwater discharge into the wetland) in the spring through mid-summer, followed by negative vertical gradients (wetland leakage into the groundwater flow system) in late summer has been observed at all of the wetland sites. Observed positive vertical gradients for these wetland systems ranged from 0.5 to 0.01 feet while negative vertical gradients ranged from 0.01 to 1.8 feet. Water level data for the other wetlands can be found in Appendix D.

Graphs of seepage meter flux (Figures 14 and 15) from Beaver Creek (P45) wetland during the 1999 field season and Piper Creek (P90) wetland during the 2000 field season show hydraulic flux trends (no detailed data were collected at P20). Figures 14 and 15 demonstrate the decline in groundwater flow into the wetland in late summer. Vertical gradients determined from mini-

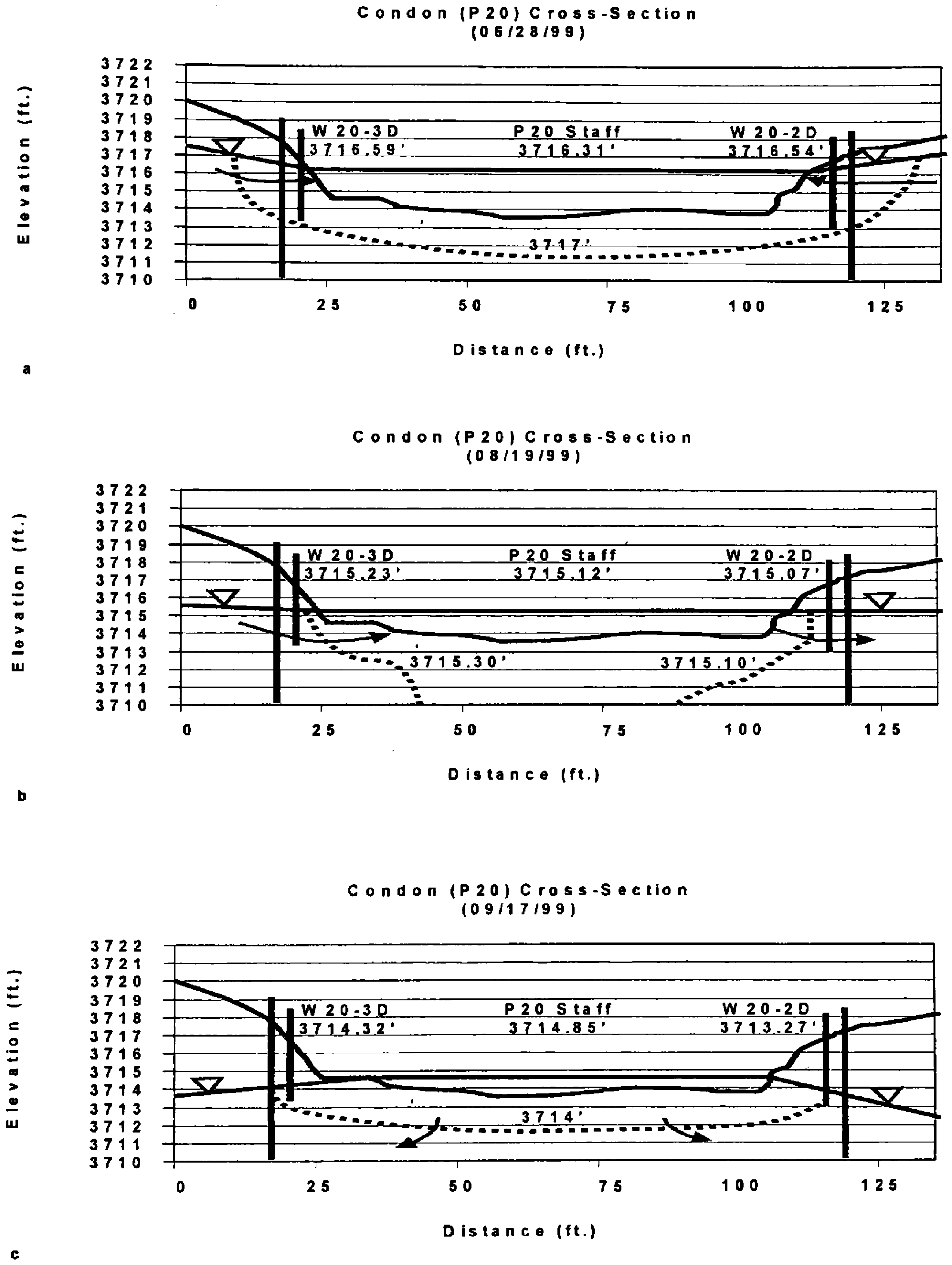


Figure 12. Condon (P20) cross-sections with seasonal variation in wetland stage and water table configuration. a) positive vertical gradients indicate GW discharge, b) flow-through conditions, and c) downward vertical gradients indicate surface water seepage.

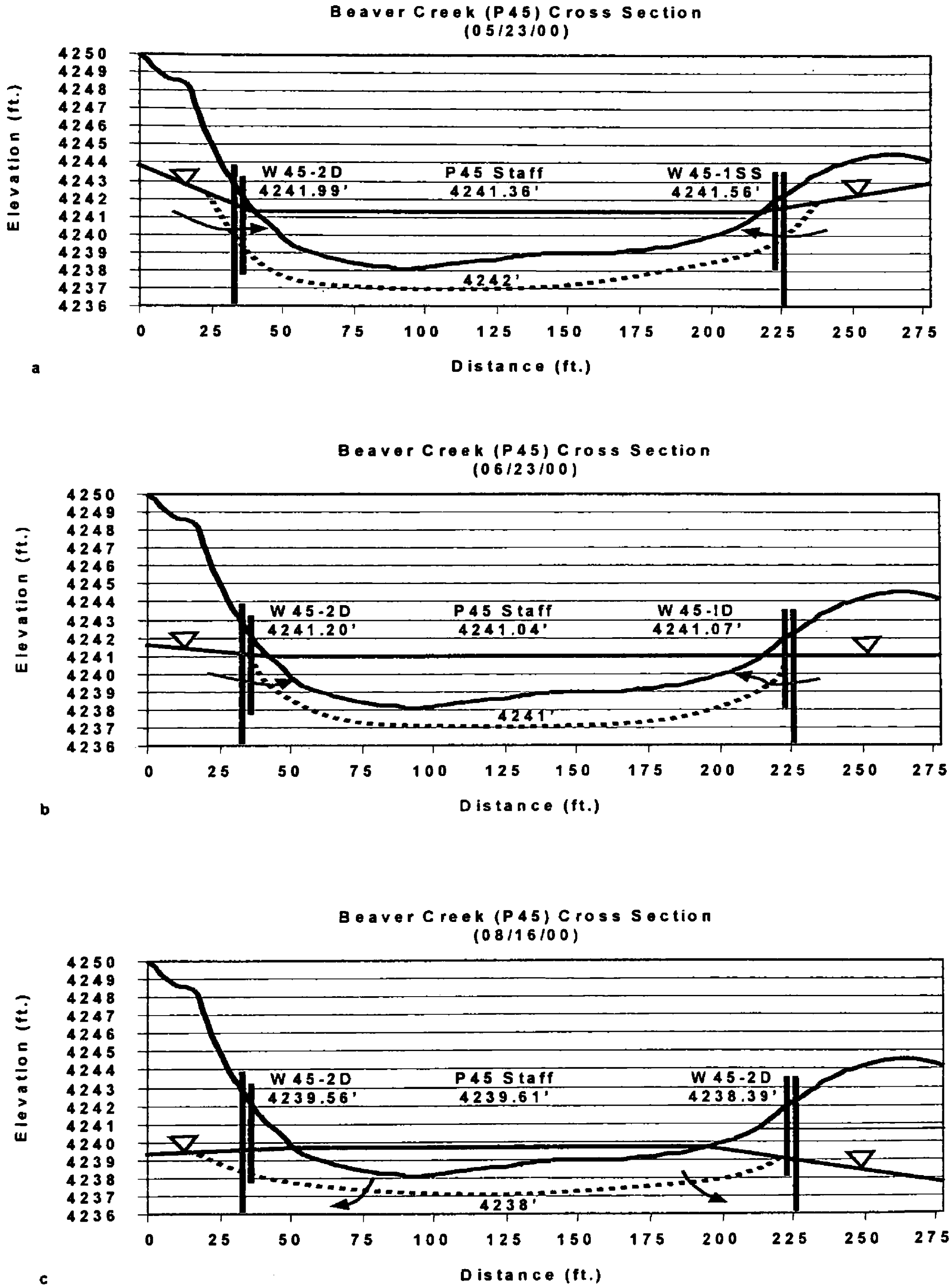


Figure 13. Beaver Creek (P45) cross-sections with seasonal variation in wetland stage and water table configuration. a) positive vertical gradients indicate GW discharge, b) flow-through conditions, and c) downward vertical gradients indicate surface water seepage.

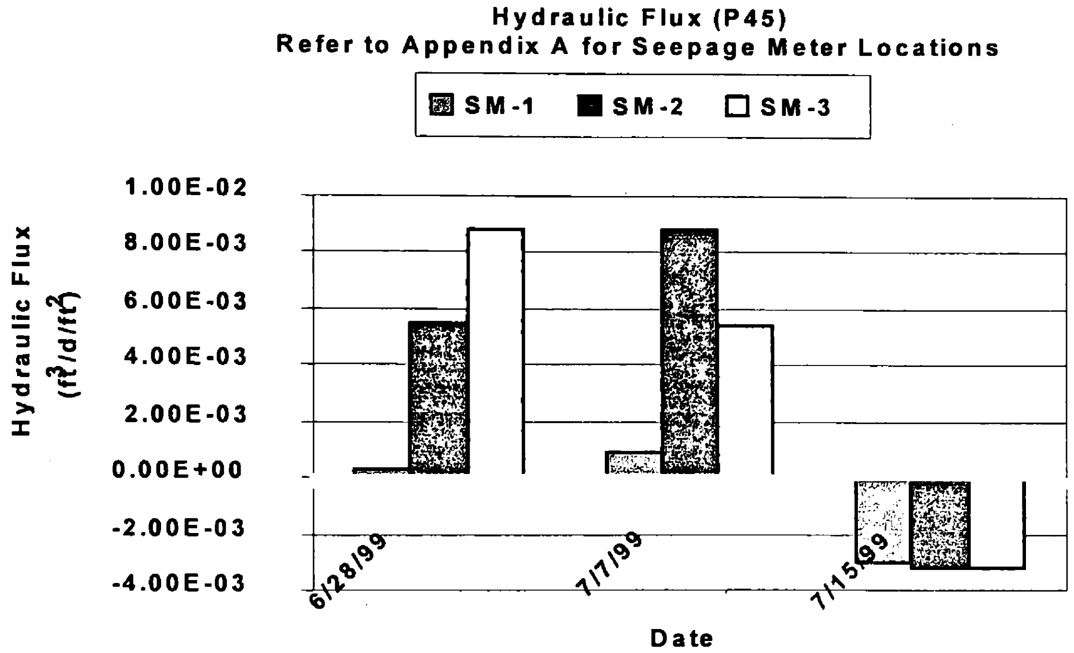


Figure 14: Seepage meter flux from Beaver Creek wetland-1999 field season

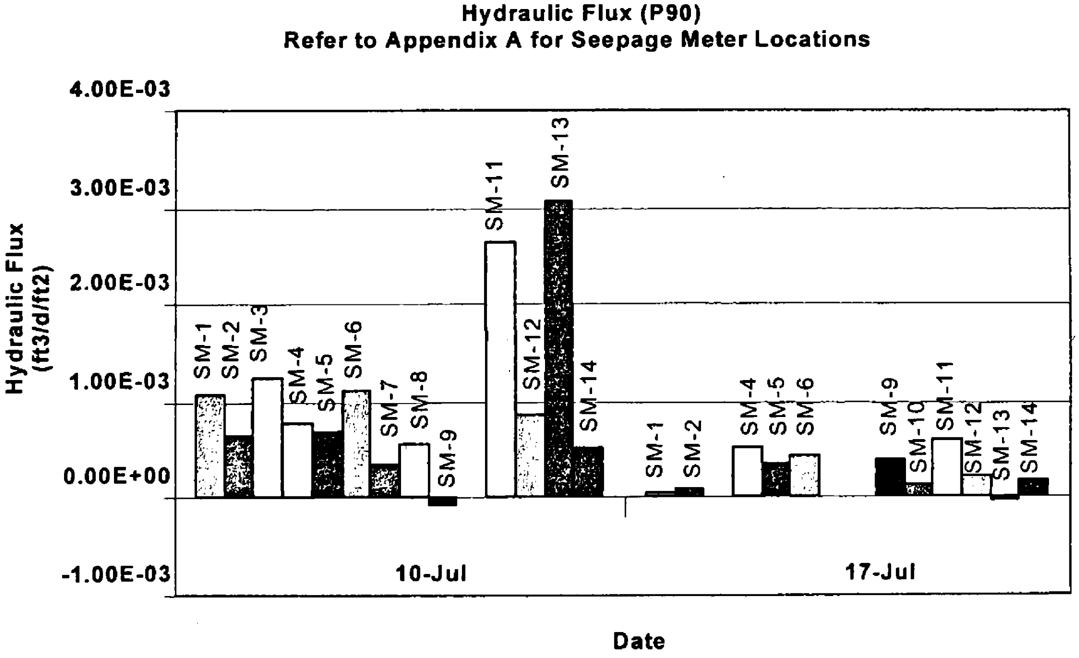


Figure 15. Seepage meter flux from Piper Creek wetland-2000 field season

piezometers are located in Appendix F. The combination of seepage flux with vertical gradients allows for the calculation of vertical hydraulic conductivity of the wetland sediment. Results from these calculations are presented in Table 20.

In summary, potentiometric maps, vertical gradients in the wetland and watershed, seepage meter flux rates, and the groundwater inflow component of the water balance support the hypothesis that seasonal changes in the wetland are driven by a localized groundwater flow system.

Land Management Implications

The WRENSS handbook classifies the Swan Valley as having a continental-maritime climate that is dominated by both snow and rain precipitation. Monthly precipitation averages from the Lindbergh Lake weather station were used for both sites. Snow in the Swan Valley is relatively "heavy" so the snow scouring (snow redistribution by wind) was not allowed in the model. The area of the watershed for each wetland was 1 acre for Condon (P20) and 8 acres for Beaver Creek (P45). An east-west aspect was used to represent an "average" exposure to the sun. A tree type of spruce and fir was the closest match for the species found at these sites. The size of the clearcut was equal to the entire area of the P20 and P45 watershed basins. A value of 150 ft^2/acre was used to estimate basal area of the trees in the watershed. Additional parameters such as roughness of cut, width of cut block, and area of cut block were automatically calculated by the model (Appendix H)

The unimpacted watershed simulates the wetland watershed basin in its present condition. The impacted watershed simulates clearcutting or burning the entire area of the watershed basin with complete removal of vegetation (Tables 23 and 24). Processes removing all the watershed vegetation result in a gain of 2.4 inches in annual water yield due to decreases in evapotranspirational demands. All input values and parameters for the WRNSHYD model are located in Appendix H.

Table 23. WRNSHYD model results for P20 wetland

Condon (P20) Wetland	**Unimpacted Watershed**	**Impacted Watershed**
Precipitation (in.)	26.8	26.8
Evapotranspiration (in.)	14.6	12.6
Water Yield (in.)	12.2	14.2

Table 24. WRNSHYD model results for P45 wetland

Beaver Creek (P45) Wetland	**Unimpacted Watershed**	**Impacted Watershed**
Precipitation (in.)	26.8	26.8
Evapotranspiration (in.)	14.6	12.6
Water Yield (in.)	12.2	14.2

CHAPTER 4: DISCUSSION

Water balance calculations (Tables 6 and 7), including snow surveys (Tables 13 and 14), and water chemistry analyses (Tables 15 and 16) indicate that the dominant source of water to these wetland systems is groundwater inflow from a localized flow system. Additionally, *H. aquatilis* occupied wetlands display complex groundwater-surface water interactions.

Sources of Water to the Wetlands

Water balance analyses show that the studied wetlands are dominated by groundwater exchange. Net inflow of groundwater appears to decrease with time as wetland groundwater vertical gradient reversals are observed.

Regional Climate Controls:

Based on Lindbergh Lake and Swan Lake weather stations and precipitation data collected for this work, the study was conducted during years of below average precipitation. However, during a normal or wet year, the dominance of groundwater in the water balances is not expected to change as summer precipitation inputs (even during wet periods) were an order of magnitude less than surface water outflow (when present), plant transpiration and groundwater inflow. A resulting increase in recharge from a greater snowpack would most likely sustain the wetlands for a period longer prior to dessication.

Recharge to the Watershed Basin:

Calculations from the snow survey indicate that the localized groundwater flow system is principally recharged from snow melt infiltration. Tables 13 and 14 for the Condon (P20) and Beaver Creek (P45) wetlands during March 2000 indicate that there was an annual surplus of water (200,000 to 700,000 ft^3) by applying only 10% of the snow pack water equivalent as available recharge. However, the likely presence of sand lenses, fractures, plant roots, and macropore channels within the near surface watershed soil most likely results in preferential flow paths, increasing recharge and groundwater flux rates. The presence of secondary permeability in these wetland systems is supported by the measured higher hydraulic conductivity values estimated using groundwater flux values.

Groundwater Contribution and Controls:

Based on water balance analyses, plant transpiration, surface water outflow, and groundwater inflow from the watershed basin were determined to be the major controls on the wetland hydrology in the summer. This supports the fourth water balance model proposed by Shapley and Lesica (1997), which defines the hydrology of *H. aquatilis* wetlands to be dominated by inputs from precipitation and groundwater discharge from localized groundwater flow within the surrounding watershed basin and outputs from evapotranspiration. However, this model does not include a surface water outflow component which was observed at 3 of the 4 wetland sites.

The dominance of a localized groundwater inflow component to the wetland is also supported by the geochemical data. Figure 8 shows wetland water specific conductance is low in the spring and increases only slightly during the high water loss period (increasing from 50 to 90 micromhos/cm during the 1999 and 2000 field seasons).

The wetland chemistry is also similar to the chemistry of the shallow groundwater. This trend was observed at each wetland. The Piper Creek wetland had higher specific conductance values ranging from 140 to 240 micromhos/cm, but the shallow groundwater around this wetland had similar specific conductance and ionic concentrations. The low TDS water suggests that the localized groundwater flow system is principally recharged by snow melt, and the groundwater has a short residence time. The seasonal variation in wetland specific conductance is probably influenced by evapotranspirational processes increasing ionic concentrations, addition of ionic components to the wetland system by groundwater inflow, and dilution from precipitation events.

Water chemistry results (Tables 15 and 16) also show that the groundwater sampled from the deeper wells in the watershed (i.e. MW20-1) has a different ionic concentration than water samples from the shallow wells (i.e. W20-1Deep) and the wetland surface water (P20-SW). This suggests water from the deeper wells (7-17 feet) in the watershed are more representative of an intermediate to regional groundwater flow system, a system similar to the sampled domestic wells (i.e. DW-1). This observation further supports the conceptual model that the groundwater from the shallow wells (3-8 feet) near the wetlands is dominated by a localized groundwater flow system.

Controls on Seasonal Variation in Water Influx

From spring to mid-summer, positive vertical groundwater gradients in all of the Howellia occupied wetlands indicate local watershed groundwater discharge into the wetlands (Figures 12 and 13). Then vertical gradients between a shallow flow system and the wetland stage decline until there is a short period of minimal water exchange between the wetland and the localized flow system (Figures 12 and 13). In late summer, the vertical groundwater gradients generally become negative and the wetlands lose water through seepage to the subsurface (Figures 12 and 13). Water balance results also show a net inflow of groundwater that decreases with time, corresponding with seasonal wetland gradient reversals. Seepage meter flux data and mini-piezometer data also showed similar trends.

Water levels from shallow groundwater and wetland stage (Appendix D), seepage flux and corresponding mini-piezometer data (Figure 14) from the Beaver Creek wetland (P45) (during the 1999 field season) illustrate seasonal gradient reversals in the shallow flow system. Seepage meters SM 1-3 show positive hydraulic flux from June 28 to July 7, but negative flux occurs in mid-July.

Figure 15 displays results from a seepage network in Piper Creek during the 2000 field season and demonstrates the decline in groundwater seepage to the wetland from July 10 to July 17. The decline in groundwater seepage corresponds with a decline in vertical gradients (Appendix D). The water table then changed rapidly after July 17 and it was not possible to obtain another round of seepage meter data. Most likely, if another round of seepage meter data could have been collected, a gradient reversal would have been documented.

Seepage meter flux data from other wetlands demonstrate inconclusive results as a distinctive seasonal trend in hydraulic flux is not observed (Appendix G). Furthermore, vertical gradients from mini-piezometers adjacent to seepage meters have contradicted seepage meters flux results, i.e. negative vertical gradient, positive hydraulic flux. Possible reasons for this contradiction between seepage flux and vertical gradients are as follows:

1) mini-piezometer and/or seepage meter did not penetrate sediment layer and is not connected to the groundwater flow system

2) seepage meter is collecting interflow in the organic peat layer

3) walking on the wetland sediment results in water being "pushed" into seepage bag

4) mini-piezometer placed in zones of low hydraulic conductivity were not fully recovered when water levels were recorder, resulting in a negative vertical gradient

5) seepage meter may have intersected a fracture in the wetland sediment

Conceptual Models of Wetland Hydrology

Cross-sections (Figures 16-18) of watershed flow paths were constructed based on site potentiometric maps (Figures 10 and 11). The cross-sections were orientated along a flow line to show the interpreted and conceptualized flow

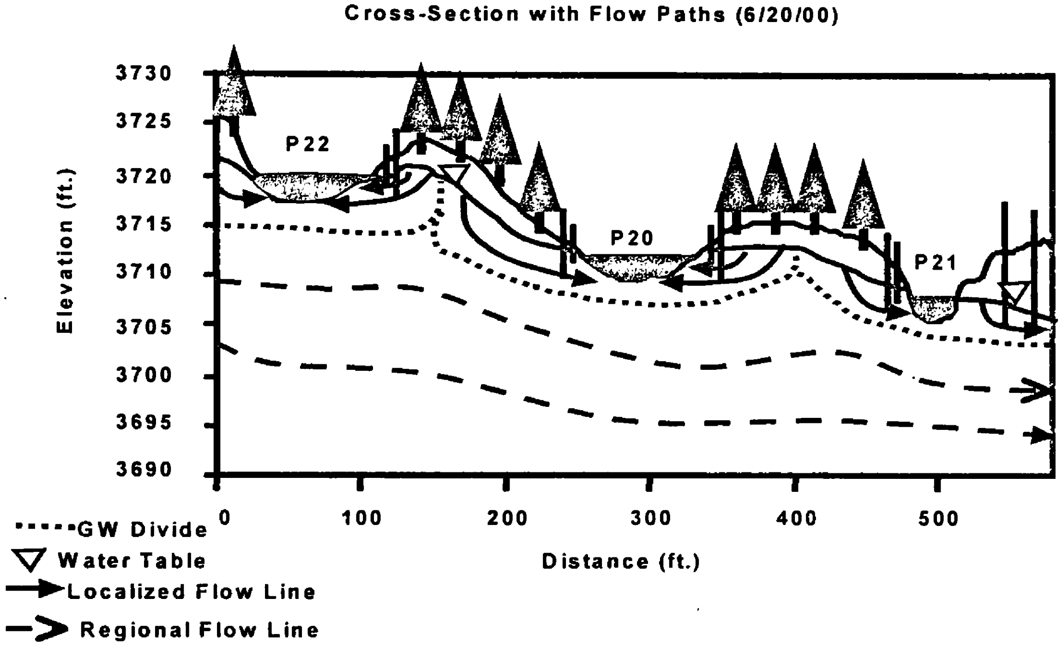


Figure 16. Cross-section of Condon Group watershed flow paths 06/20/00

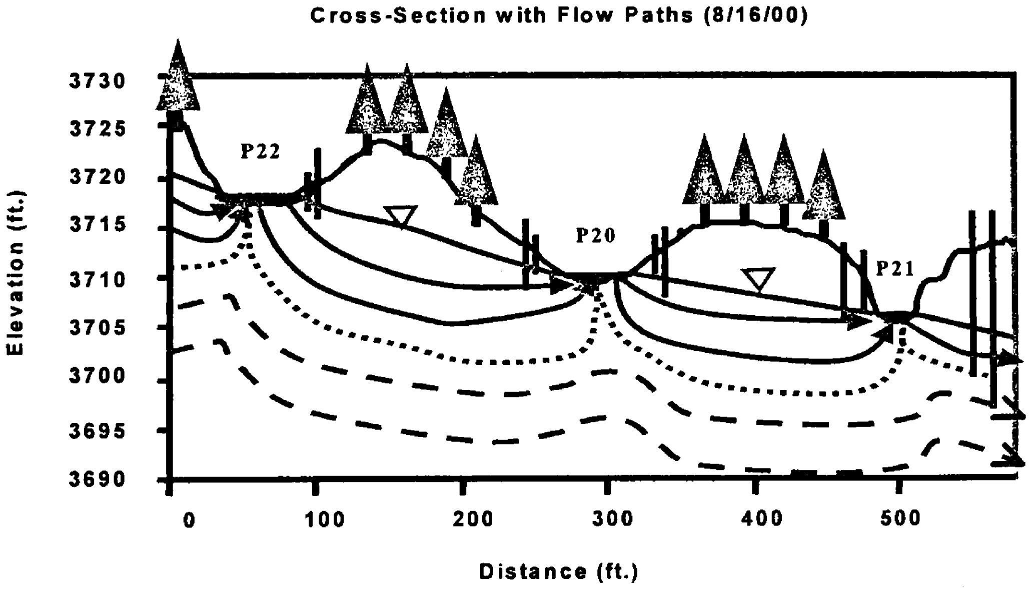


Figure 17. Cross-section of Condon Group watershed flow paths 08/16/00

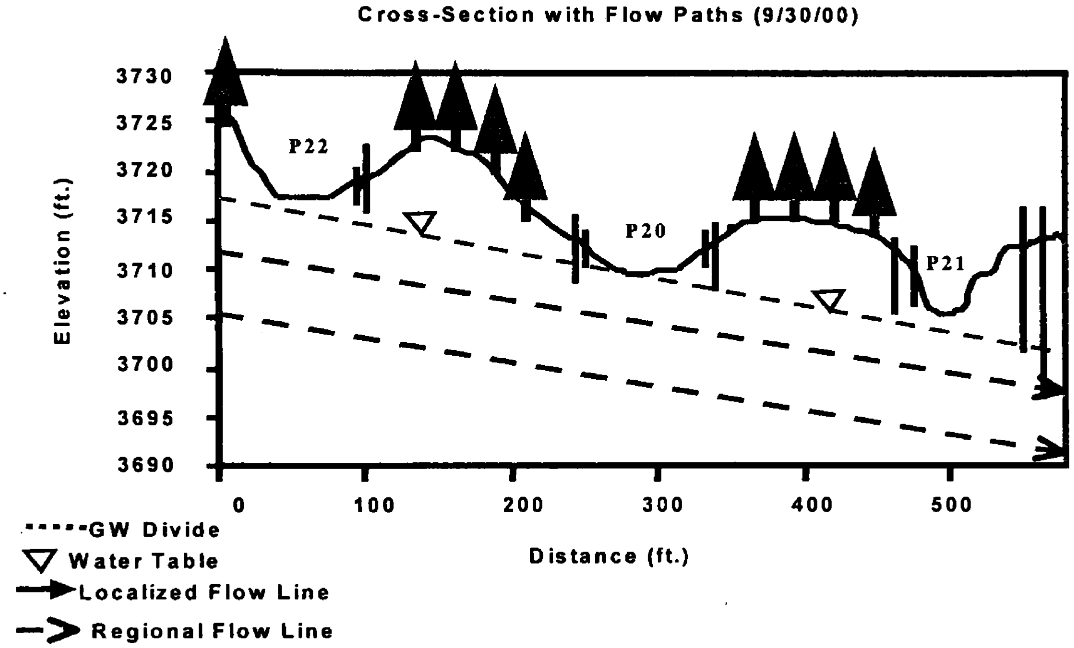


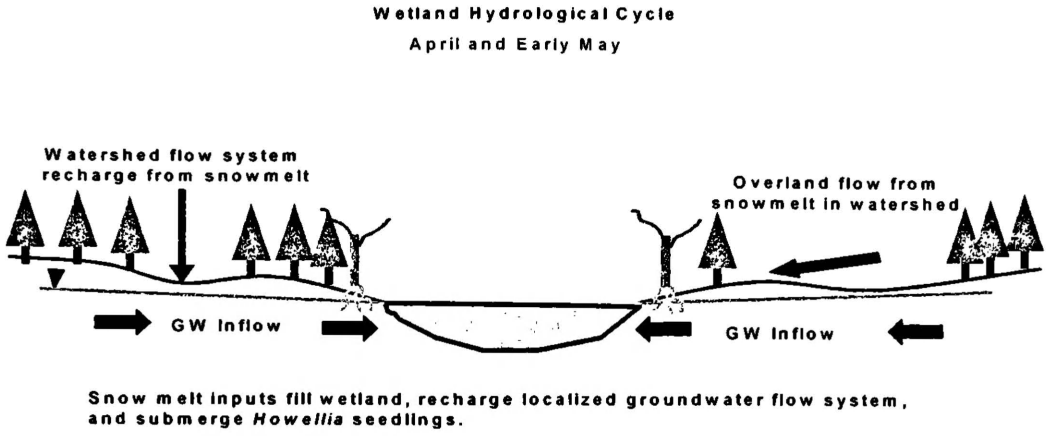
Figure 18. Cross-section of Condon Group watershed flow paths 09/30/00

paths of both localized and more intermediate to regional flow systems, and their associated divides. Localized flow systems dominate wetland hydrology in mid-June and in late summer as the wetlands dry out, flow-through groundwater systems dominate wetland hydrology.

In summary, a model of the wetland hydrological cycle and its relation to the life cycle of *Howellia aquatilis* can be constructed from seasonal data and corresponding photographs. In April and early May, snow melt fills the wetland and recharges the surrounding watershed flow system and Howellia seedlings are submerged (Figures 19 and 20). During mid-June through mid-August, groundwater inflow mitigates wetland stage decline and water quality (Figures 21 and 22). Plant transpiration from phreatophytes in and surrounding the wetland is a dominant hydrological control. Water Howellia matures, flowers, and produces seeds that are dropped into the wetland sediment.

As groundwater levels in the watershed decline, in late August through early September, the localized water table drops below wetland stage creating a gradient reversal that induces surface water seepage (Figures 23 and 24). Plant transpiration remains a dominant output from the system. Once the ponds have dried, *H. aquatilis* annuals quickly die and decompose. Howellia seeds recently dropped into wetland sediment are exposed to air.

During late September through October after several “hard frosts”, plant transpiration ceases, reducing outputs from the watershed flow system (Figure 25). Precipitation events apparently raise the water table, and result in a slight refilling of the wetland. Howellia germinates in October and remains as a small



Snow melt inputs fill wetland, recharge localized groundwater flow system, and submerge *Howellia* seedlings.

Figure 19. Wetland hydrologic cycle-April through Early May

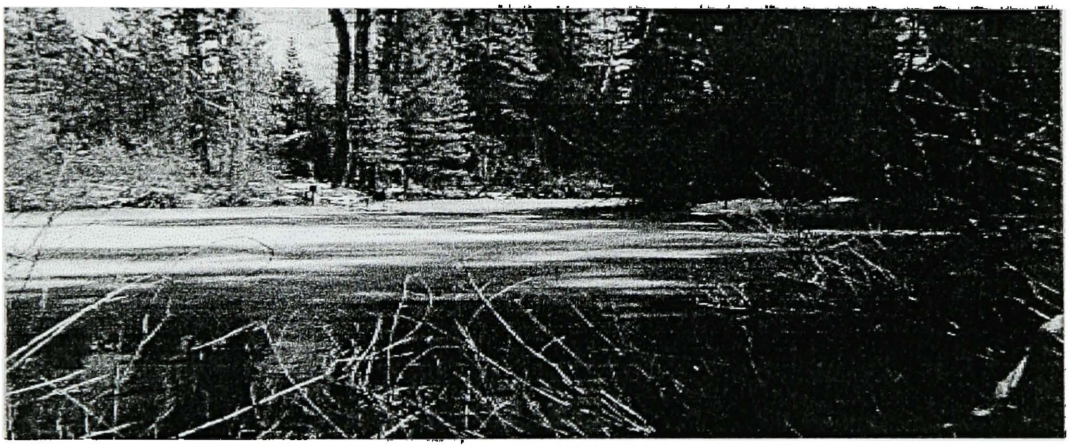
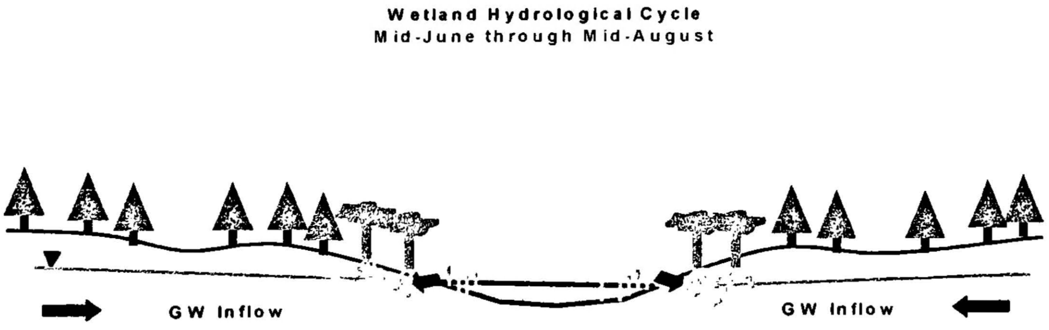


Figure 20. Photgraph of Piper Creek wetland in early April



GW inflow mitigates wetland stage and water quality. *Howellia* plants mature, flower, and drop seeds into wetland sediment. Plant transpiration from phreatophytes in the wetland and surrounding the wetland is a dominant hydrological control.

Figure 21. Wetland hydrological cycle-mid-June through Mid-August

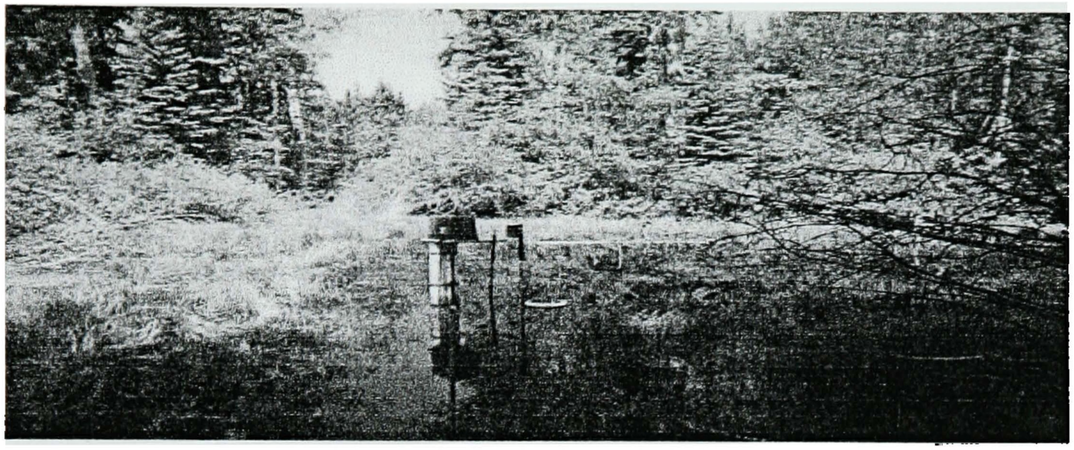
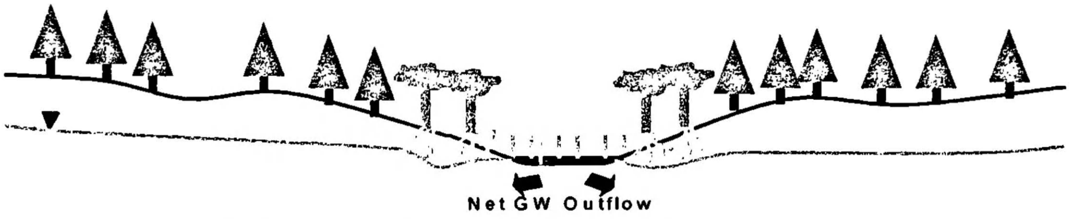


Figure 22. Photograph of Piper Creek wetland during mid-summer



Wetland Hydrological Cycle
Late August through Early September

As GW levels in watershed decline, localized water table drops below wetland stage creating a gradient reversal that induces GW outflow. Plant transpiration remains a dominant output from the system. As wetland dessicates, *Howellia* plants quickly die and decompose.

Figure 23. Wetland hydrological cycle-late August through early September

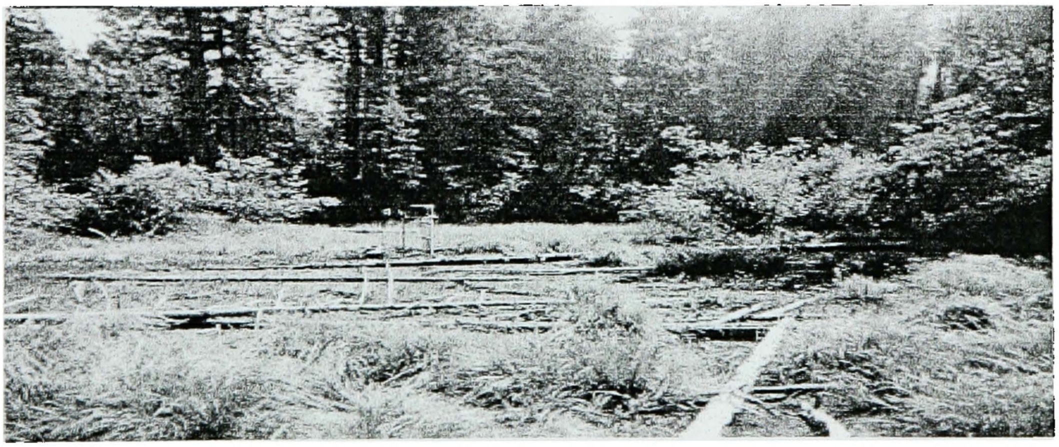
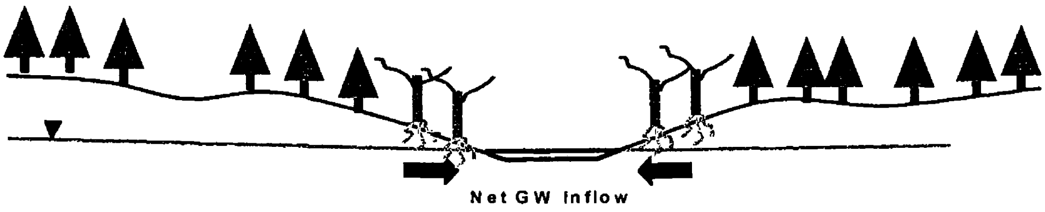


Figure 24. Photograph of Piper Creek wetland in early September

Wetland Hydrological Cycle
Late September through October



In Late Fall after several "hard frosts", plant transpiration ceases, reducing outputs from the watershed flow system. Precipitation events raise water table, filling the wetland and allowing for "cold stratification" of *Howellia* seeds.

Figure 25. Wetland hydrological cycle-late September through October

seedling beneath the winter snowpack (Shapley and Lesica, 1997).

Land Management Implications

Howellia aquatilis, designated as a threatened and endangered species, is entitled to conservancy strategies to ensure its survival and viability. Previous research has indicated that the most important factor in conserving this wetland plant species is for the wetland habitat to remain intact (Lesica, 1992; Shapley and Lesica, 1997). The checker board ownership of the land in the Swan Valley raises concern as to how land management decisions may impact the future of Water Howellia wetlands.

Analyses of water balance studies, groundwater-surface water interactions, and water chemistry results indicate that a localized flow system, principally recharged by snow melt, maintains water quality, wetland stage, and is the dominant hydrological input into these forested wetland systems. The growth cycle of Water Howellia is dependant upon these transient localized groundwater flow systems for wetland re-establishment in the spring, maintenance during growing season, and dessication in the fall. This localized groundwater flow system is dependent on the size and condition of the watershed basin in which these wetlands are located.

Since the *H. aquatilis* occupied wetlands are annually recharged from snow melt that recharges a localized groundwater flow system, it is important to understand and attempt to predict how land uses will affect the snow accumulation, timing and duration of snow melt, and recharge to the localized flow system. Timber harvesting, and associated road building to a lesser degree, and fire are the primary practices which are of concern in land management issues regarding the protection of Water Howellia. This study addresses hydrologic impacts from the removal of vegetative cover in the watershed basins surrounding the wetlands. Data were not collected to access the impact of roads on wetland hydrology, although road building in the watershed basins of *H. aquatilis* occupied wetlands is a concern (Liz Hill, 2001).

The results from the WRNSHYD model (Tables 22 and 23), which simulates a complete removal of trees in the watershed basin, supports that removal of trees in a watershed basin increases water yield (Troendle, 1983; Cheng, 1989; Adams et al., 1991; Hicks et. al., 1991). The increase in water yield is caused by different factors, primarily the loss of trees decreases soil-water depletion from plant transpirational demands (Troendle, 1983; Adams et al., 1991). Although an initial gain in water yield is observed immediately after tree loss, returning successional vegetation cover may reduce the water yield after only a few years (Troendle, 1983; Adams et al., 1991) or a water surplus could exist for 25-40 years. In some cases, successional plant species can use more water than the tree dominated system and further reduce water yield to levels that are less than that of the unharvested forest. Adams et al. (1991) report that a clearcut in a Douglas-fir forest resulted in an initial 4 inch surplus in water yield. In 5 years, this surplus turned into a 1 inch deficit.

Although *H. aquatilis* occupied wetlands are surface water bodies, it is the localized ground water flow systems that sustains them until late July and

August. A number of adverse impacts can occur if the watershed basin is managed in such a way that all trees are removed. First, opening the canopy allows for more energy to reach the ground resulting in snow melt events that occur earlier in the spring (up to 3 weeks earlier) and are of higher intensity which results in an increased amount of overland flow (Troendle, 1983; Cheng, 1989). Even though the wetland receives more water from overland flow, the localized groundwater system will not have the same amount of recharge due to a suspected reduction in meltwater infiltration. Optimal groundwater recharge would occur during a slower snow melt which allows more water to infiltrate. Three of the four, wetlands, Condon, Holland Lake, and Piper Creek have surface water outlets. The outlets would regulate wetland depth in the early part of the year, thus excess water would be lost as surface water outflow. In the wetlands that do not have a surface water outlet, wetland stage would be increased. The lack of canopy would also result in a higher energy budget that would increase evaporation and plant transpirational outputs from the system. This corresponding additional water use or loss would most likely decrease available recharge to the localized flow system as infiltration soil water is captured. A temporary reduction in wetland volume in late summer and early fall would probably occur. The wetland would most likely dessicate at an earlier time than observed.

Fire in these forested wetland systems can also affect these wetlands in a similar manner as timber harvest. Fire has been suppressed in the forests of the Swan Valley over the last 60 years (Mantas, 1998). Research on the age of fire scars on trees in old-growth plots in the Swan Valley have determined a fire frequency ranging from 25-30 years (Arno et al., 1995; Arno et al., 1997). The 25-30 year fire cycle represents surface fires that clear the forest of ground fuels and most likely do not affect the hydrology of the watersheds of *H. aquatilis* wetlands. Stand replacement fires best represent logging. Research indicates that old growth plots in the Swan Valley revealed a stand clearing fire occurred during the 1600's, resulting in a stand replacement fire cycle of 350-400 years for these plots (Arno et al., 1995). Arno et al. (1997) suggest an overall stand replacement fire cycle of 150-350 years for the Swan Valley. The stand replacement fire cycle implies that the watershed surrounding *H. aquatilis* occupied wetlands has been naturally “logged” a minimum of every 150-400 years during this species’ existence in the Swan Valley, possibly over the last 12,000 years.

In summary, tree removal in the local watershed, would most likely affect the wetland hydrological support system. If an initial increase in water yield would occur, it may be either short lived or could extend to 25-40 years. However, the degree to which the *Howellia* life cycle would be altered is unknown. It would appear that the natural fire cycle has not resulted in a loss of minimal hydrologic conditions needed for *Howellia* survival.

CHAPTER 5: CONCLUSIONS

1) Snow melt runoff into the wetland and infiltration in the watershed basin recharges the localized groundwater flow system for each wetland. The localized groundwater flow system mitigates wetland stage and water quality in the wetlands until mid-August/early September when the wetlands partially or fully dessicate.

2) Water balance calculations show groundwater inflow, surface water outflow (when present), and plant transpiration are the dominant hydrological controls in these wetland systems.

3) Groundwater levels, mini-piezometer, and seepage meter flux data show seasonal groundwater gradient reversals change wetland from groundwater discharge (spring), to flow through (summer), to recharge (fall).

4) Processes that would remove all trees from the wetland watershed will alter the wetland hydrology by increasing initial water yield and most likely enhancing direct evaporation. The surplus of water may only be a short-term gain until successional plant species are established in the watershed basin or a water surplus could exist for 25-40 years. A reduction in groundwater recharge due to less than optimal recharge conditions from a lack of canopy will most likely cause H. aquatilis wetlands to dessicate earlier than observed. To ensure species survival, the watershed basin of *H. aquatilis* occupied wetlands should be left

intact.

CHAPTER 6: RECOMMENDATIONS FOR ADDITIONAL WORK

1) Additional hydrologic studies on other Howellia occupied wetlands need to be conducted to further study the larger population of Howellia occupied wetlands. It would be useful to compare the function of timber harvested wetlands with unharvested wetlands. Furthermore, a study designed to observe any differences in wetland hydrology and water chemistry between Water Howellia unoccupied and occupied wetlands may help define habitat limitations for Water Howellia.

2) This research needs to be expanded to examine how the wetlands, their associated groundwater flow system, and the regional flow system interact in regions with isolated and closely spaced wetland clusters.

3) Research designed to investigate the presence of fractures or zones of higher hydraulic conductivity would greatly enhance the understanding of these wetland systems as these features most likely increase permeability in these wetland systems.

4) Long-term hydrologic monitoring of H. aquatilis occupied wetlands would aid in our understanding of the degree that natural variation in the wetland systems impact Water Howellia survival.

REFERENCES

Adams, P.W., Flint, A.L., and Fredriksen, R.L., 1991, Long-term patterns in soil moisture and revegetation after a clearcut of a Douglas-fir forest in Oregon.

Anderson, M. and Munter A., 1981, Seasonal reversals of groundwater flow around lakes and the relevance to stagnation points and lake budgets. Water Resources Research, v. 17, no. 4, p.1139-1150.

Armstrong, R.L., 1981, A step-by-step look at snowcover metamorphism, National Avalanche School, Reno, NV, 1981, Proceedings.

Arno, S.F., Scott, J.H., and Hartwell, M.G., 1995, Age-class structure of old growth Ponderosa Pine/Dougas-Fir strands and its relationship to fire, Research Paper INT-RP-481, USDA Forest Service, Intermountain Research Station, Ogden, UT, 25 pp.

Arno, S.F., Smith, H.Y., and Krebs, M.A., 1997, Old growth ponderosa pine and western larch stand structures: influences of pre-1900 fires and fire exclusion, Reseach Paper INT-RP-495, USDA Forest Service, Intermountain Research Station, Ogden, UT, 20 pp.

Cheng, J.D., 1989, Streamflow changes after clear-cut logging of a pine bettle-infested watershed in southern British Columbia, Canada, Water Resources Research, v. 25, no. 3, p. 449-546.

Driscoll, F.G, 1986, Groundwater and Wells, U.S. Filter/Johnson Screens, 1089 pp.

Fetter, C.W., 1994, Applied Hydrogeology, Columbus:Merrill Publishing, 691 pp.

Gordon, N.D., McMahon, T.A., and Finlayson, B.L, 1992, Stream Hydrology, New York, John Wiley and Sons Publishing, 526 pp.

Griask, G.E., and Cherry, J.A., 1975, Hydrologic characteristics and response of fractured till and clay confining a shallow aquifer, Can. Geotech. Journal, v. 12, no. 23, p. 23-43.

Grisak, G.E., Cherry, J.A., Vanhof, J.A., and Blumek, J.P., 1976, Hydrogeologic and hydrochemical properties of fractured till in the Interior Plains region. In Glacial till: an interdisciplinary study, edited by R.F. Legget, Royal Society of Canada, Special pub. no. 12, p. 304-335.

Hendry, J.M., 1982, Hydraulic conductivity of a glacial till in Alberta, Groundwater, v. 20, no. 2, p. 162-169.

Hicks, B.J, Beschta, R.L., and Harr, R.D., 1991, Long-term changes in streamflow following logging in western Oregon and associated fisheries implications, Water Resources Bulletin, v. 27, no. 20, pp. 217-226.

Hill, L., 2001, Hydrologist, Flathead Forest District, personal communication, regarding the impact of roads on wetland hydrology of Water Howellia wetlands.

Hyashi, M., Kamp, G., and Rudolph, D., 1998, Water and solute transfer between a prairie wetland and adjacent uplands, 1. Water balance, Journal of Hydrology, p.42-55.

Johns, W., 1970, Geology and Mineral Deposits of Lincoln and Flathead Counties, MT, Montana Bureau of Mines and Geology, Bulletin 79, 182 pp.

Kamp, G. and Hayashi, M., 1998, The groundwater recharge function of small wetlands in the semi-arid northern prairies, Great Plains Research, p. 39-56.

Keller, C.K, G. Van de Kamp, 1988, Hydrogeology of two Saskatchewan tills, I. Fractures bulk permeability, and spacial variability of downward flow, Journal of Hydrology, v. 101, p. 97-120.

Kleinkopf, M.D. and Mudge, M.R., 1972, Aeromagnetic, Bouguer Gravity and Generalized Geologic Studies of the Great Falls-Mission Range Area, Northwest Montana, U.S.G.S. Professional Paper 726-A, 19 pp.

Koerselman, W., 1989, Groundwater and surface water hydrology of a small groundwater-fed fen, Wetlands Ecology and Management, v. 1, no. 1, p.31-43

Leathe, S.A. and Enk, M.D., 1985, Cumulative Effects of MicroHydro Development on the Fisheries of the Swan River Drainage, Montana, VI; Summary Report. Prepared for Bonneville Power Administration, Division of Fish and Wildlife, Portland, OR, 202 pp.

Lee, D.R. and Cherry, J.A., 1978, A field exercise on groundwater flow using seepage meters and mini-piezometers, Journal of Geological Education, v. 27, p. 9-10.

Lesica, P. 1992, Autecology of the endangered plant *Howellia aquatilis*: implications for management and reserve design, Ecological Applications, n. 2, v. 4, p. 411-421.

Mantas, M, 1998a, Historical vs. current conditions of upland forests surrounding *Howellia aquatilis* habitats in the Swan Valley, Montana, Forum on research and management of *Howellia aquatilis*, Cheney, WA, March 24-25, 1988, Proceedings.

Mantas, M, 2001, Botantist, Flathead Forest District, personal communication via electronic mail, regarding known occurances of H. aquatilis.

Martin, T.D., C.A. Brockhoff, J.T. Creed, 1994, Determination of metals and trace metals in water by Ultrasonic Nebulization Inductively Coupled Plasma-Atomic Emission Spectrometry (200.15), Environmental Monitoring Systems Laboratory, ORD, U.S.E.P.A., 45pp.

Meyboom, P. 1967. Mass-transfer studies to determine the groundwater regime of permanent lakes in hummocky moraine of Western Canada. Journal of Hydrology v. 5, p. 117-142.

Minister of Supply and Services, 1989, WreNSs HYDrology version 1.1, Rel 11/01/90, Canada.

Mitsch, W.J. and J.G. Gosselink, 1993, Wetlands, 2nd ed., Van Nostrand Reinhold, N.Y.

Pfaff, J.D., 1993, Determination of inorganic anions by Ion Chromatography (300.0), EPA Methods for the Determination of Inorganic Substances in Environmental Samples, U.S.E.P.A./600/R-93, 100pp.

Rosenberry, D. and Winter, T., 1997, Dynamics of water-table fluctuations in an upland between two prairie-pothole wetlands in North Dakota, Journal of Hydrology, v.191, p. 266-289.

Ross, C.P., Andrews, D.A., and Witkind, I.J., 1955, Geologic Map of Montana, U.S.G.S.

Shapley, M. and Lesica, P., 1997, *Howellia aquatilis* (Water Howellia) wetlands of the Swan Valley: conceptual hydrologic models and ecological implications, Unpublished report to the U.S. Fish and Wildlife Service, Montana Natural Heritage Program, Helena.

Shapley, M. 1998, Preliminary evaluation of basin morphometry and field chemistry of Montana's *Howellia aquatilis* wetlands, Unpublished report to

Flathead National Forest and the U.S. Fish and Wildlife Service Montana Natural Heritage Program, 44 pp.

Shaw, R.D. and Prepas, E.E., 1989, Anomalous, short-term influx of water into seepage meters, Limmol. Oceanogr., v. 34, no. 7, p. 1343-1351.

Shelly, J.S. and Gamon, J., 1996, *Howellia aquatilis* (Water Howellia) recovery plan, Unpublished draft for the U.S. Fish and Wildlife Service, Montana Natural Hertiage Program, 44 pp.

Sparks, D.L, 1995, Environmental Soil Chemistry, Academic Press, San Diego, 267 pp.

Langmuir, D., 1997, Aqueous Environmental Chemistry, Prentice Hill, New Jersey, 600 pp.

Toth, J.A., 1963, A theoretical analysis of ground-water flow in small drainage basins, Journal of Geophysical Research, v. 68, no. 16, p. 4795-4811.

Troendle, C.A., 1983, The potential for water yield augmentation from forest management in the Rocky Mountain region, Water Resources Bulletin, v. 19, no. 3, p. 359-373.

Troxell, H.C., 1936, The diurnal fluctuation in the ground-water and flow of the Santa Ana River and its meaning, Trans. American Geophysical Union, v. 17, p. 496-504.

U.S. Environmental Protection Agency, 1989, An approach to water resources evaluation of non-point silvicultural sources (A procedural handbook), US EPA, Environmental Research Laboratory, Athens, Georgia, EPA-600/8-80-012, 861 pp.

U.S. Geological Survey, 2001, Montana histroric stream flow of Swan River, U.S.G.S. Montana current streamflow conditions, retrieved March 29,2001 from World Wide Web, http://montana.usgs.gov/rt-cgi/gen_tbl.pg.

U.S. Fish and Wildlife Service, 1994, Endangered and Threatened wildlife and plants; the plant, Water Howellia (*Howellia aquatilis*) determined to be a Threatened species, 50 CFR Part 17, Federal Register n. 59, v. 134, p. 33860-35864.

Western Regional Climate Center, 2001, Montana climate summaries for Linbergh Lake, Seeley Lake, and Swan Lake weather stations, Western Climate Center, retrieved March 1, 2001 from World Wide Web, http://www.wrcc.dri.edu/summary/climsmmt.html.

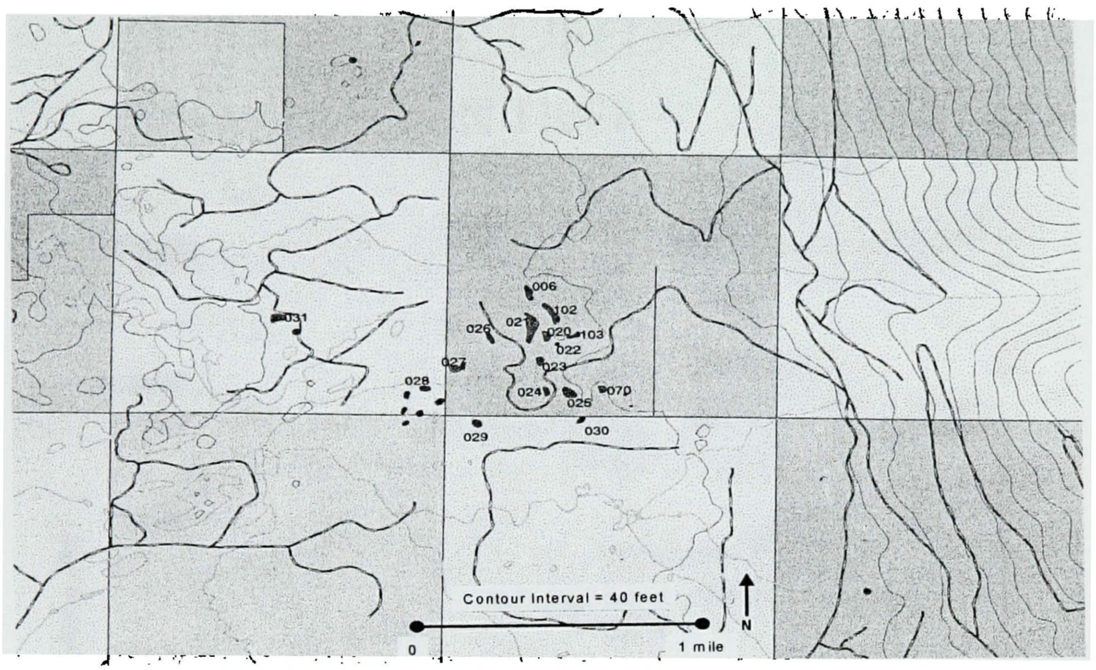
Winter, T., 1978, Numerical simulation of steady state three-dimensional groundwater flow near lakes, Water Resources Research, v. 14, no. 2, p. 245-254.

Witkind, I.J., 1978, Surficial Geology Map of the Swan Lake Quadrangle, Montana, U.S.G.S. Open File Report OF 77-136.

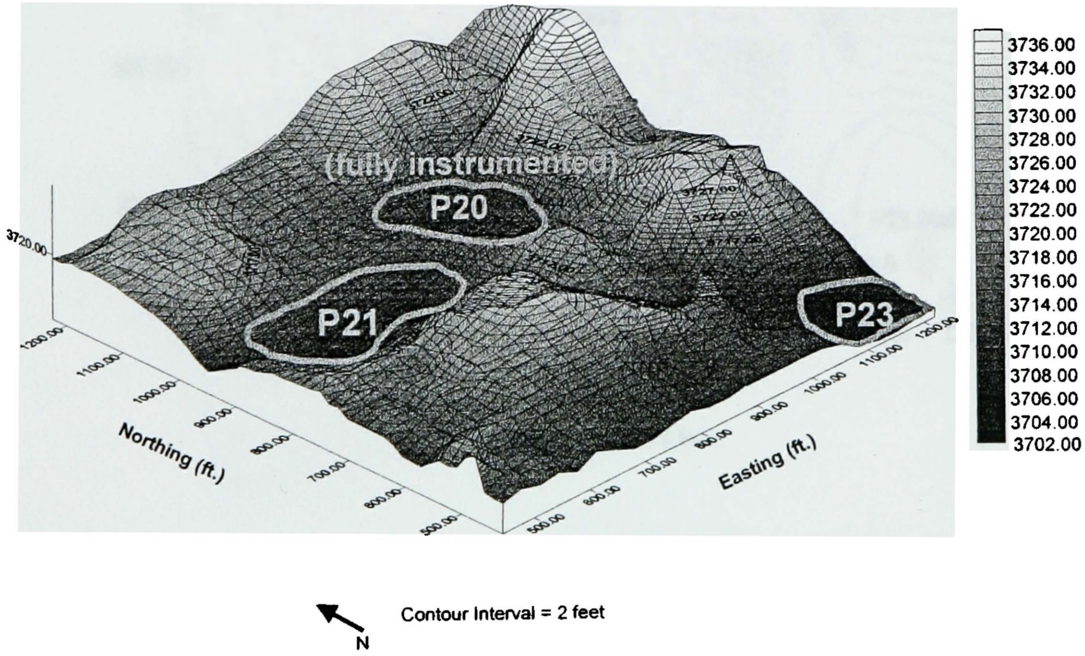
Wolfs, F., 2001, Error analysis, Frank Wolfs' personal web page, retrieved April 1, 2001 from World Wide Web, http://teacher.nsrl.rochester.edu/phy_labs/AppendixB/AppendixB.html.

APPENDIX A

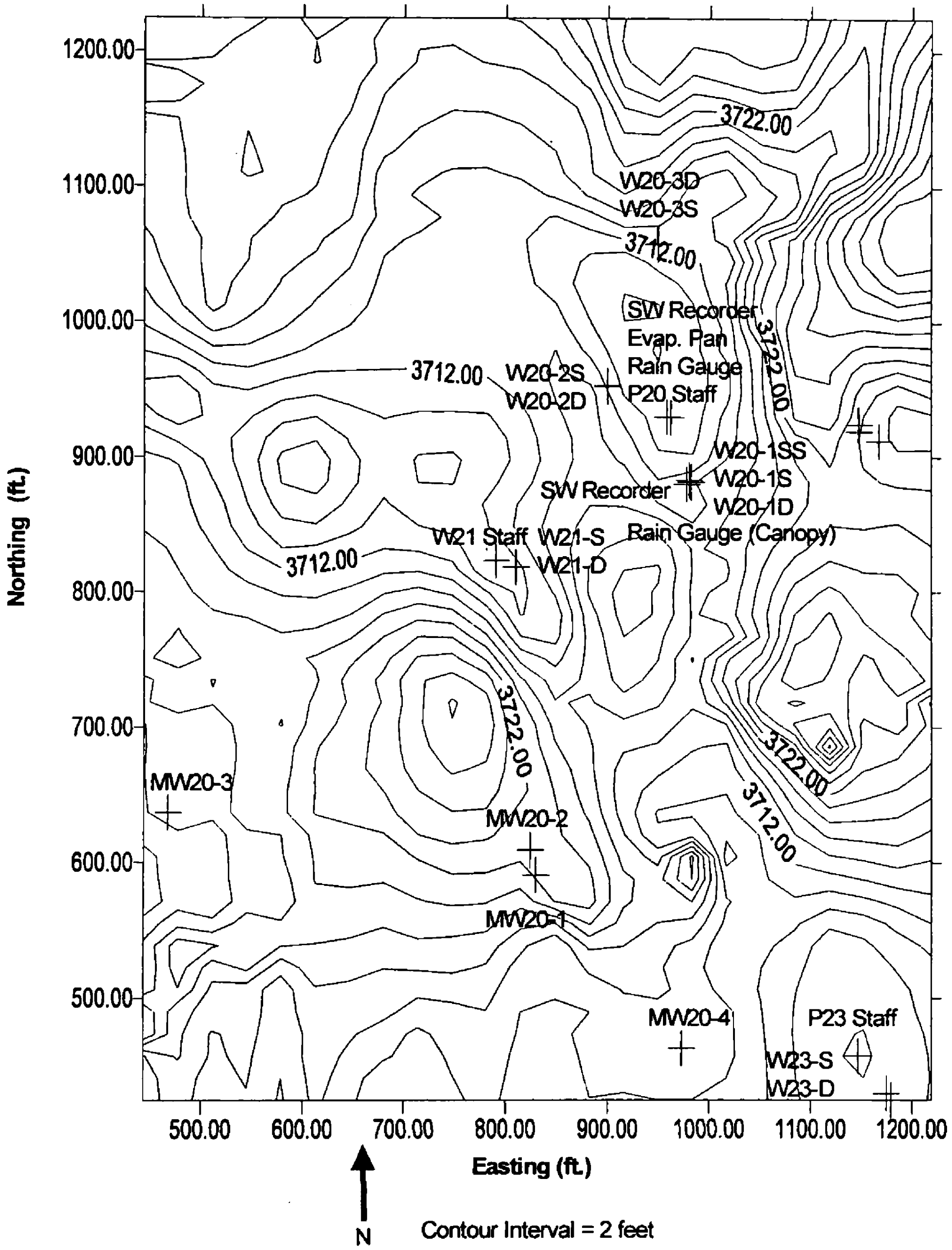
SITE MAPS



Condon Group (P20-23, labeled O20-O23) wetland cluster map.

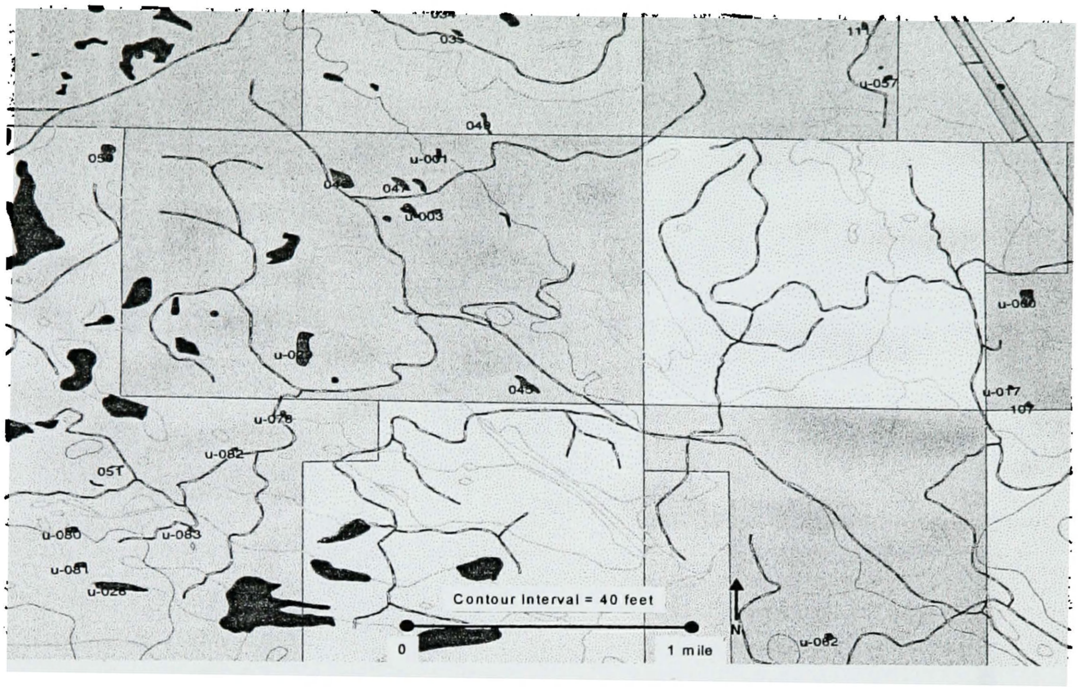


Surface map of Condon Group (P20-23) wetlands. All wetlands are outlined. All units are in feet.

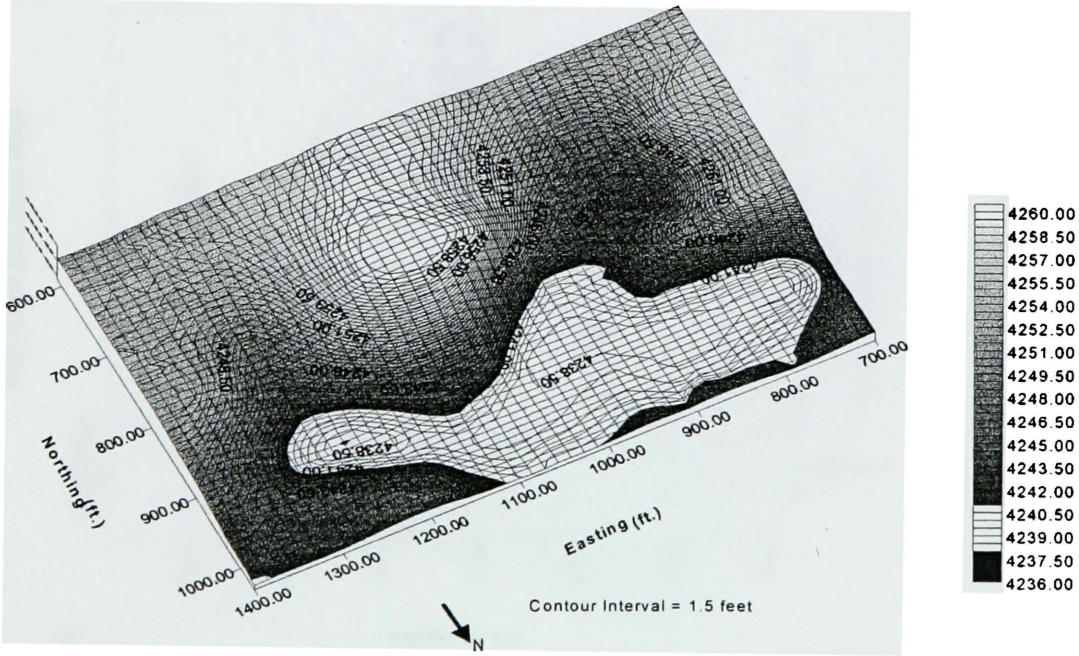


P20-23 Post Contour Map

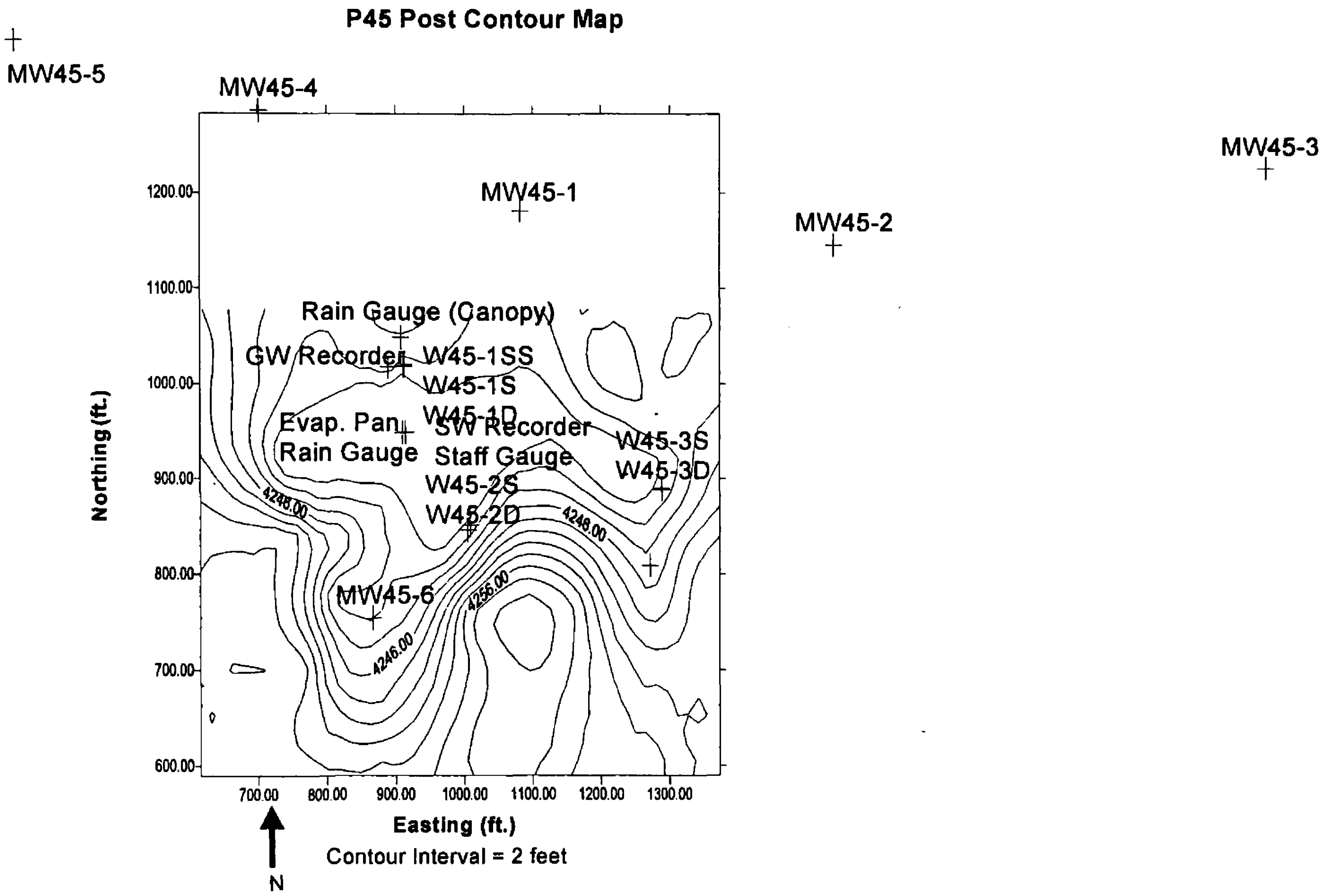
Post contour map of Condon Group (P20-23) wetlands showing positions of wetland instrumentation.



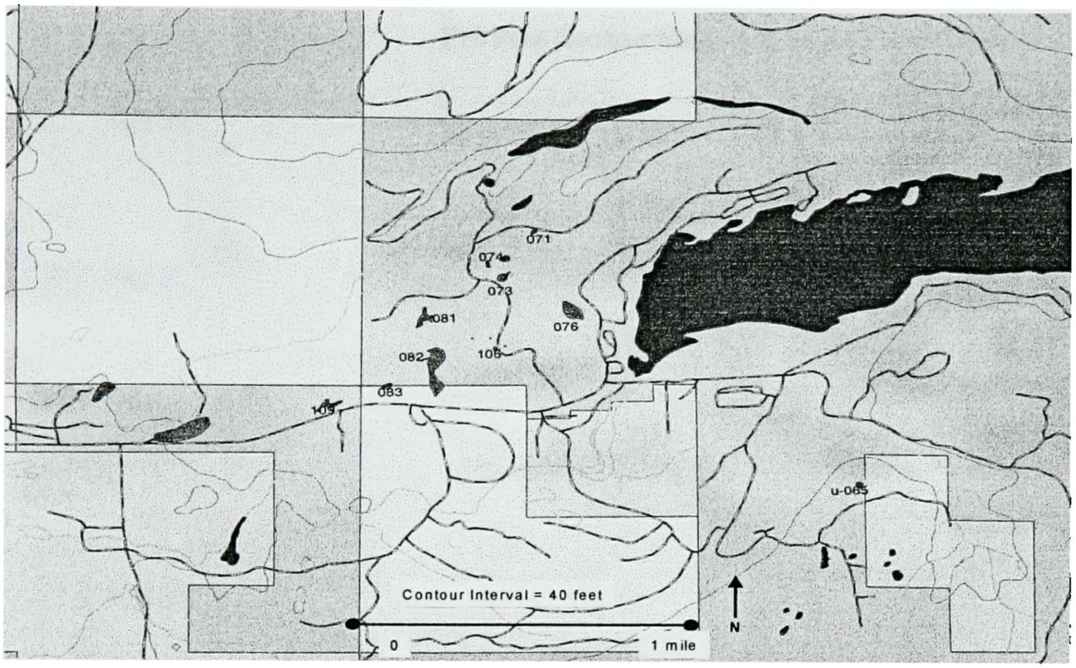
Beaver Creek (P45, labeled O45) wetland cluster map



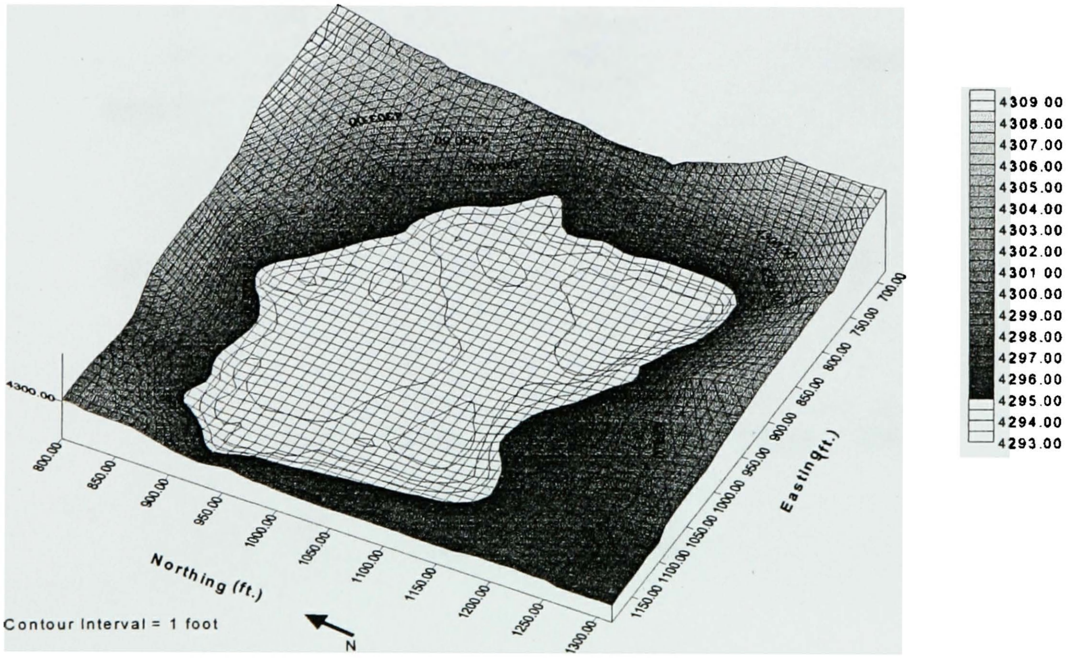
Surface map of Beaver Creek (P45) wetland. Location of wetland is shown by transparent area. All units are in feet.



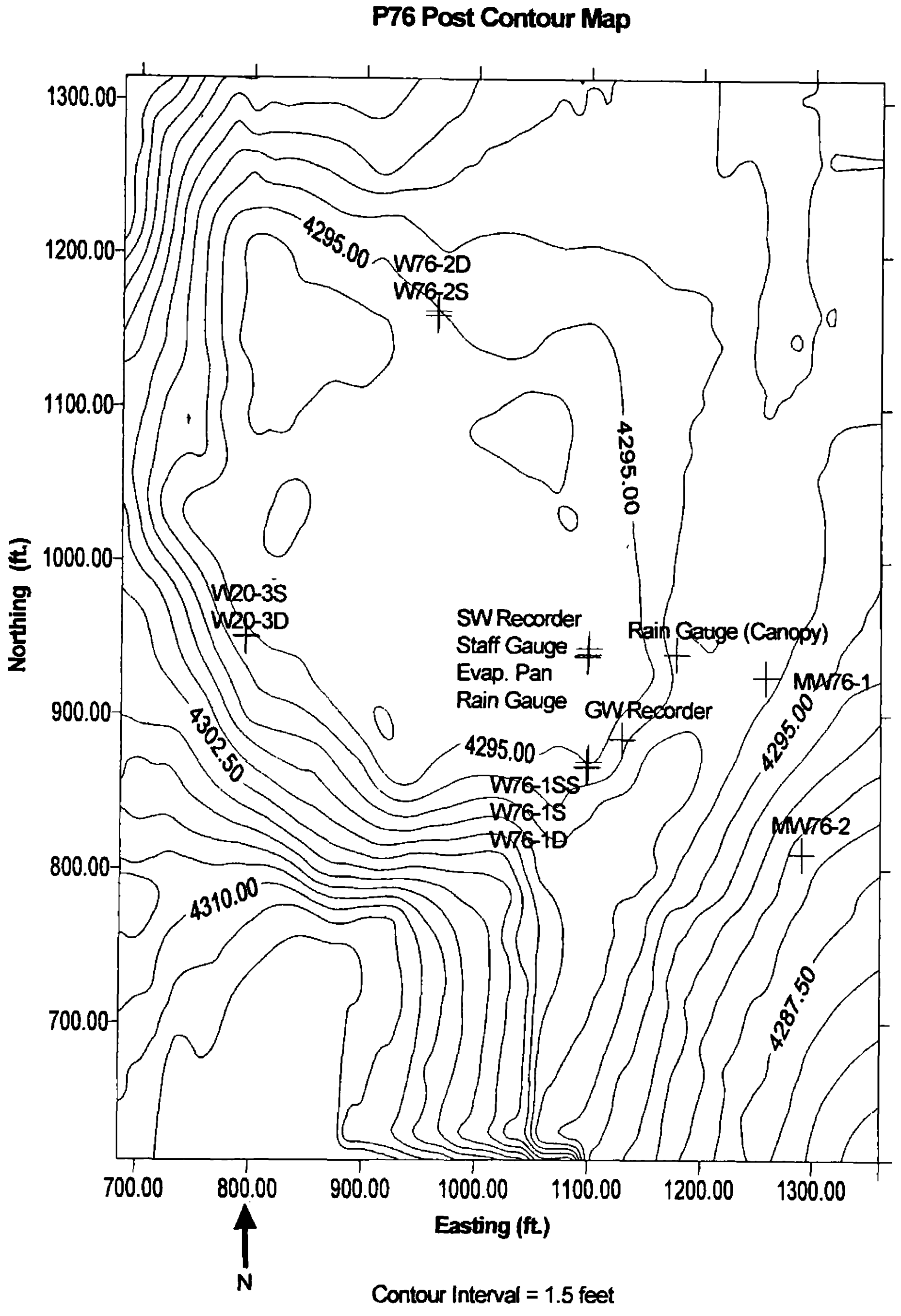
Post contour map of Beaver Creek (P45) wetland showing positions of wetland instrumentation.



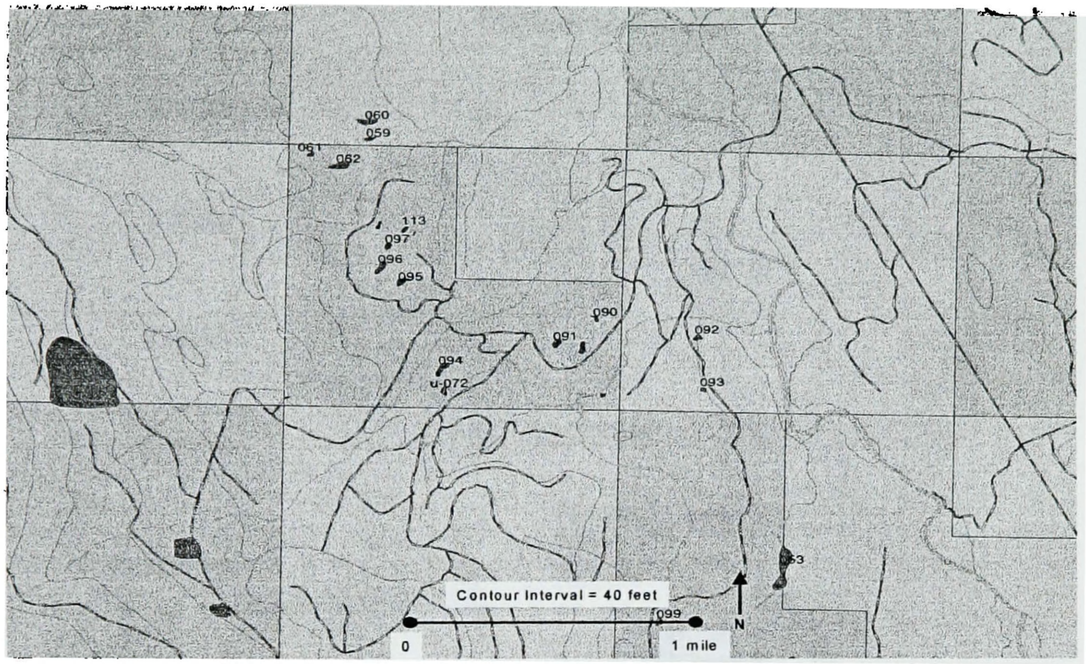
Holland Lake (P76, labeled O76) wetland cluster map.



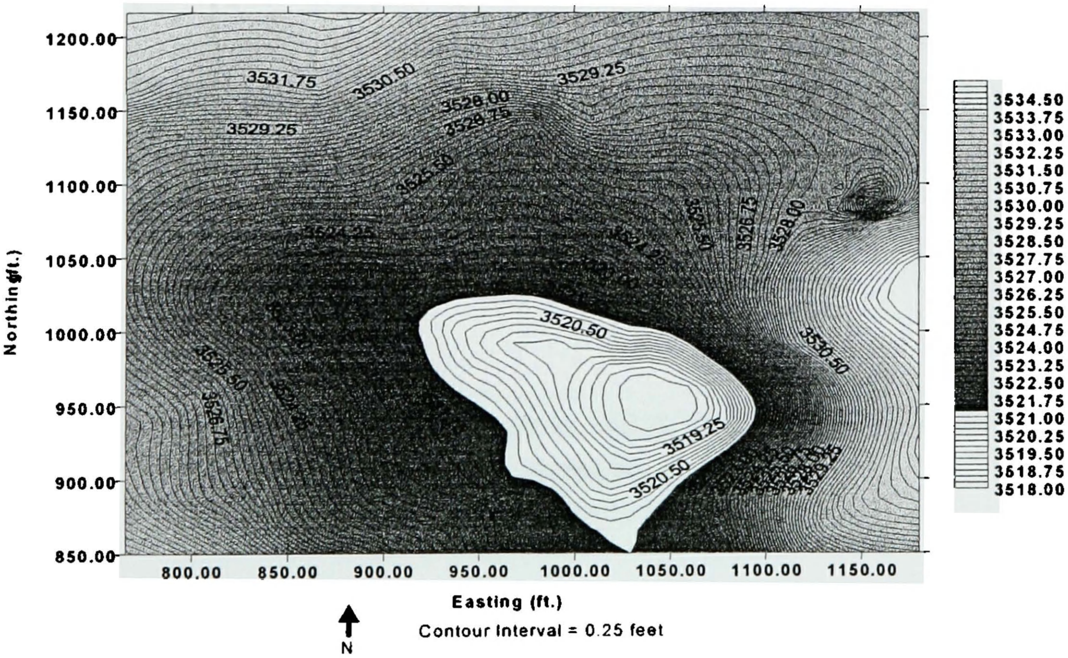
Surface map of Holland Lake (P76) wetland. Location of wetland is shown by transparent area. All units are in feet.



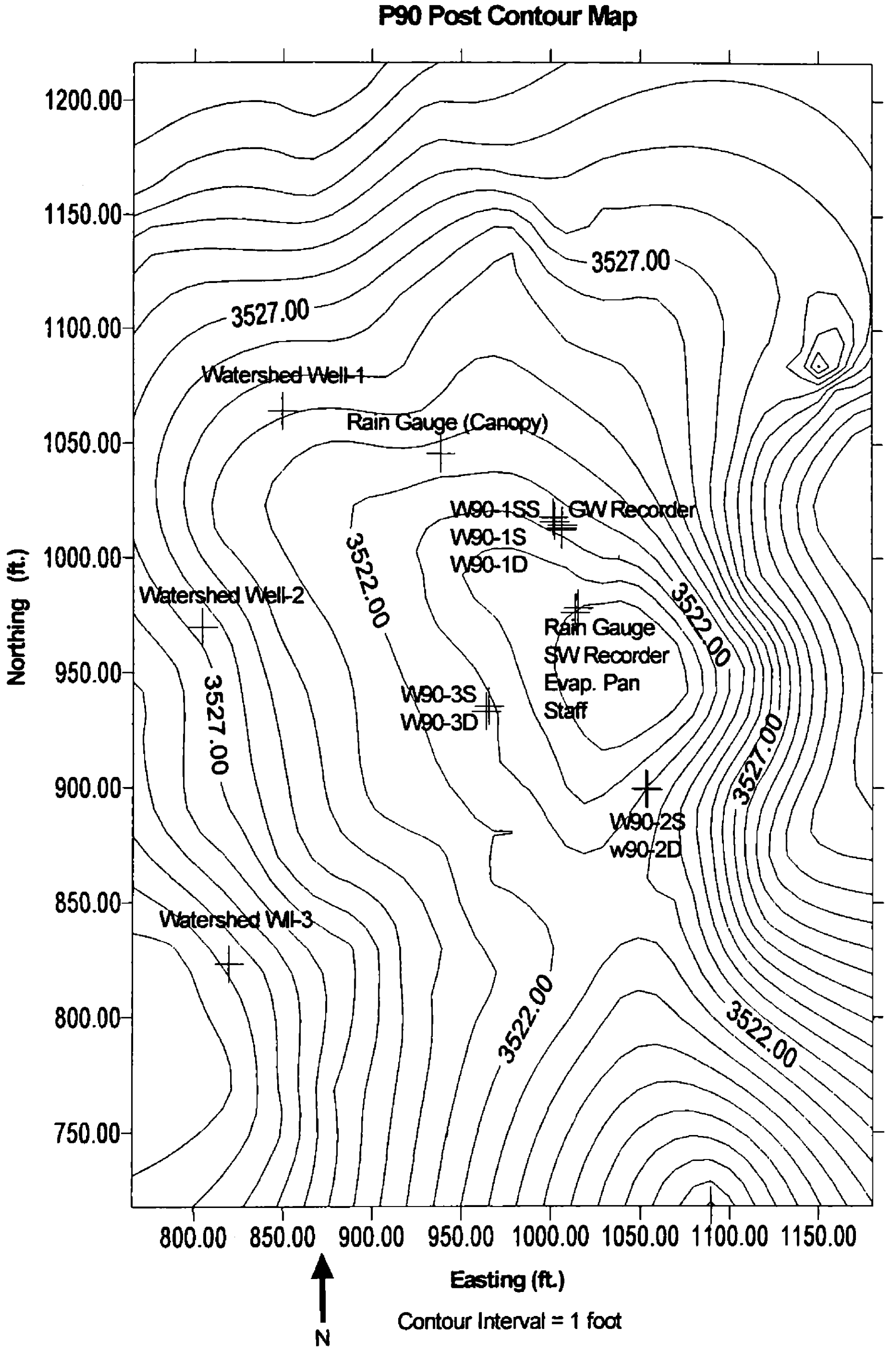
Post contour map of Holland Lake (P76) wetland showing positions of wetland instrumentation.



Piper Creek (P90-91, labeled O90-91) wetland cluster map.

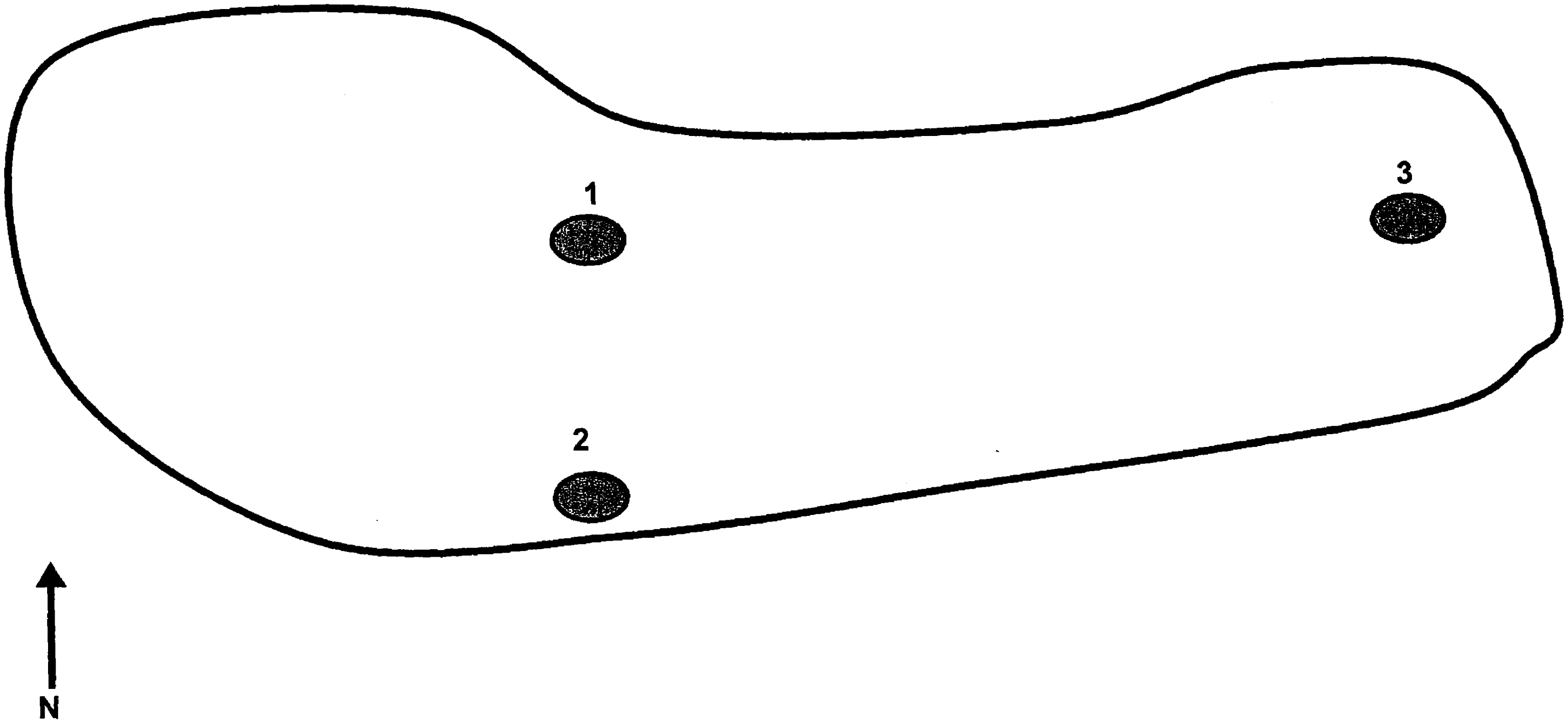


Surface map of Piper Creek (P90) wetland. Location of wetland is shown by transparent area. All units are in feet.

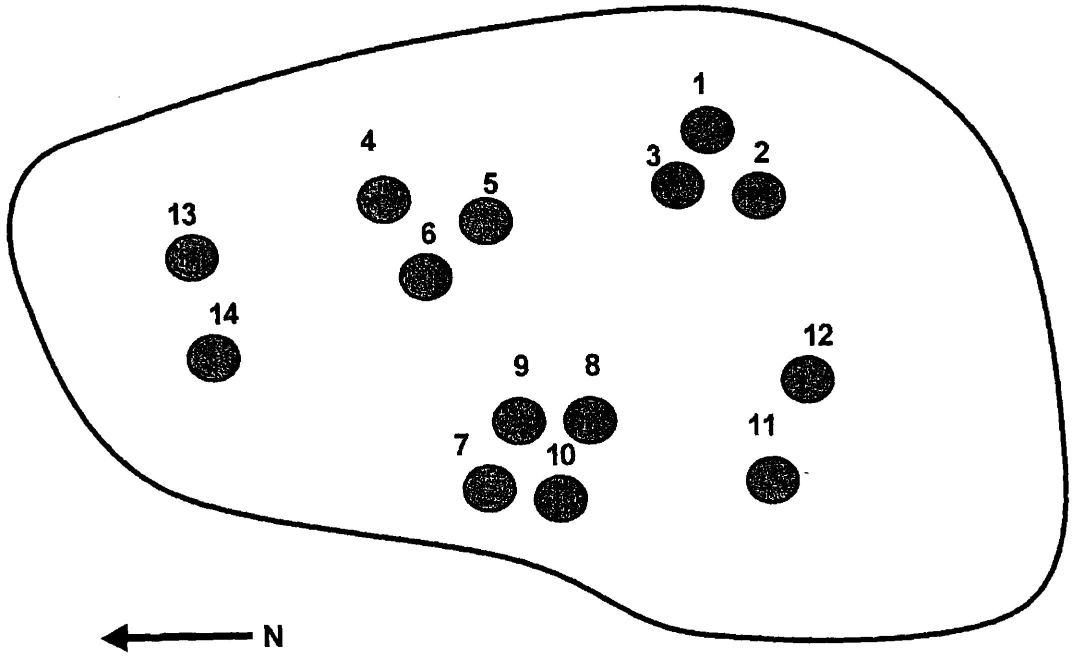


Post contour map of Piper Creek (P90) wetland showing positions of wetland instrumentation.

Approximate locations for seepage meters in the Beaver Creek (P45) wetland during the 1999 field season. Figure is not to scale.



Approximate location for seepage meters in the Piper Creek (P90) wetland during the 2000 field season. Figure is not to scale.



APPENDIX B

WATER BALANCE CALCULATIONS

P20 Condon Snow Survey, 3/4/00

Yardstick Measurements (inches)

9	22	8.5	2	10	
10	8	8.5	6	12	
3	5	13	4.5	9.5	
6	8	14.5	7	7	
11	12	8.5	14		
14	9	5	15		
18	14	2	16		
11	8	8	11		
9	9	10	18		
13	11	6	10		
15	10	3	9		
15	9.5	2	2.5		
9	6	6.5	5	**mean =**	**9**

surface area of watershed = 189219 ft^2

surface area of wetland = 60000 ft^2

P45 Snow Survey, 3/11/00

Yardstick Measurements (inches)

Pond			**Basin**		
11	23		4	3	
15	24		4	7	
16	24		9	16	
15.5	26		4	16	
17	26		12	11	
20	21		9	17	
18	27		7	13	
19	20		10	4	
22	24		13	10	
23	25		8	14	
	mean =	**21**		**mean =**	**10**

surface area of watershed = 309501 ft^2

surface area of wetland = 57147 ft^2

P76 Snow Survey, 3-4/00

surface area of watershed = 258414 ft^2
surface area of wetland = 96090 ft^2

Yardstick Measurements (inches)

Pond	
17	20
18	19
25	26
19.5	21
27	22
17	22
17	24
17	23

pond mean = 21 "

Basin			
9	16	9	8.5
8	13	7	8
10	8	11	5
1.5	6	9	9
4	6	8.5	
12	6	4	
12	2	12	
8	5	15	
5	9	9	
15	6	4	
11	5	6	

basin mean = 8 "

P90 Snow Survey, 3/4/00

Yardstick Measurements (inches)

20	8	14	15
18	5	7	13
15	9	11	18
15	4	3	19
13	11	9	18
18	10	12	17
19	14	14	13
16	18	13	23
4	13	12	14
4	20	7	15
8	14	11	

mean = 13 "

surface area of watershed = 152499 ft^2
snow input volume = 81865 ft^3

P20-Condon Water Balance 1999 Field Season

Date	Water Balance Period (days)	Precipitation (ft^3)	Evaporation (ft^3)	Transpiration (ft^3)	Change in Pond Volume (ft^3)	Net GW Inflow (ft^3)	Net GW Inflow (ft^3/d)
6/17-6/28	9	1000	600	1700	-1700	400	40
6/28-7/6	8	1500	500	1200	0	200	30
7/6-7/15	9	30	800	1100	-3500	1600	200
7/15-7/27	12	0	1100	2100	-3000	200	20
7/27-8/2	6	0	500	no data	-4100	no data	no data
8/2-8/11	9	160	0	5400	-2800	2400	300
8/11-8/19	8	500	1300	1300	-1500	600	80
8/19-8/26	7	0	400	400	-2200	1400	200

P20-Condon Water Balance 2000 Field Season

Date	Water Balance Period (days)	Precipitation (ft^3)	Evaporation (ft^3)	Transpiration (ft^3)	SW Out (ft^3)	Change in Pond Volume (ft^3)	Net GW Inflow (ft^3)	Net GW Inflow (ft^3/day)
04/30/00-05/16/00	16	500	900	2300	25200	-8300	19600	1200
05/16/00-05/23/00	7	60	800	1700	13300	-1500	14200	2000
05/23/00-06/20/00	28	3600	2400	11400	1300	-3000	8500	300
06/20/00-07/07/00	17	2000	2000	3200	2600	-3000	2800	200
07/07/00-07/25/00	18	0	2600	3000	2800	-7500	900	50
07/25/00-08/16/00	22	0	1800	5400	700	-7600	300	10

P45-Beaver Creek Water Balance 1999 Field Season

Date	Water Balance Period (days)	Precipitation (ft^3)	Evaporation (ft^3)	Transpiration (ft^3)	Change in Pond Volume (ft^3)	Net GW Inflow (ft^3)	Net GW Inflow (ft^3/day)
6/7-6/17	9	2400	5000	13100	-6600	9100	1000
6/17-6/28	11	4900	100	23000	-6300	11900	1100
6/28-7/6	8	5100	0	no data	-1500	no data	no data
7/6-7/15	9	0	9700	12600	-12200	10100	1100
7/15-7/27	13	1300	3400	28400	-11000	19500	1500
7/27-8/2	6	0	2500	11300	-7500	6300	1000
8/2-8/11	9	30	30	16800	-7900	8900	1000
8/11-8/19	8	1000	500	8100	-3000	4600	600
8/19-8/26	7	200	2100	7200	-4600	4500	600
8/26-9/6	11	400	800	12600	-2800	10200	900

P45-Beaver Creek Water Balance 2000 Field Season

Date	Water Balance Period (days)	Precipitation (ft^3)	Evaporation (ft^3)	Transpiration (ft^3)	Change in Pond Volume (ft^3)	Net GW Inflow (ft^3)	Net GW Inflow (ft^3/day)
06/01/00-06/23/00	22	5900	9100	37500	-15400	25300	1200
06/23/00-07/19/00	26	3200	10600	41500	-28400	20500	800
07/19/00-07/27/00	8	0	3600	11400	-10000	5000	600
07/27/00-08/16/00	20	0	4900	21700	-15600	1100	600

P76-Holland Lake 1999 Field Season

Date	Water Balance Period (days)	Precipitation (ft^3)	Evaporation (ft^3)	Transpiration (ft^3)	Change in Pond Volume (ft^3)	Net GW Inflow (ft^3)	Net GW Inflow (ft^3/day)
6/17-6/28	11	7400	5400	29100	-900	26200	2400
6/28-7/6	8	9400	2600	23700	0	16900	2100
7/6-7/15	9	30	8600	17500	-14700	11400	1300
7/15-7/27	13	800	7600	41400	-16600	31600	2400
7/27-8/2	6	0	3400	15900	-9200	10100	1700
8/2-8/11	9	80	3600	15900	-8200	11200	1200

P76-Holland Lake Water Balance 2000 Field Season

Date	Water Balance Period (days)	Precipitation (ft^3)	Evaporation (ft^3)	Transpiration (ft^3)	Change in Pond Volume (ft^3)	Net GW Inflow (ft^3)	Net GW inflow (ft^3/day)
05/16/00-05/23/00	7	40	8000	9300	-6900	10400	1500
05/23/00-06/23/00	31	23500	19700	100700	-8700	88200	2800
06/23/00-07/10/00	17	6100	10500	42600	-17800	29200	1700
07/10/00-08/01/00	28	0	14300	19400	-40300	6600	200

P90-Piper Creek Water Balance 1999 Field Season

	Water Balance				Change in	Net GW	Net GW
Date	Period	Precipitation	Evaporation	Transpiration	Pond Volume	inflow	inflow
	(days)	(ft^3)	(ft^3)	(ft^3)	(ft^3)	(ft^3)	(ft^3/day)
6/17-6/28	11	700	1300	6900	-2400	5100	500
6/28-7/6	8	1100	300	5200	-500	3900	500
7/6-7/15	9	20	1000	no data	-4100	no data	no data
7/15-7/27	13	20	no data	no data	-3800	no data	no data
7/27-8/2	6	0	no data	no data	-1700	no data	no data
8/2-8/11	9	100	0	2400	-1200	1100	100
8/11-8/19	8	200	no data	no data	-500	no data	no data
8/19-8/26	7	0	200	1600	-300	1500	200
8/26-9/6	11	80	60	2400	-100	2300	200

P90-Piper Creek 2000 Field Season

Date	Water Balance					Change in	Net GW	Net GW
	Period	Precipitation	Evaporation	Transpiration	SW Out	Pond Volume	Inflow	Inflow
	(days)	(ft^3)	(ft^3)	(ft^3)	(ft^3)	(ft^3)	(ft^3/day)	(ft3/day)
04/08/00-04/30/00	22	3600	5600	2500	67900	-3000	69400	3200
04/30/00-05/14/00	14	800	1600	8500	43200	-4500	48000	3400
05/14/00-05/23/00	9	200	700	6900	DRY	-2600	4800	500
05/23/00-06/20/00	28	3200	2000	18300	DRY	-3900	13200	500
06/20/00-06/29/00	9	300	600	4600	DRY	-3500	1400	200
06/29/00-07/10/00	11	800	1000	6500	DRY	-3200	3500	300
07/10/00-07/17/00	7	0	700	2800	DRY	-3200	300	40
07/17/00-07/27/00	10	60	900	4900	DRY	-3600	2100	200
07/27/00-08/01/00	5	0	300	1600	DRY	-1400	500	100
08/01/00-08/16/00	15	40	700	4000	DRY	-2500	2200	100

Precipitation 1999 Field Season

RG_C = rain gage in canopy
RG_P = rain gage in pond
np = no precipitation

Diameter Funnel 5.875 inches
Diameter RG 6.625 inches
Area RG (using 27.11 in^2
funnel dia.)

Precipitation P20 1999 Field Season

Condon P20							**Volumetric**
	Time Since					**Surface Area**	**Input into**
Date	**27-May**	**RG_C**	**RG_P**	**RG_P**	**RG_P (ht.)**	**of Wetland**	**Wetland**
	(days)	(ml)	(ml)	(in^3)	(in.)	(ft^2)	(ft^3)
5/27/99	0					15680	no data
6/7/99	11	446	425	25.94	0.96	15374	1200
6/17-6/18/99	21	40	75	4.58	0.17	14061	200
6/28-6/29/99	32	218	307	18.73	0.69	12426	700
7/6-7/7/99	39	265	510	31.12	1.15	11669	1100
7/15-7/16/99	47	3	9	0.55	0.02	10333	20
7/19-7/20/99	51	no data	no data			no data	no data
7/27-7/28/99	59	0	13	0.79	0.03	7786	20
8/2-8/3/99	65	0	0	0.00	0.00	5564	0.00
8/11/99	74	80	156	9.52	0.35	4210	100
8/19/99	82	334	364	22.21	0.82	3542	200
8/26/99	89	0	0	0.00	0.00	3198	0.00
9/6/99	100	94	140	8.54	0.32	2982	80
9/11/99	105	0	25	1.53	0.06	no data	no data
9/17/99	111	0	0	0.00	0.00	no data	no data
10/2/99	126	353	424	25.85	0.95	no data	no data

Precipitation P45 1999 Field Season

Beaver Creek P45							Volumetric
	Time Since					Surface Area	Input Into
Date	27-May	RG$_C$	RG$_P$	RG$_P$	RG$_P$ (ht.)	of Wetland	Wetland
	(days)	(ml)	(ml)	(in^3)	(in.)	(ft^2)	(ft^3)
5/27/99	0					57063	no data
6/7/99	11	149	319	19.47	0.72	56369	3400
6/17-6/18/99	21	118	234	14.28	0.53	54657	2400
6/28-6/29/99	32	196	500	30.51	1.13	52600	4900
7/6-7/7/99	39	315	535	32.65	1.20	51298	5100
7/15-7/16/99	47	0	0	0.00	0.00	48738	0.00
7/19-7/20/99	51	No rain gage measurements		0.00	0.00	46346	no data
7/27-7/28/99	59	112	154	9.40	0.35	43979	1300
8/2-8/3/99	65	0	0	0.00	0.00	39286	0.00
8/11/99	74	0	5	0.31	0.01	34091	32
8/19/99	82	178	216	13.18	0.49	24732	1000
8/26/99	89	25	40	2.44	0.09	25559	190
9/6/99	100	36	99	6.04	0.22	20347	400
9/11/99	105	15	0	0.00	0.00	no data	no data
9/17/99	111	0	0	0.00	0.00	no data	no data
10/2/99	126	282	212	12.93	0.48	no data	no data

Precipitation P76 1999 Field Season

Holland Lake P76							**Volumetric**
	Time Since					**Surface Area**	**Input into**
Date	**27-May**	**RG$_C$**	**RGP**	**RGP**	**RGP (ht.)**	**of Wetland**	**Wetland**
	(days)	(ml)	(ml)	(in^3)	(in.)	(ft^2)	(ft^3)
5/27/99	0					96052	
6/7/99	11	276	468	28.56	1.05	96052	8400
6/17-6/18/99	21	188	264	16.11	0.59	95077	4700
6/28-6/29/99	32	355	417	25.45	0.94	93978	7400
7/6-7/7/99	39	445	535	32.65	1.20	93854	9400
7/15-7/16/99	47	0	2	0.12	4.50E-03	91783	30
7/19-7/20/99	51	no data		0.00	0.00	89018	no data
7/27-7/28/99	59	0	51	3.11	0.11	81401	800
8/2-8/3/99	65	0	0	0.00	0.00	65402	0
8/11/99	74	1	9	0.55	0.02	47951	80
8/19/99	82	180	228	13.91	0.51	34831	1500
8/26/99	89	62	162	9.89	0.36	no data	no data
9/6/99	100	12	86	5.25	0.19	no data	no data
9/11/99	105	np	0	0.00	0.00	no data	no data
9/17/99	111	0	0	0.00	0.00	no data	no data
10/2/99	126	75	140	8.54	0.32	no data	no data

Precipitation P90 1999 Field Season

Piper Creek P90							Volumetric
	Time Since					Surface Area	Input Into
Date	27-May	$\mathrm{RG_C}$	$\mathrm{RG_P}$	$\mathrm{RG_P}$	$\mathrm{RG_P}$ (ht.)	of Wetland	Wetland
	(days)	(ml)	(ml)	(in^3)	(in.)	(ft^2)	(ft^3)
5/27/99	0	no data	no data			18231	no data
6/7/99	11	425	446	27.22	1.00	17142	1400
6/17-6/18/99	21	45	132	8.06	0.30	15720	400
6/28-6/29/99	32	278	340	20.75	0.77	15185	1000
7/6-7/7/99	39	405	530	32.34	1.19	14981	1500
7/15-7/16/99	47	5	12	0.73	0.03	14522	30
7/19-7/20/99	51	no data	no data	0.00		no data	no data
7/27-7/28/99	59	0	0	0.00	0.00	13616	0.00
8/2-8/3/99	65	0	0	0.00	0.00	12420	0.00
8/11/99	74	24	78	4.76	0.18	11050	200
8/19/99	82	260	265	16.17	0.60	10010	500
8/26/99	89	0	0	0.00	0.00	8738	0.00
9/6/99	100	77	124	7.57	0.28	no data	no data
9/11/99	105	0	0	0.00	0.00	no data	no data
9/17/99	111	0	0	0.00	0.00	no data	no data
10/2/99	126	35	106	6.46	0.24	no data	no data

P20 Precipitation 2000 Field Season

Condon P20							Volumetric
	Time Since					Surface Area	Input into
Date	4-Mar	RG_C	RG_P	RG_P	RG_P (ht.)	of Wetland	Wetland
	(days)	(ml)	(ml)	(in^3)	(in.)	(ft^2)	(ft^3)
05/16/00	74	87	160	9.76	0.36	17794	500
05/23/00	81	14	20	1.22	0.05	16959	60
06/20/00	108	on ground	1180	72.01	2.66	16425	3600
07/07/00	125	450	680	41.50	1.53	15739	2000
07/25/00	143	0	0	0.00	0.00	14383	0
08/16/00	165	0	37	2.26	0.08	11877	0
09/21/00	201	445	625	38.14	1.41	no data	no data

P45 Precipitation 2000 Field Season

Beaver Creek P45							Volumetric
	Time Since					Surface Area	Input into
Date	4-Mar	RG_C	RG_P	RG_P	RG_P (ht.)	of Wetland	Wetland
	(days)	(ml)	(ml)	(in^3)	(in.)	(ft^2)	(ft^3)
05/14/00	72	898	1690	103.13	3.80	60137	19100
05/23/00	81	0	2	0.12	0.00	59203	20
06/01/00	89	332	423	25.81	0.95	57925	4600
07/19/00	137	47	363	22.15	0.82	47148	3200
07/27/00	145	0	0	0.00	0.00	38394	0
08/16/00	165	0	0	0.00	0.00	26752	0
9/21/00	201	242	470	28.68	1.06	no data	no data

P76 Precipitation 2000 Field Season

Holland Lake P76							Volumetric
	Time Since					Surface Area	input into
Date	4-Mar	RG_C	RGP	RGP	RGP (ht.)	of Wetland	Wetland
	(days)	(ml)	(ml)	(in^3)	(in.)	(ft^2)	(ft^3)
04/30/00	57	960	753	45.95	1.70	102652	14500
05/16/00	74	230	260	15.87	0.59	100710	4900
05/23/00	81	0	2	0.12	0.00	99033	40
06/23/00	111	1051	1290	78.72	2.90	97108	23500
07/10/00	128	330	345	21.05	0.78	93681	6100
08/01/00	150	0	0	0.00	0.00	72254	0
08/16/00	165	0	0	0.00	0.00	no data	no data
09/13/00	193	245	270	16.48	0.61	no data	no data

P90 Precipitation 2000 Field Season

Piper Creek							Volumetric
		Time Since				Surface Area	input into
Date	4-Mar	RG_C	RGP	RGP	RGP (ht.)	of Wetland	Wetland
	(days)	(ml)	(ml)	(in^3)	(in.)	(ft^2)	(ft^3)
04/30/00	57	855	932	56.87	2.10	20720	3600
05/14/00	72	190	205	12.51	0.46	19522	800
05/23/00	81	20	60	3.66	0.14	17554	200
06/20/00	108	965	1102	67.25	2.48	15645	3200
06/29/00	117	96	119	7.26	0.27	13577	300
07/10/00	128	325	355	21.66	0.80	11782	800
07/17/00	135	0	0			9962	0
07/27/00	145	0	34	2.07	0.08	8707	60
08/01/00	150	0	0	0.00	0.00	5796	0
08/16/00	165	5	54	3.30	0.12	3957	40
09/13/00	193	490	505	30.82	1.14	no data	no data

Wetland ET Calculation P20 Condon 1999 Field Season

Date	Hydrograph	Pond Area	Time Period	ET	ET
	Change (avg.)		for ET		
	(ft/d)	(ft2)	(days)	(ft3)	(ft3/d)
6/17-6/28	0.015	15185	11	2506	200
6/28-7/6	0.013	14981	8	1558	200
7/6-7/15	0.014	14522	9	1830	200
7/15-7/27	0.018	13616	13	3186	200
7/27-8/2	no data	12420	6	no data	no data
8/2-8/11	0.026	11050	9	2586	300
8/11-8/19	0.021	10010	8	1682	200
8/19-8/26	0.024	8738	7	1468	200

Wetland ET Calculation P45 Beaver Creek 1999 Field Season

Date	Hydrograph	Pond Area	Time Period	ET	ET
	Change (avg.)		for ET		
	(ft/d)	(ft2)	(days)	(ft3)	(ft3/d)
6/7-6/17	0.037	54657	9	18037	2000
6/17-6/28	0.040	52600	11	23144	2100
6/28-7/6	no data	51298	8	no data	no data
7/6-7/15	0.051	48737.5	9	22297	2500
7/15-7/27	0.056	43979	13	31802	2500
7/27-8/2	0.058	39285.5	6	13750	2300
8/2-8/11	0.055	34091	9	16875	1900
8/11-8/19	0.043	24731.5	8	8574	1100
8/19-8/26	0.052	25559	7	9281	1300
8/26-9/6	0.060	20347	11	13429	1200

Wetland ET Calculation P76 Holland Lake 1999 Field Season

Date	Hydrograph	Pond Area	Time Period	ET	ET
	Change (avg.)		for ET		
	(ft/d)	(ft2)	(days)	(ft3)	(ft3/d)
6/17-6/28	0.033	93978	11	34459	3133
6/28-7/6	0.035	93854	8	26279	3285
7/6-7/15	0.032	91783	9	26158	2906
7/15-7/27	0.046	81401	13	48942	3765
7/27-8/2	0.049	65402	6	19294	3216
8/2-8/11	0.045	47951	9	19420	2158

Wetland ET Calculation P90 Piper Creek 1999 Field Season

Date	Hydrograph	Pond Area	Time Period	ET	ET
	Change (avg.)		for ET		
	(ft/d)	(ft2)	(days)	(ft3)	(ft3/d)
6/17-6/28	0.060	12426	11	8201	700
6/28-7/6	0.058	11669	8	5446	700
7/6-7/15	no data	10333	9	no data	no data
7/15-7/27	0.061	7786	13	6174	500
7/27-8/2	0.062	5564	6	2066	300
8/2-8/11	0.063	4210	9	2392	300
8/11-8/19	0.079	3542	8	2243	300
8/19-8/26	0.078	3198	7	1735	200
8/26-9/6	0.074	2982	11	2433	200

Wetland ET Calculation P20 Condon 2000 Field Season

Date	Hydrograph Change (avg.) (ft/d)	Pond Area (ft2)	Time Period for ET (days)	ET (ft3)	ET (ft3/d)
04/30/00-05/16/00	0.011	17794	16	3203	200
05/16/00-05/23/00	0.021	16959	7	2473	400
05/23/00-06/20/00	0.030	16425	28	13797	500
06/20/00-07/07/00	0.019	15739	17	5184	300
07/07/00-07/25/00	0.022	14383	18	5663	300
07/25/00-08/16/00	0.028	11877	22	7186	300

Wetland ET Calculation P45 Beaver Creek 2000 Field Season

Date	Hydrograph Change (avg.) (ft/d)	Pond Area (ft2)	Time Period for ET (days)	ET (ft3)	ET (ft3/d)
06/01/00-06/23/00	0.038	55180	22	46535	2100
06/23/00-07/19/00	0.043	47148	26	52099	2000
07/19/00-07/27/00	0.049	38394	8	14974	1900
07/27/00-08/16/00	0.050	26752	20	26585	1300

Wetland ET Calculation P76 Holland Lake 2000 Field Season

Date	Hydrograph Change (avg.) (ft/d)	Pond Area (ft2)	Time Period for ET (days)	ET (ft3)	ET (ft3/d)
05/16/00-05/23/00	0.025	99033	7	17331	2500
05/23/00-06/23/00	0.040	97108	31	120414	3900
06/23/00-07/10/00	0.033	93681	17	53086	3100
07/10/00-08/01/00	0.017	72254	28	33719	1200

Wetland ET Calculation P90 Piper Creek 2000 Field Season

Date	Hydrograph Change (avg.) (ft/d)	Pond Area (ft2)	Time Period for ET (days)	ET (ft3)	ET (ft3/d)
04/08/00-04/30/00	0.005	22372	22	2461	0
04/30/00-05/14/00	0.037	19522	14	10078	700
05/14/00-05/23/00	0.048	17554	9	7636	800
05/23/00-06/20/00	0.046	15645	28	20339	700
06/20/00-06/29/00	0.043	13577	9	5193	600
06/29/00-07/10/00	0.058	11782	11	7560	700
07/10/00-07/17/00	0.051	9962	7	3545	500
07/17/00-07/27/00	0.067	8707	10	5805	600
07/27/00-08/01/00	0.065	5796	5	1884	400
08/01/00-08/16/00	0.079	3957	15	4705	300

Surface Area and Volume 1999 Field Season

	Days	P20	P20	P45	P45	P76	P76	P90	P90
Date	Since	Area	Volume	Area	Volume	Area	Volume	Area	Volume
	27-May	(ft^2)	(ft^3)	(ft^2)	(ft^3)	(ft^2)	(ft^3)	(ft^2)	(ft^3)
5/27/99	0	18231	34952	57053	72734	96052	73624	15680	20629
6/7/99	11	16052	26598	55675	68214	96052	73624	15067	16553
6/17-6/18/99	21	15388	23769	53639	61656	94102	66018	13054	15765
6/28-6/29/99	32	14981	22098	51561	55343	93854	65078	11797	13405
7/6-7/7/99	39	14981	22098	51035	53804	93854	65078	11541	12938
7/15-7/16/99	47	14063	18612	46440	41614	89711	50388	9124	8813
7/19-7/20/99	51	no data	no data	46251	41151	88325	45937	no data	no data
7/27-7/28/99	59	13169	15615	41518	30610	74476	29386	6448	5013
8/2-8/3/99	65	11671	11514	37053	23126	56328	20209	4680	3343
8/11/99	74	10429	8749	31129	15275	39574	12031	3739	2169
8/19/99	82	9590	7246	28334	12301	30037	8245	3344	1709
8/26/99	89	7885	5055	22784	7686	No SW	No SW	3054	1389
9/6/99	100	No SW	No SW	17910	4840	"	"	2910	1240

Surface Area and Volume 2000 Field Season

	Days	P20	P20	P45	P45	P76	P76	P90	P90
	Since	Area	Volume	Area	Volume	Area	Volume	Area	Volume
Date	4-Mar	(ft^2)	(ft^3)	(ft^2)	(ft^3)	(ft^2)	(ft^3)	(ft^2)	(ft^3)
03/04/00	0	17021	30728			95812	72665	11287	12482
03/11/00	7			33538	18186				
03/31/00	27					103787	106610	22432	32767
04/08/00	35							22312	32543
04/30/00	57	18431	39502			101517	96345	20720	29533
05/14/00	72			60137	82273			18323	25047
05/16/00	74	17157	31241			99902	89295		
05/23/00	81	16761	29715	58268	76760	98164	82365	16784	22413
06/01/00	89			57582	74443			15500	20317
06/20/00	108	16089	26759					14505	18518
06/23/00	111			52778	58995	96052	73625		
06/29/00	117							12649	14994
07/07/00	125	15388	23769						
07/10/00	128					91309	55819	10914	11816
07/17/00	135							9009	8632
07/19/00	137			41518	30610				
07/25/00	143	13377	16279						
07/27/00	145			35270	20595			6500	5078
08/01/00	150					53198	15569	5091	3682
08/16/00	165	10377	8645	18324	5021			2822	1154

Volunteer Precipitation Data

June

*Volunteer	Location in Swan Valley	Watershed (east-west)	Elevation (ft.)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Terrillion	Pierce Lake	East	4300	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	Start	0	0	0	no data	0
Don Erickson	Holland Creek	East	4000	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	Start	0.06	0.015	0.2	0.1	0	0	0	0.02	0.025	0	0	0	0	trace
Suzanne Vernon	~Loon Lake	West	4200	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	Start	0	0	0	0	0	0	0.05	0	0	0	0	0	0
Anne Dahl	Glacier Creek~2 mi South of SEC	West	3780	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	Start	0.7	no data	no data	no data	no data	no data	no data	0.51	0	0	0.05	0	0	0	0	0
Paula Clarke	~2 mi West of SEC	East	4000	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	Start	0	trace	0.35	0	0	0	0	0
Swan Ecosystem Center	~5 mi. South of Condon	Center	3684	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	Start	0.56	0.06	no data	no data	trace	0.6	0	0	0	0	0	0	0	0	0	0
Rod Ash	Condon Loop Rd.	East	3540	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data
Patricia Robinson-Grant	Salmon Prairie	West	3500	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	Start 0.25	0.04	0.1	0	0.2	0.14	0	0.05	0	0	0.09	0	0	0	0	0

July

Volunteer	Location in Swan Valley	Watershed (east-west)	Elevation (ft.)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Terrillion	Pierce Lake	East	4300	0	0	0.05	0	0	0.51	0.05	0.04	0.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	trace	0	0	0	0	0
Don Erickson	Holland Creek	East	4000	0	0	0.01	no data	0	0.62	0	0	0.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Suzanne Vernon	~Loon Lake	West	4200	0	0	0.07	0	0	0	0.7	0.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anne Dahl	Glacier Creek~2 mi South of SEC	West	3780	0	0	0.085	0	0	1.25	0.01	0.012	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paula Clarke	~2 mi West of SEC	East	4000	trace	0	1.2	0.03	no data	no data	0.2	trace	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Swan Ecosystem Center	~5 mi. South of Condon	Center	3684	0	0	0.105	0	0	1.25	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rod Ash	Condon Loop Rd.	East	3540	Start	0	0.11	0	0	0.72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Patricia Robinson-Grant	Salmon Prairie	West	3500	0	0	0.05	0.01	0	0.68	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

August

Volunteer	Location in Swan Valley	Watershed (east-west)	Elevation (ft.)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Terrillion	Pierce Lake	East	4300	0	0	0	0.03	0	0	0	0	0	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	trace	0
Don Erickson	Holland Creek	East	4000	0	0	0	0.04	0	0	0	0	0	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	trace	0	0	0	0	0	0	trace
Suzanne Vernon	~Loon Lake	West	4200	0	0	0	0	0	0	0	0	0	0	trace	0	0	0	0	0	0	0	0	0	0	0	0	trace	0	0	0	0	trace	0	0
Anne Dahl	Glacier Creek~2 mi South of SEC	West	3780	0	0	0	0.09	0	0	0	0	0	0	0.05	0	0	0	0	0	0	0	0	0	0	0		0.005	0	0	0	0.006	0	0.006	0
Paula Clarke	~2 mi West of SEC	East	4000																															
Swan Ecosystem Center	~5 mi. South of Condon	Center	3684	0	0	0	0.08	0	0	0	0	0	0	0.07	0	0	0	0	0	0	0	0	0	0	0	0	trace	0	0	0	0	trace	0	0
Rod Ash	Condon Loop Rd.	East	3540	0	0	0	0.1	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0.03	0
Patricia Robinson-Grant	Salmon Prairie	West	3500	0	0	0	0.07	0	0	0	0	0	trace	trace	0	0	0	0	0	0	0	0	0	0	0	0	trace	0	0	0	0.035	0	0.01	0

September

Volunteer	Location in Swan Valley	Watershed (east-west)	Elevation (ft.)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Terrillion	Pierce Lake	East	4300	0.11	0.15	0.05	0	trace	0.04	0.01	rain	0.05	0	0.21	0	0.005	0	trace	0	0	rain	0	rain	0.3	0.02	0	0	0	0	0	0	rain	rain all day	1.25
Don Erickson	Holland Creek	East	4000	0.11	0.15	0	trace	0	0	0	rain	rain	0.28 total	0	0	0	0	0	0	0	0.01	0	0	0.21	0	0	0	0	0	0	0	0.13	0.9	
Suzanne Vernon	~Loon Lake	West	4200	0.05	0.3	0	0	0	0	0	0	0	gone	gone	gone	gone	0.4	0	0	0	0.03	0	0	0.22	0	0	0	0	0	0	0	rain pm	rain all day	1.45

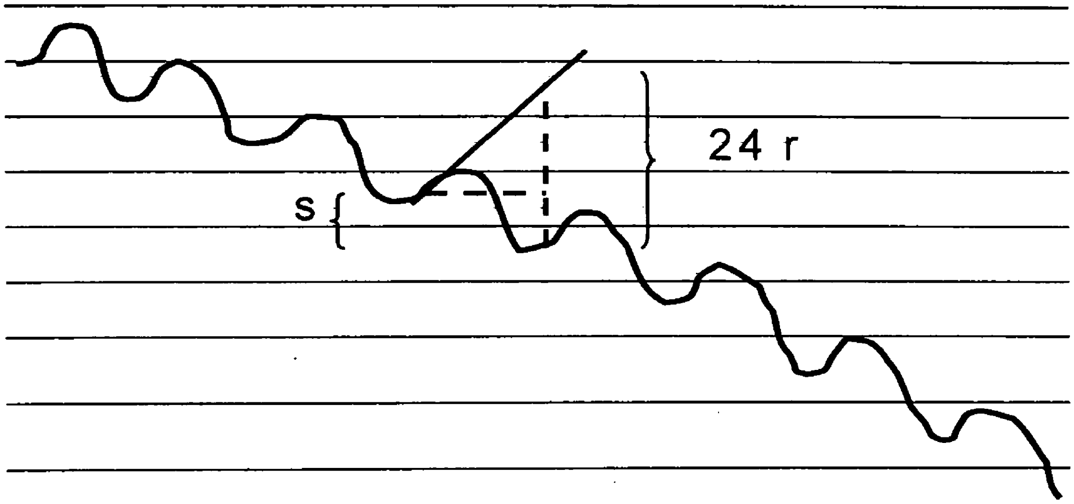
APPENDIX C

GROUNDWATER AND SURFACE WATER HYDROGRAPHS

Wetland Evapotranspiration Calculation

$$ET = 24r +/- s*Area_{wetland}*Sy$$

Sy for wetland = 1



Hydrograph Key

x-axis

1 full chart = 32 days

3 line interval = 1 day

each line interval = 8 hour

y-axis

1 full chart = 1 foot

bold lines = 0.1 feet

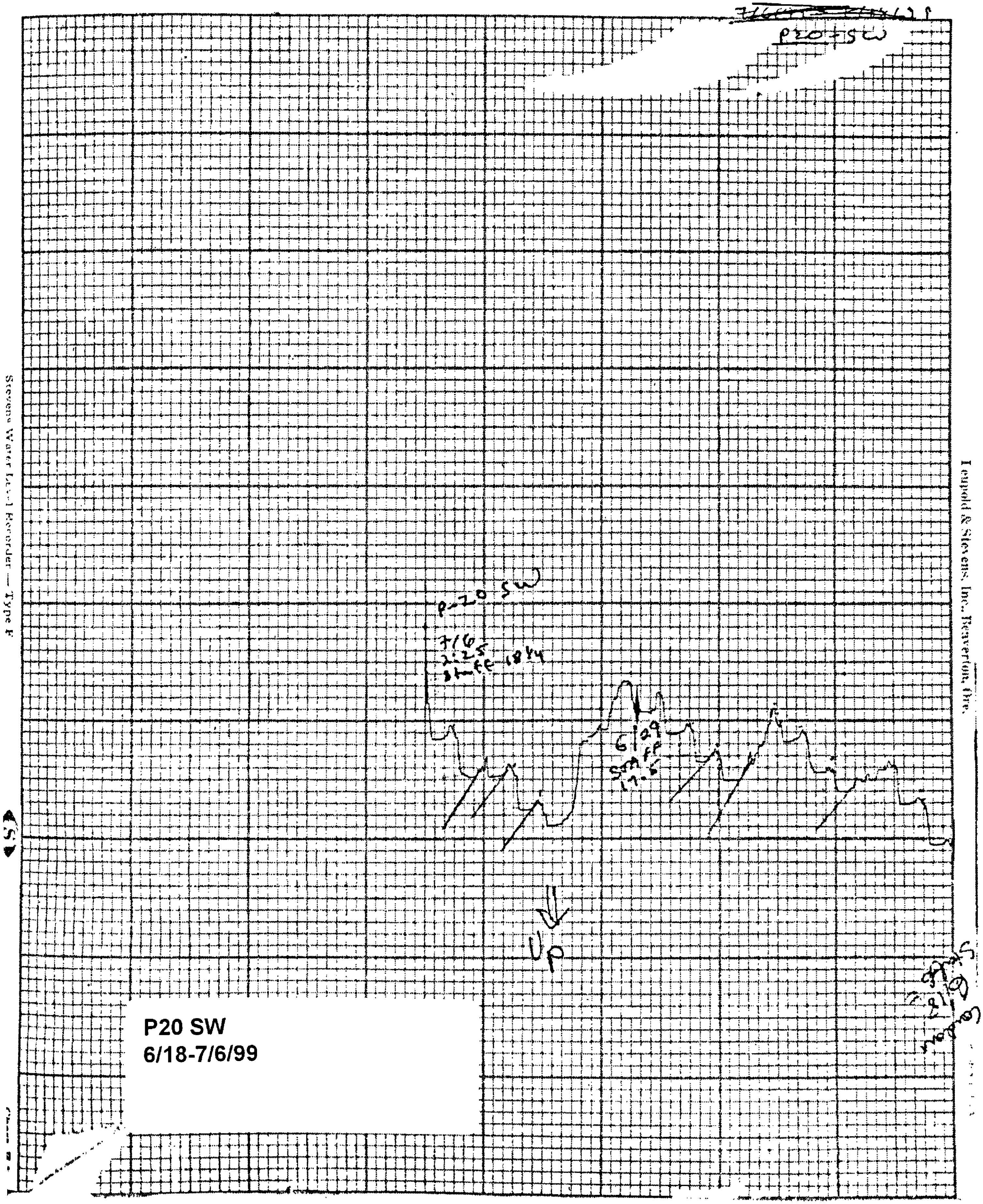
thin lines = 0.01 feet

1999 Field Season Hydrographs

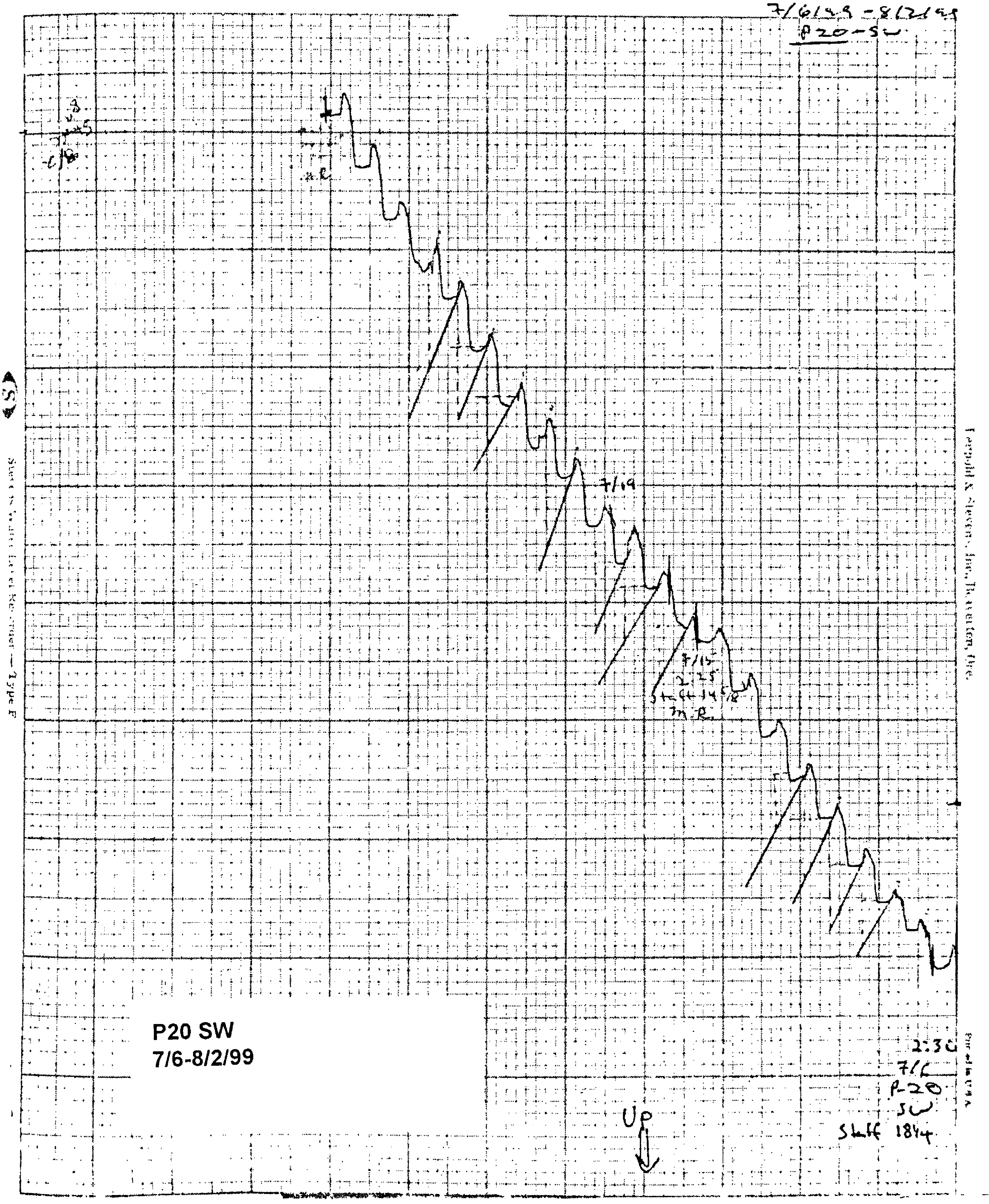
6/18/99 – 7/6/99

~~7/6/99~~

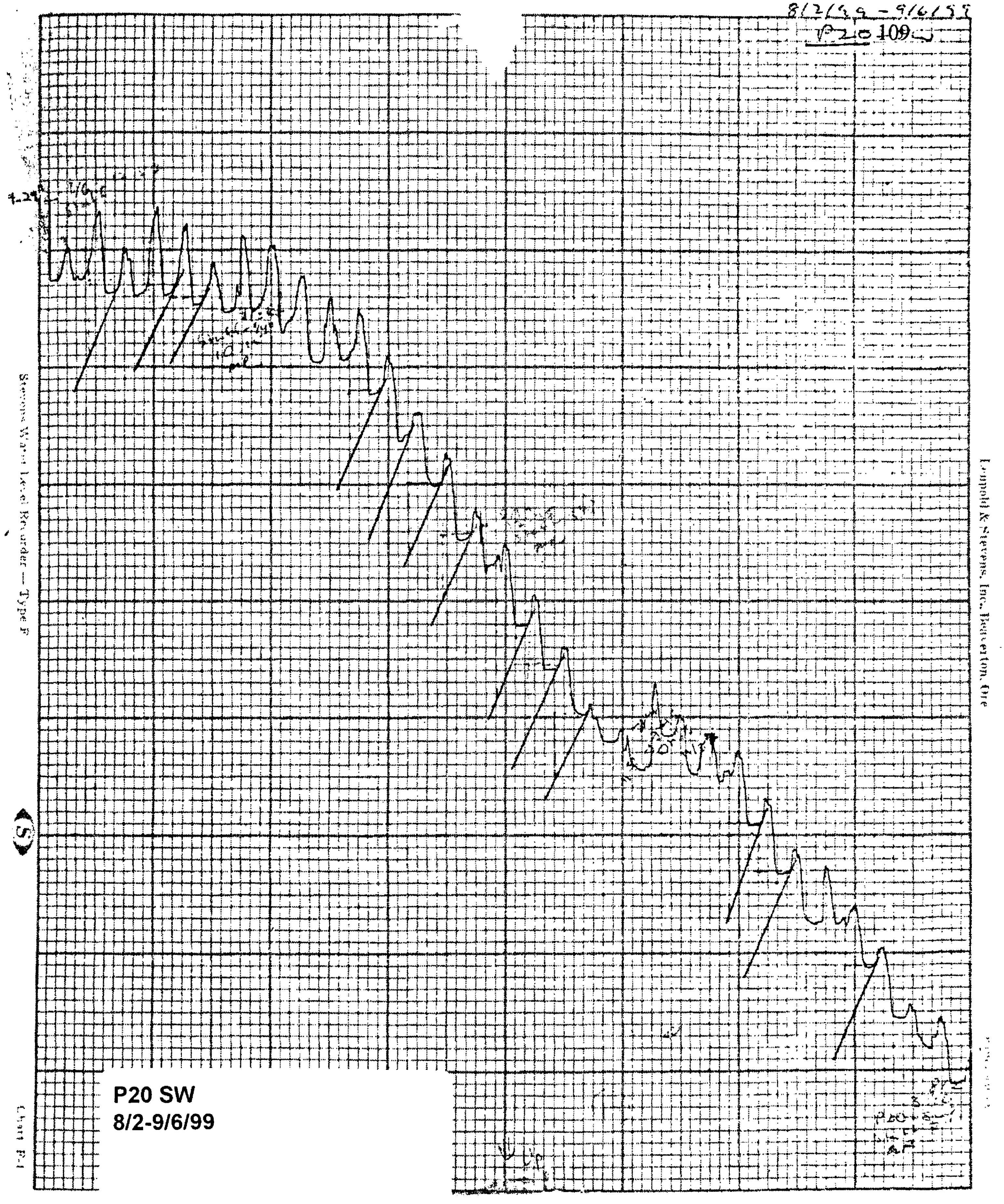
P20 SW



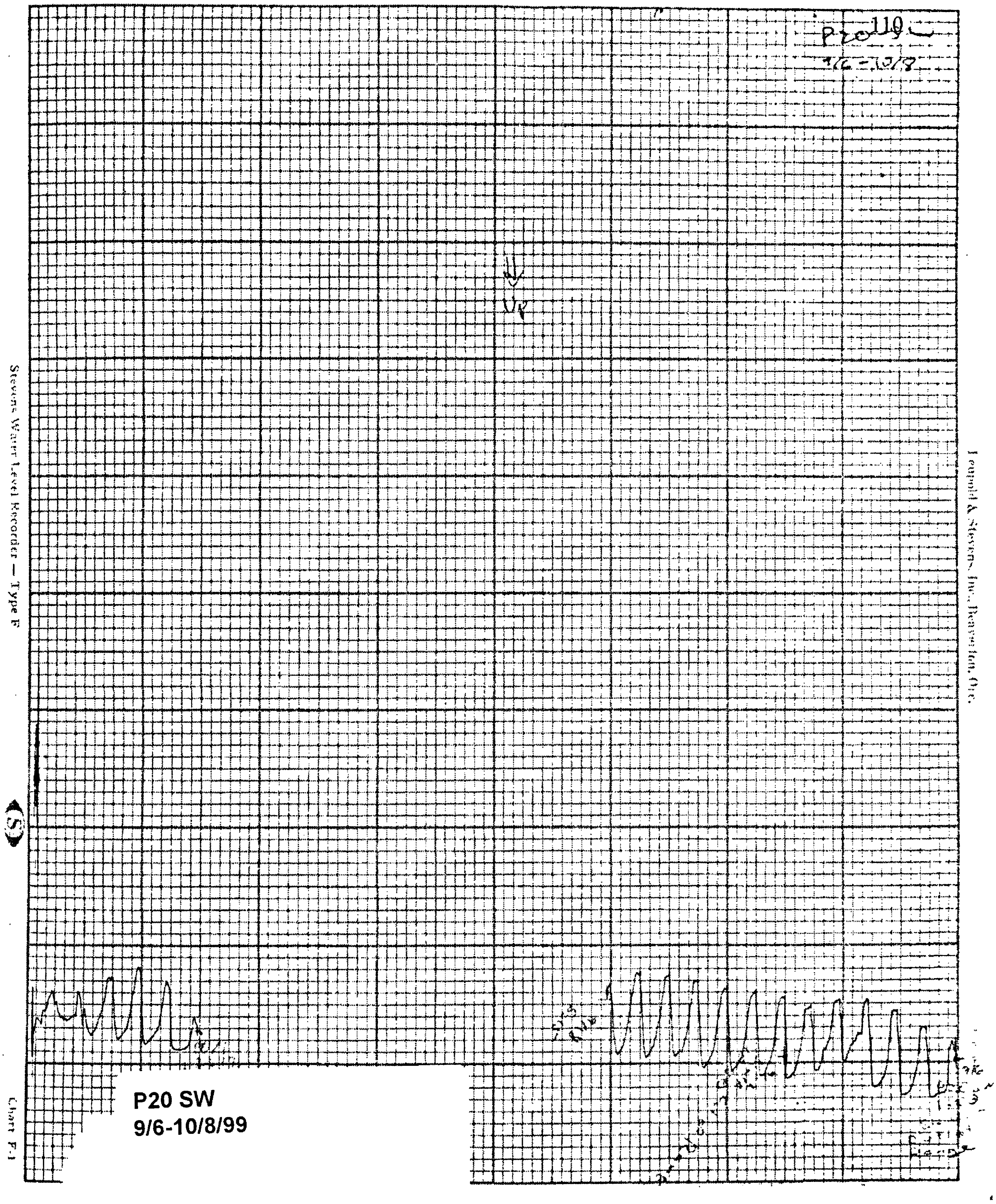
P20 SW
6/18-7/6/99



P20 SW
7/6-8/2/99

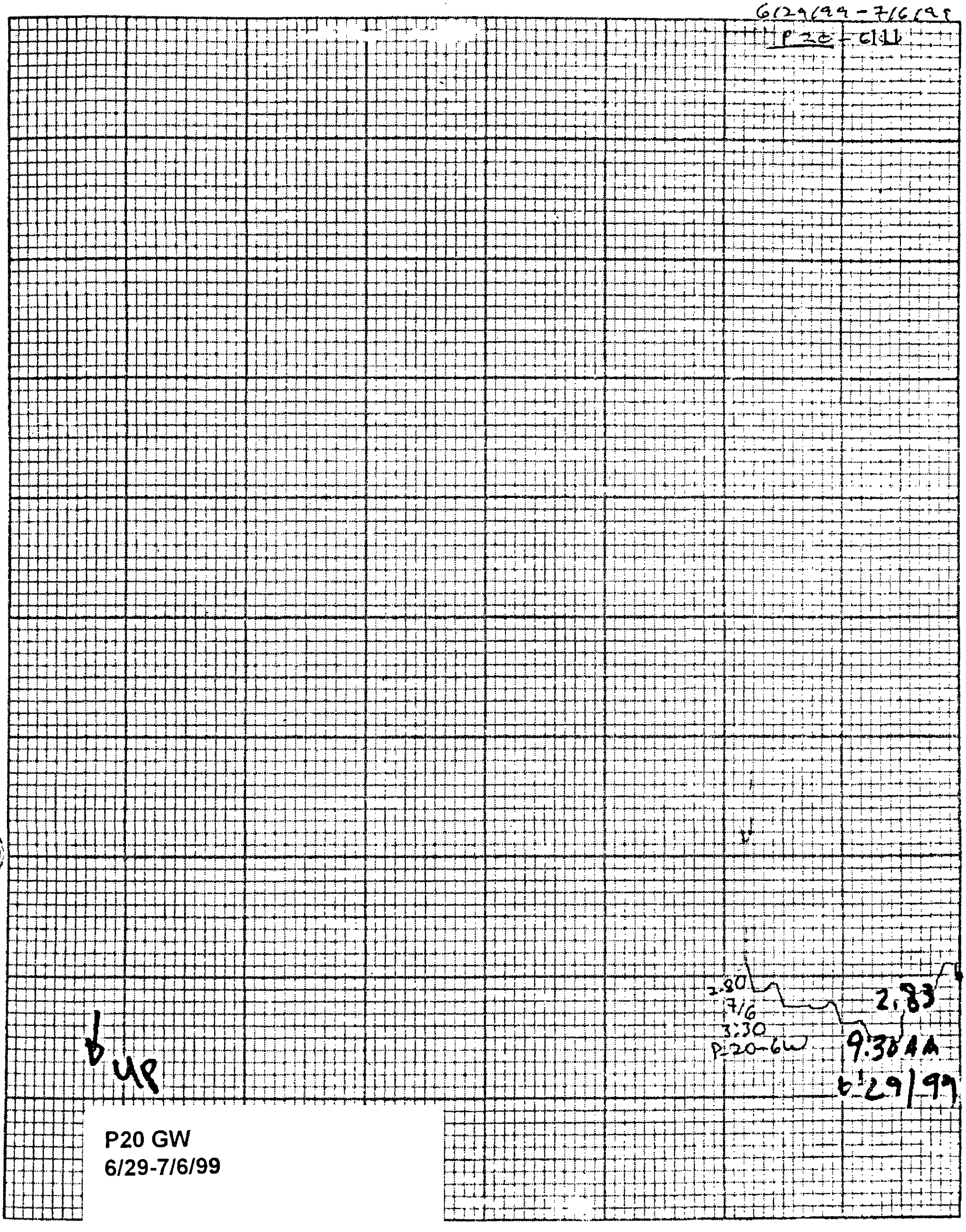


P20 SW
8/2-9/6/99

P20 110
9/6-10/8
Up
Stevens Water Level Recorder — Type F
Leupold & Stevens, Inc., Beaverton, Ore.
Chart F-1
P20 SW
9/6-10/8/99

6/29/99 - 7/6/99

P20 - GW

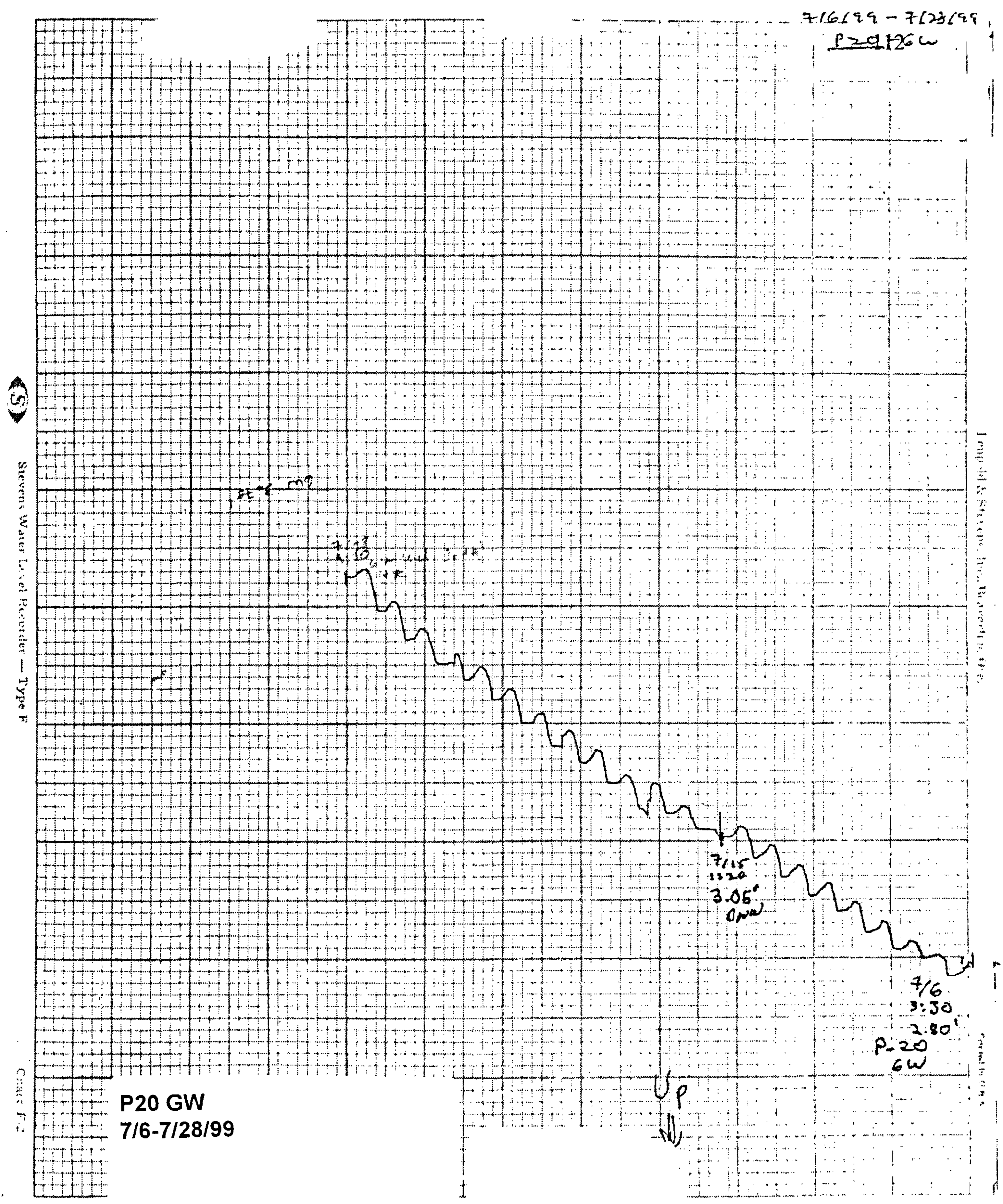


2.80
7/6
3:30
P-20-GW

2.83
9:30 AM
6/29/99

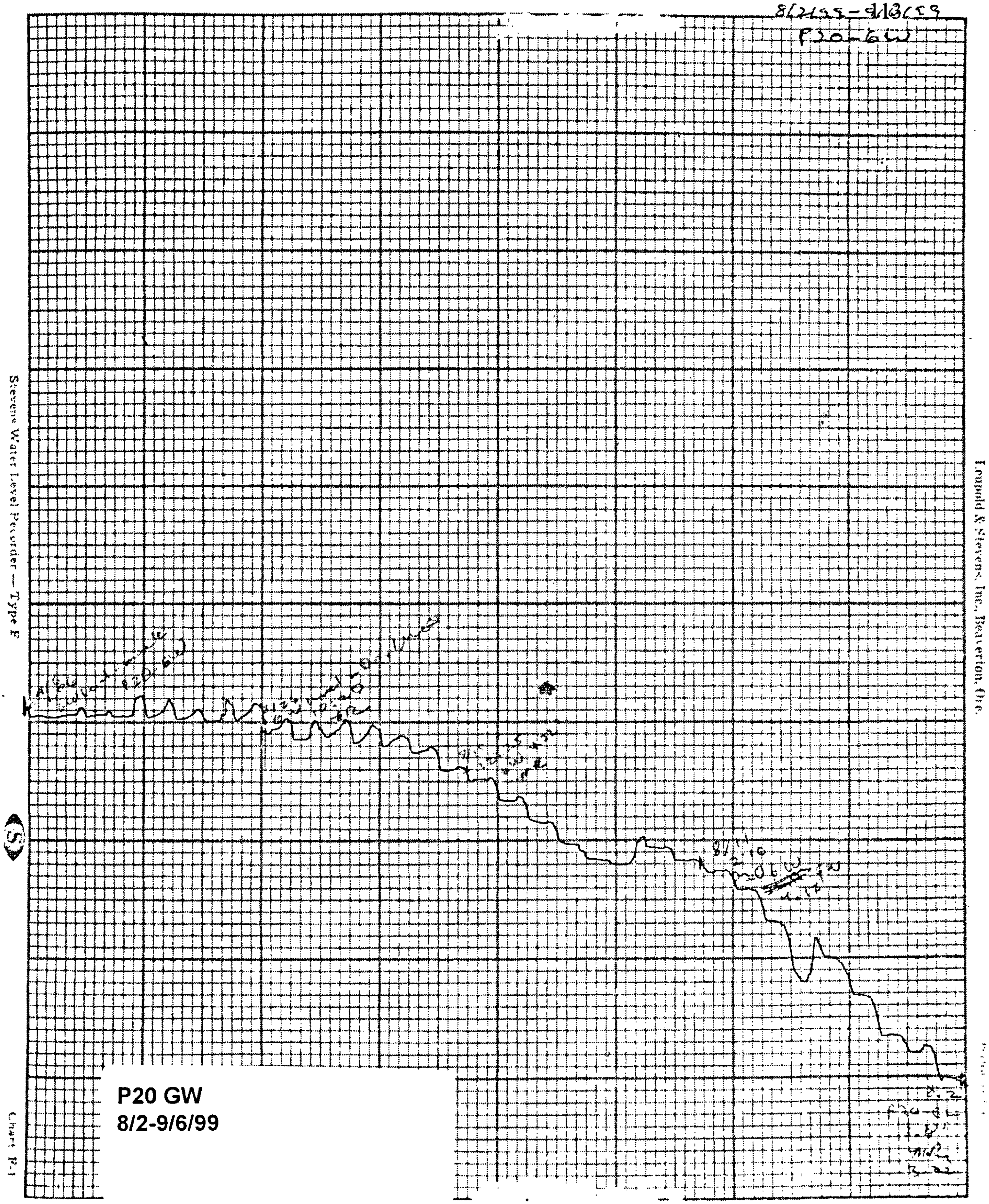
↓ UP

P20 GW
6/29-7/6/99



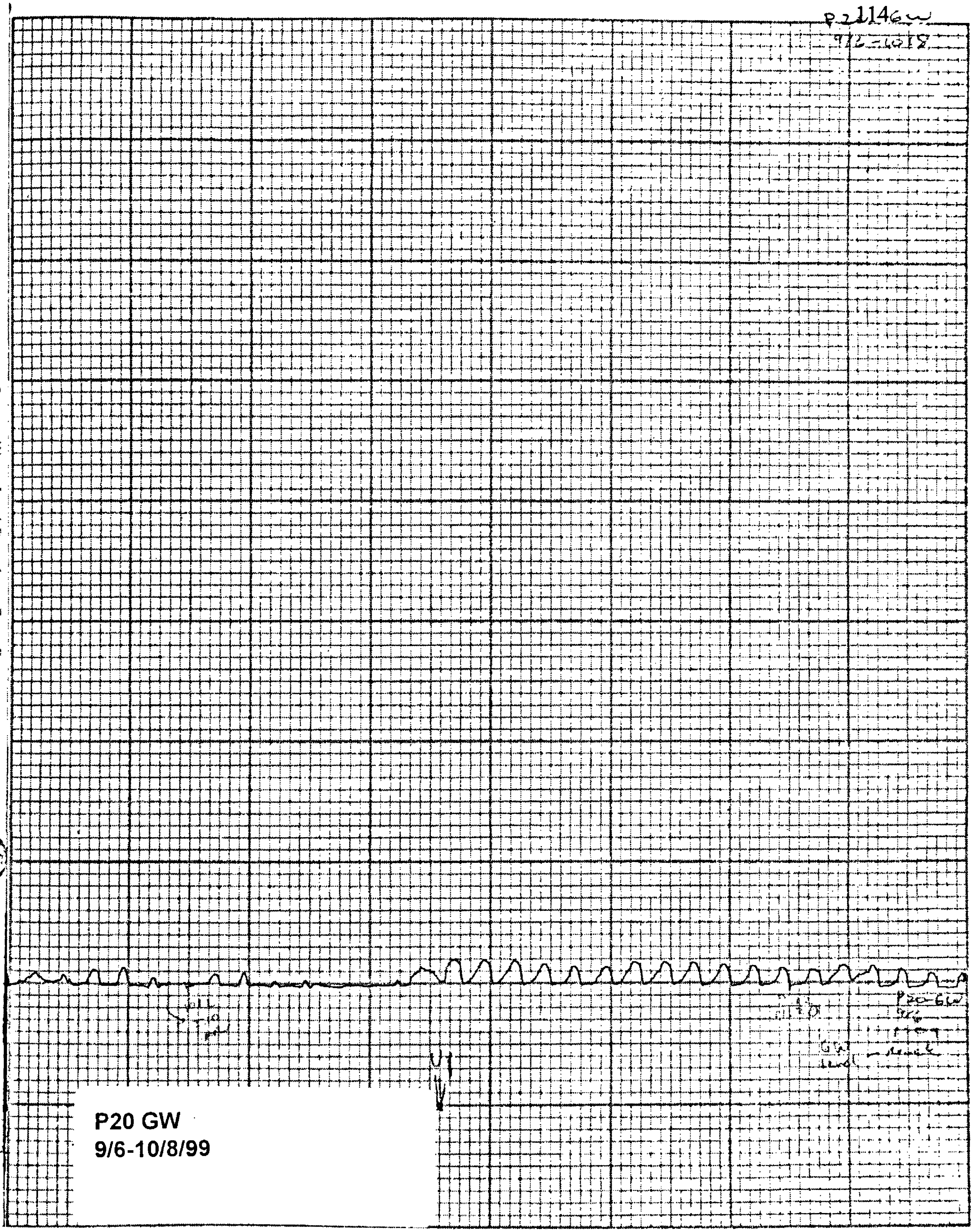
P20 GW
7/6-7/28/99

8/2/99-9/13/99
P20-GW



P20 GW
8/2-9/6/99

P21146w
9/2-10/8

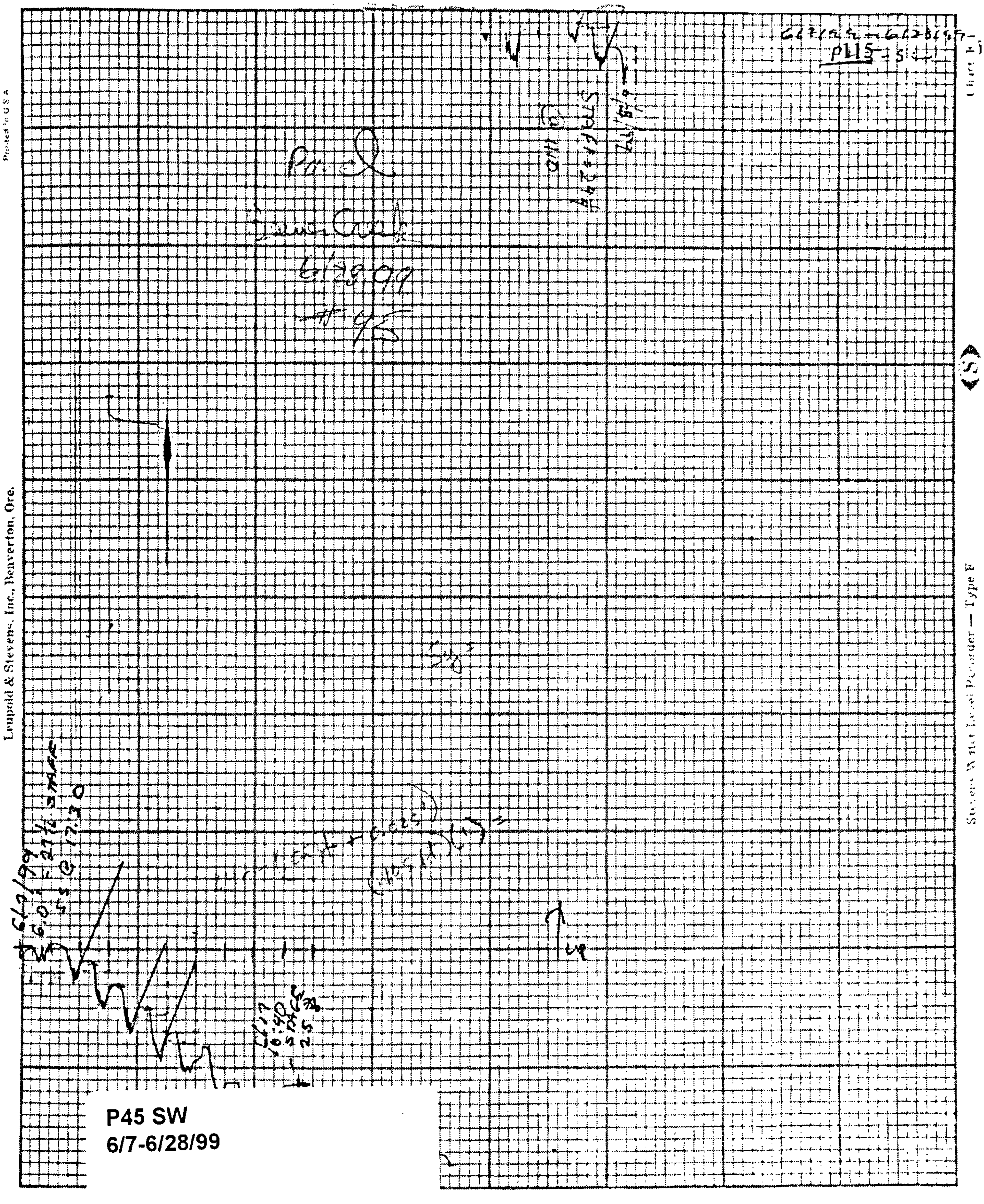


P20 GW
9/6-10/8/99

Stevens Water Level Recorder — Type F

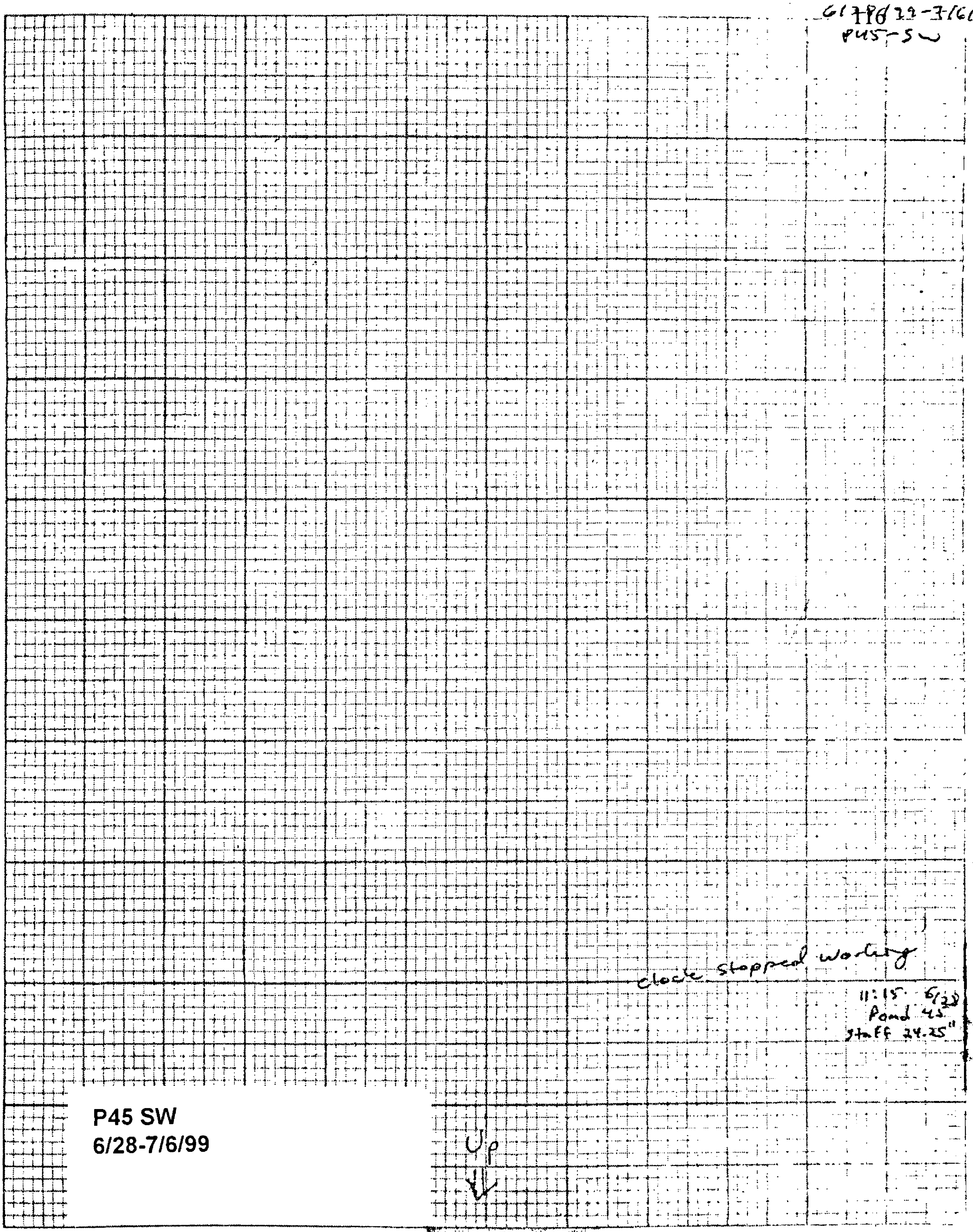
Leupold & Stevens, Inc., Beaverton, Ore.

Chart F-1



P45 SW
6/7-6/28/99

6/28/99-7/6/99 116
P45-SW

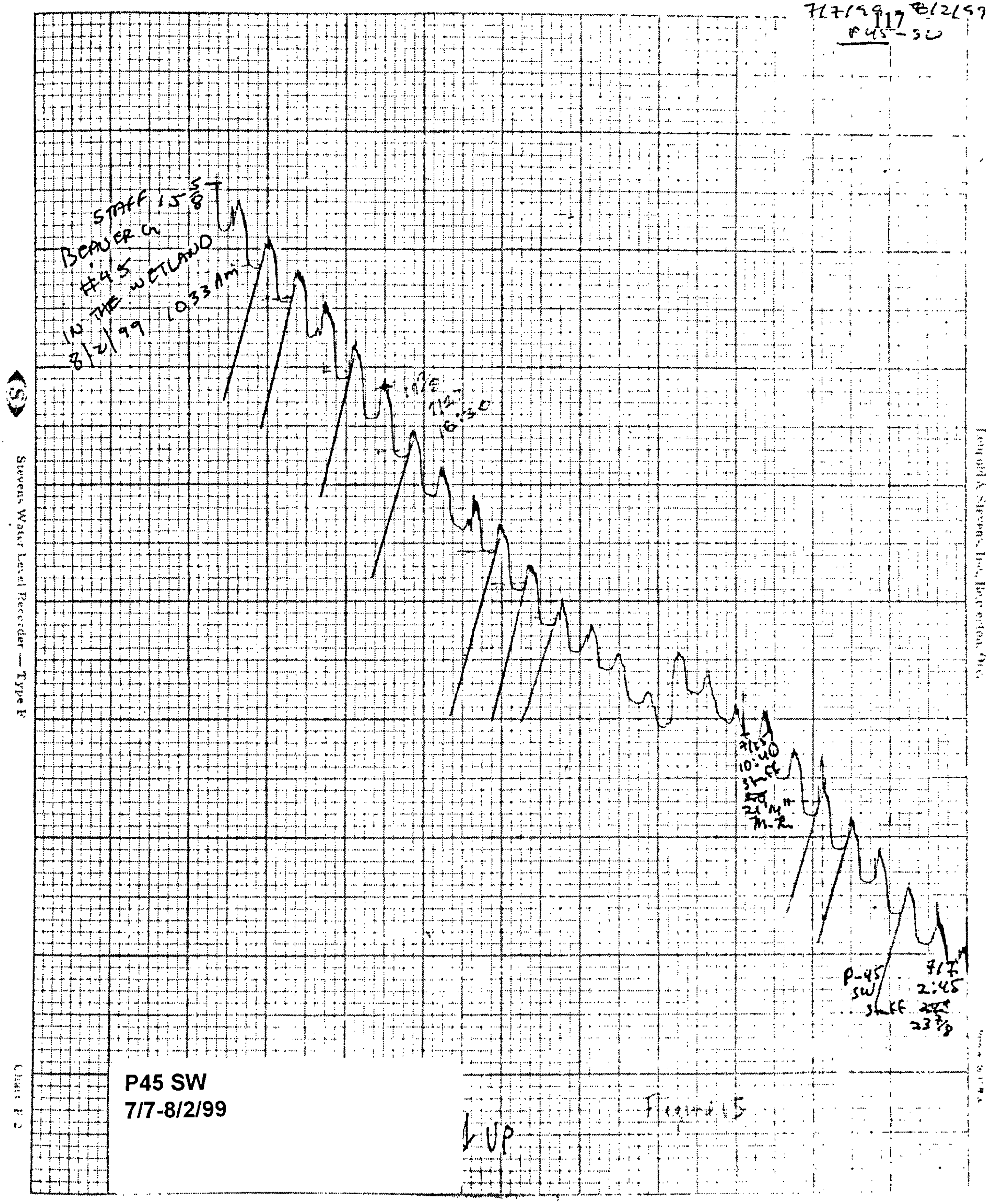


clock stopped working

11:15 6/28
Pond 45"
staff 24.25"

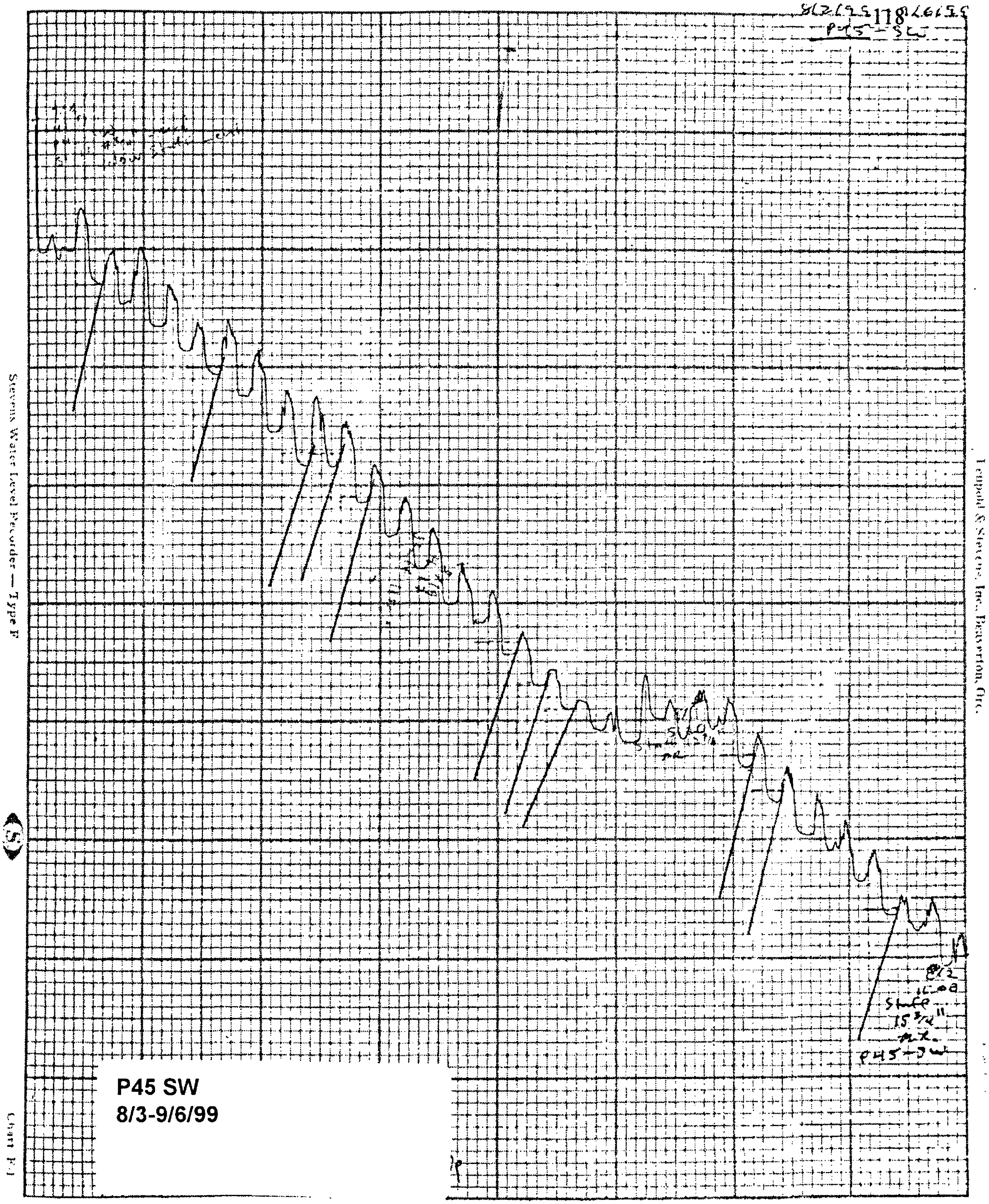
P45 SW
6/28-7/6/99

Up ↓



P45 SW
7/7-8/2/99

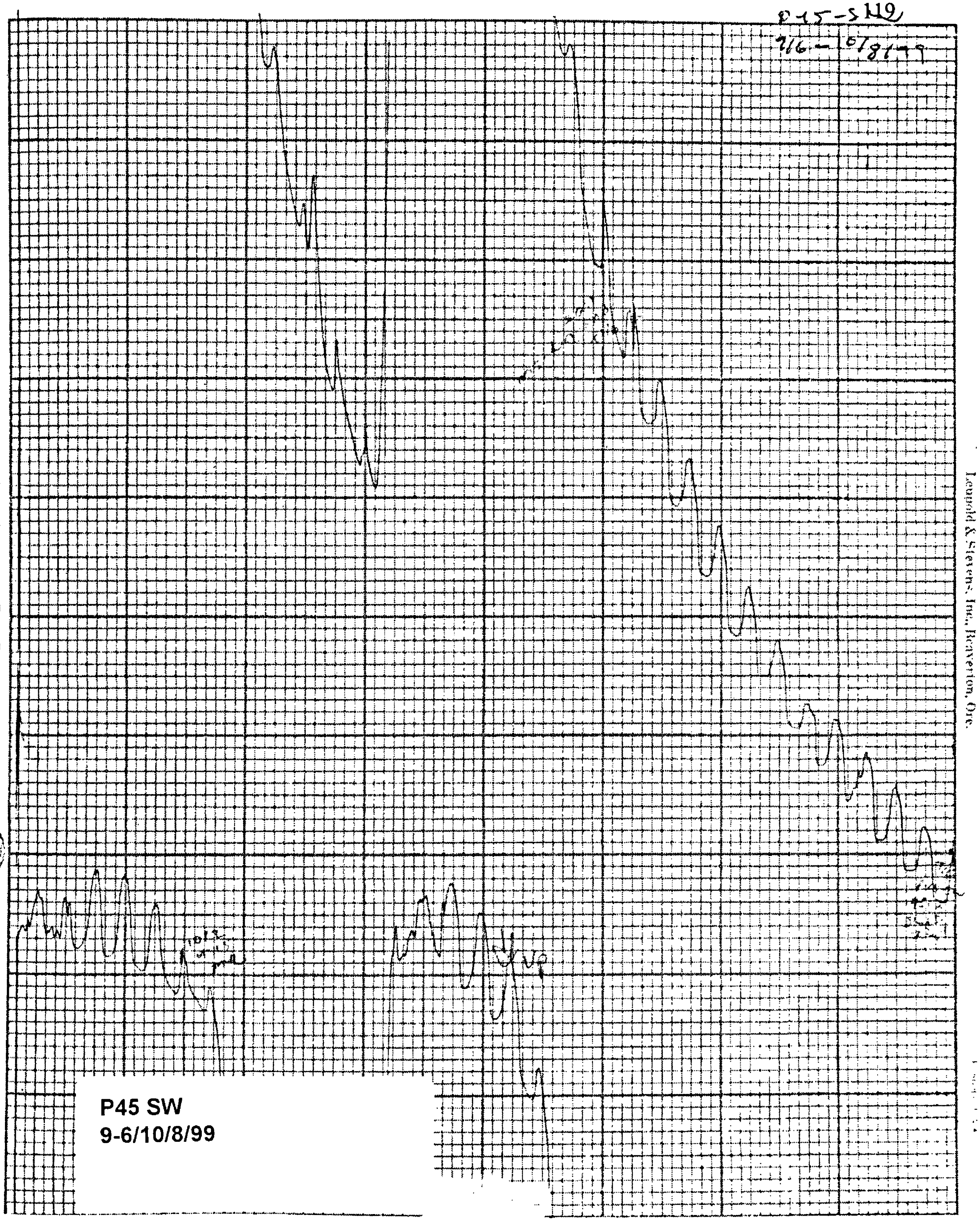
Figure 15



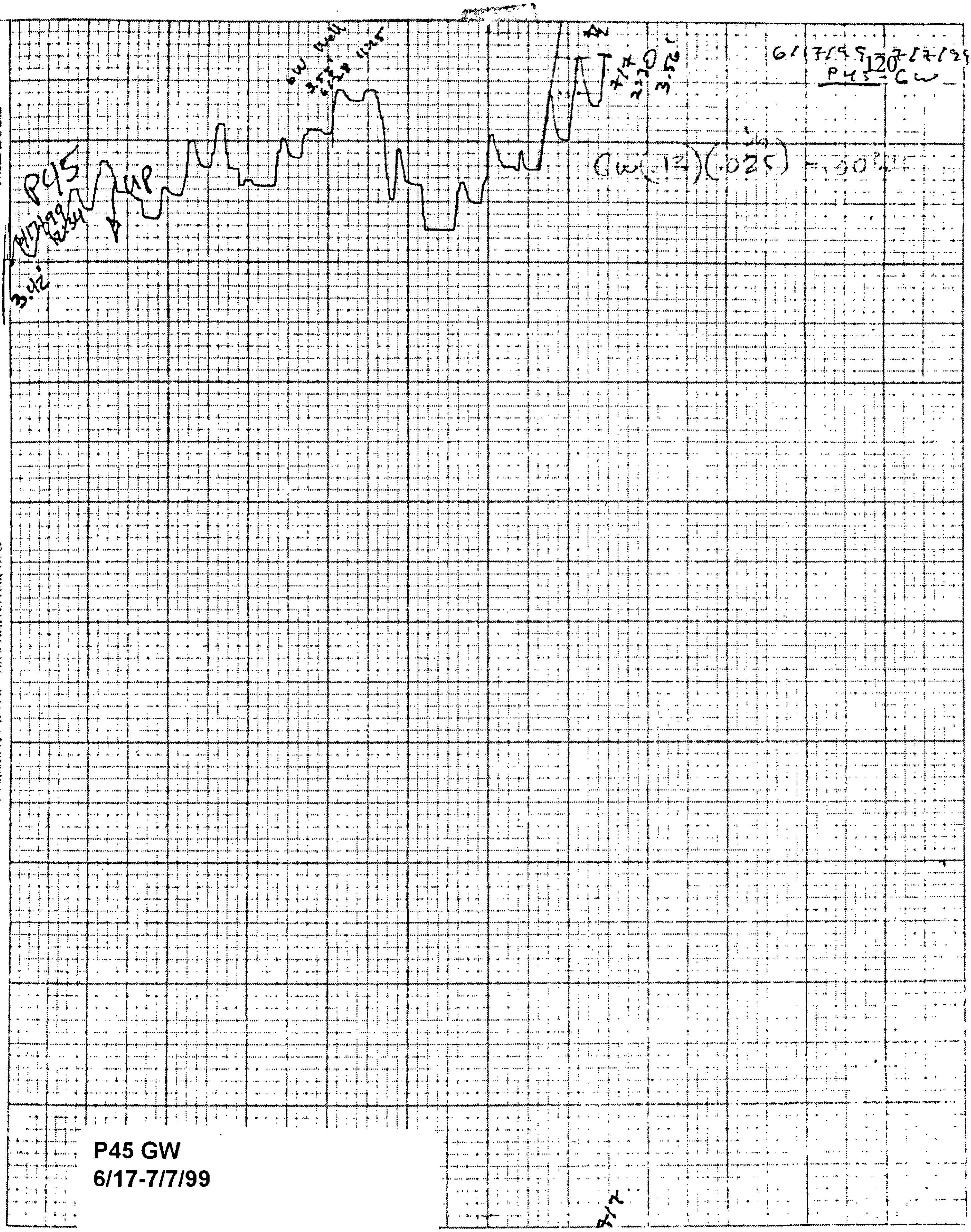
P45 SW
8/3-9/6/99

8-15-5119

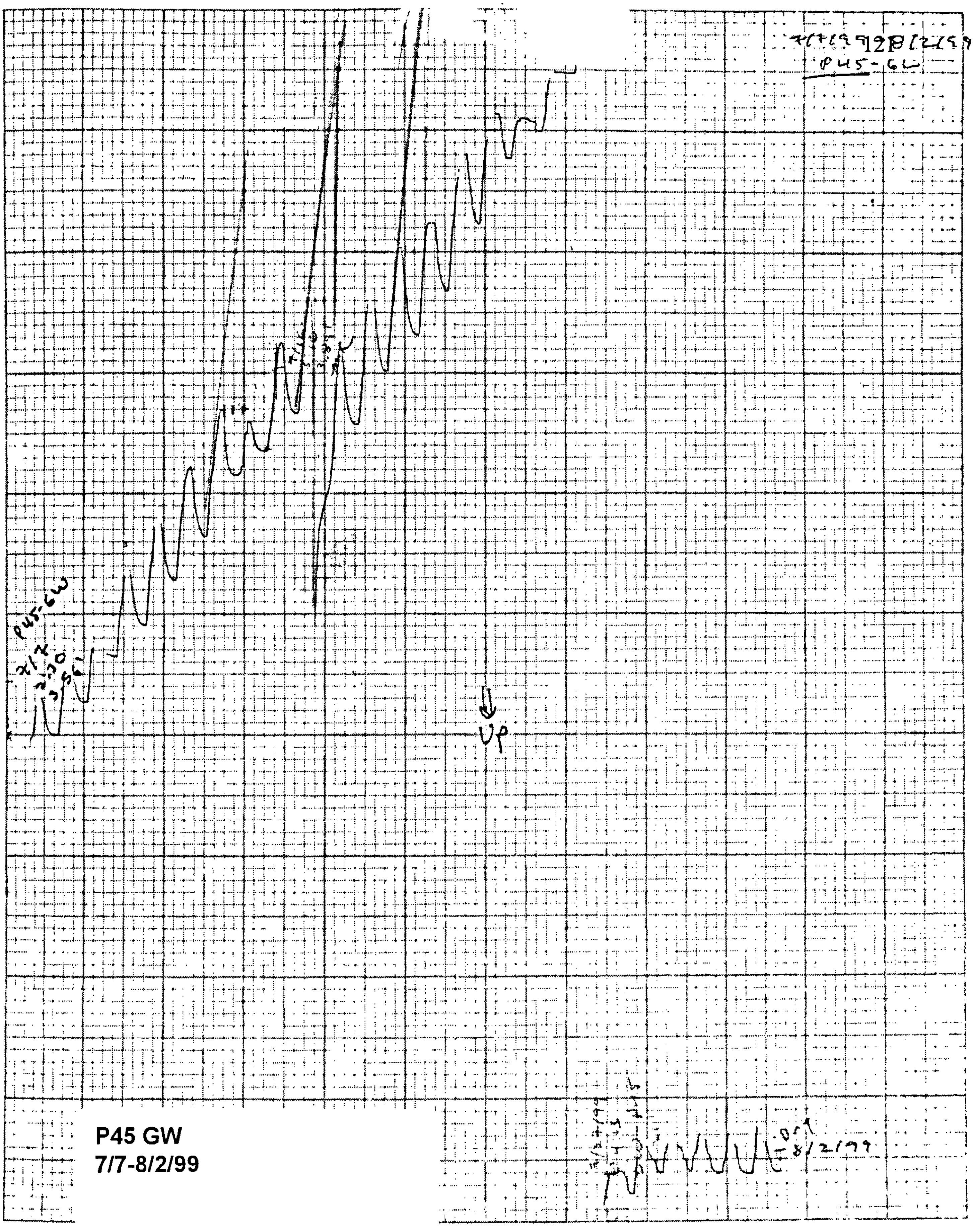
9/6 – 10/8/99



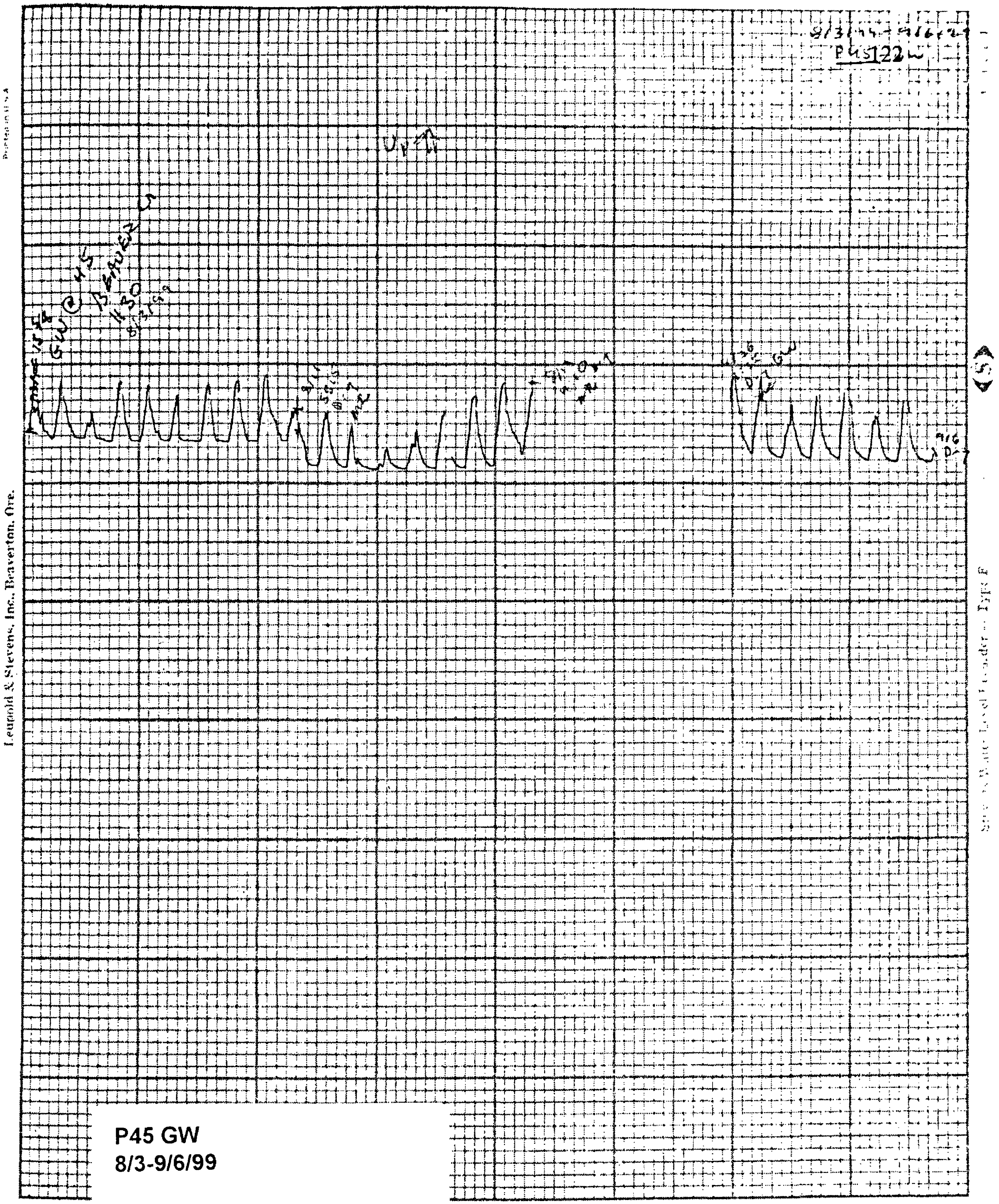
P45 SW
9-6/10/8/99



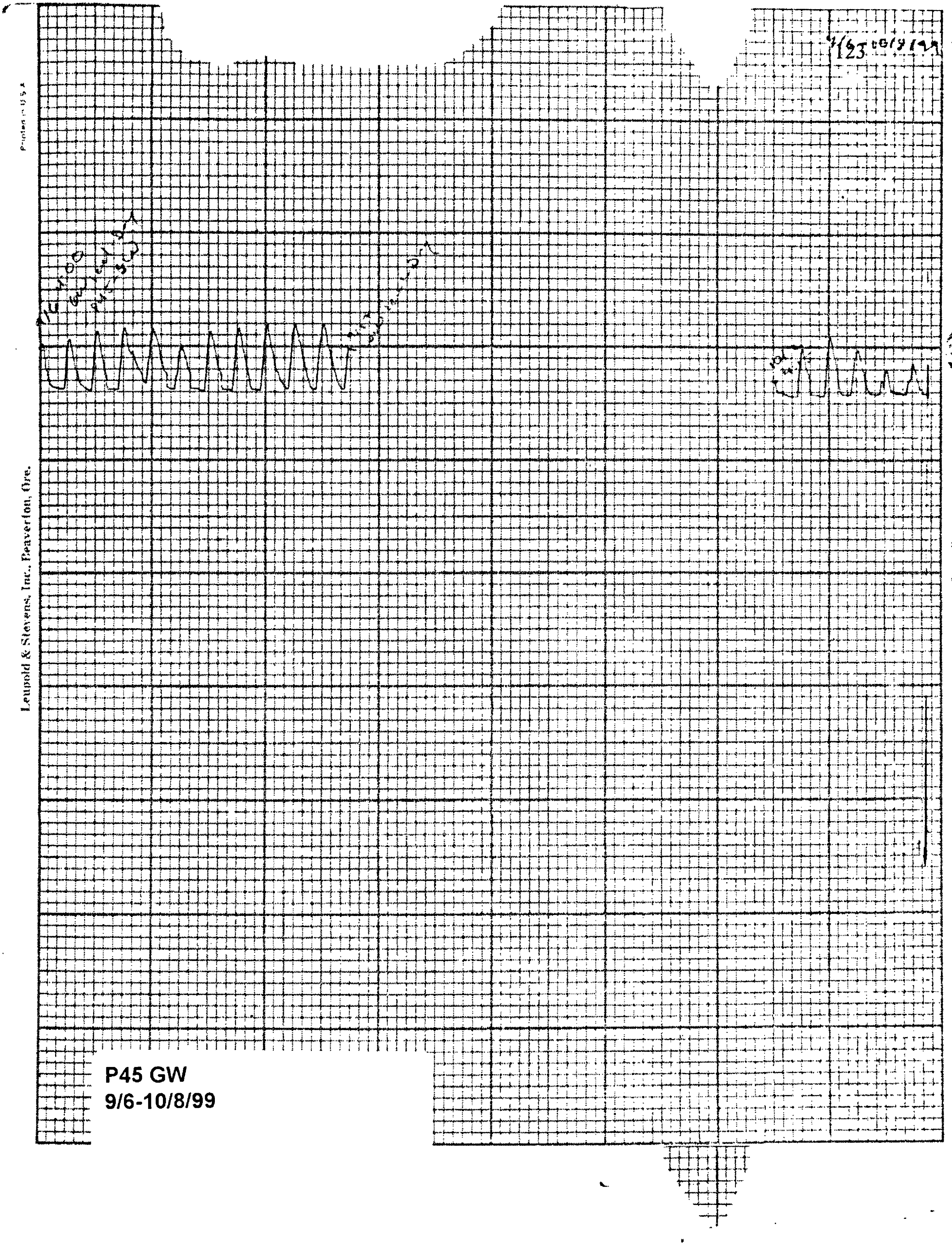
P45 GW
6/17-7/7/99



P45 GW
7/7-8/2/99

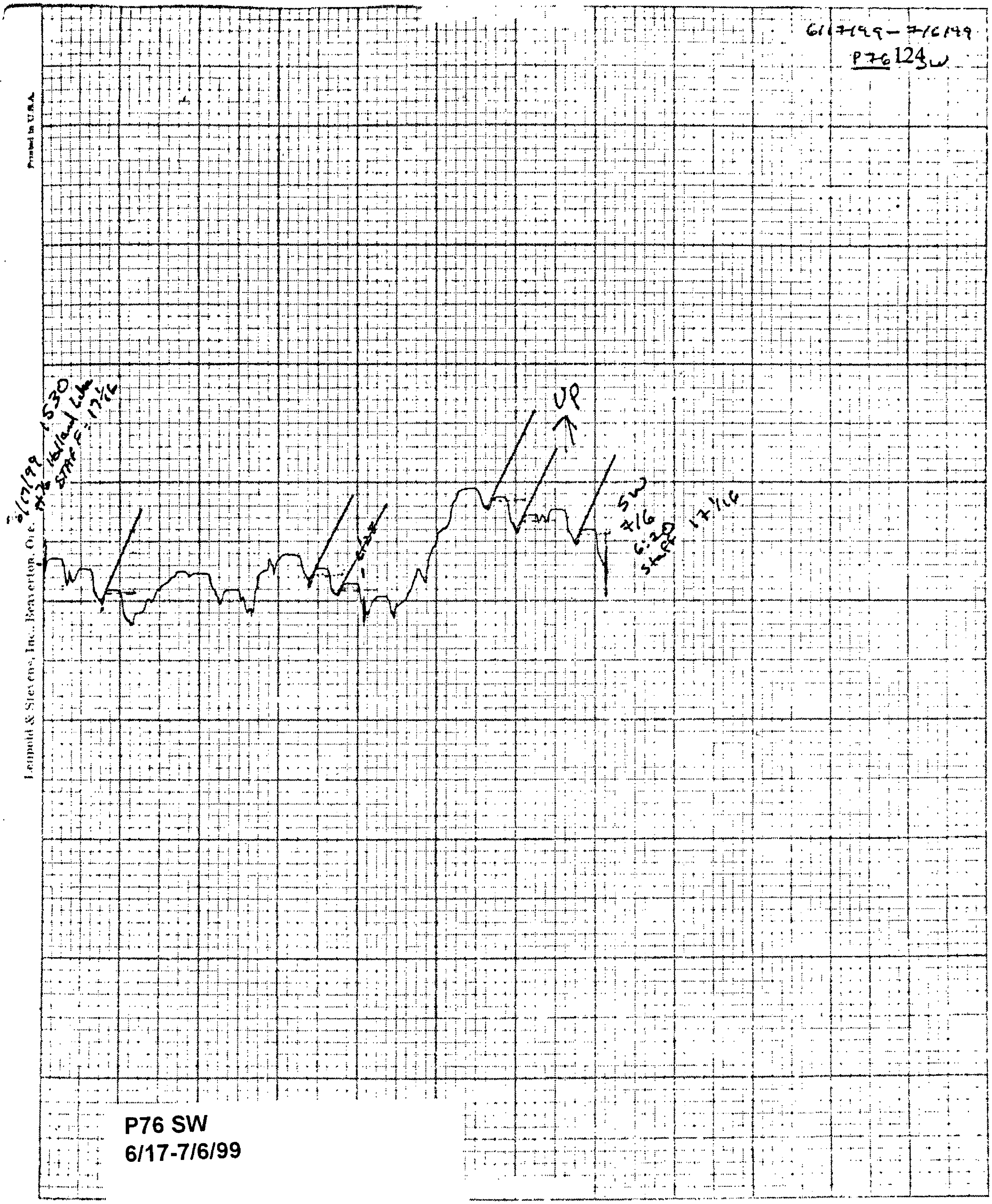


P45 GW
8/3-9/6/99



P45 GW
9/6-10/8/99

6/17/99 – 7/6/99
P76 124 SW

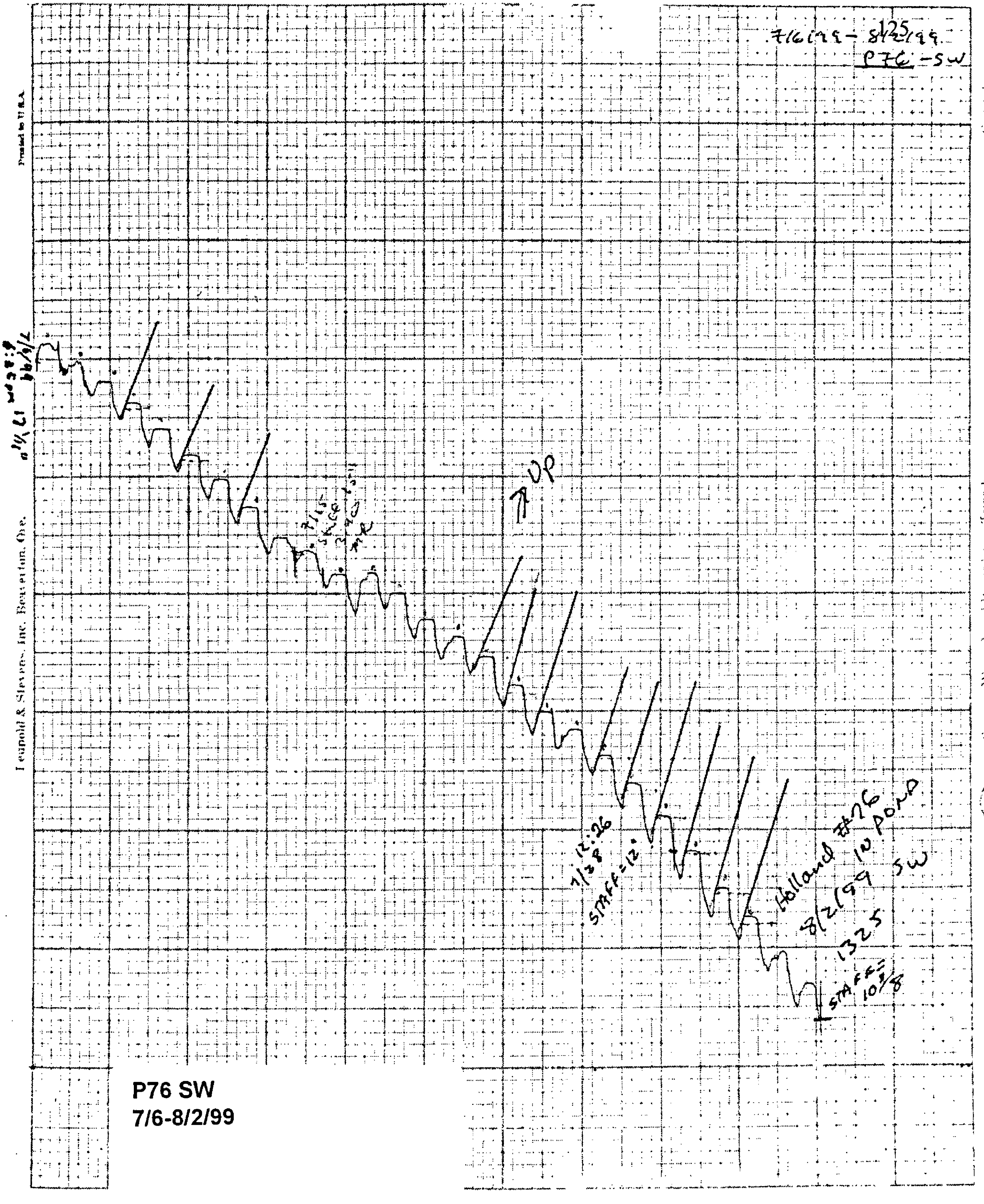


6/17/99 1530
Holland Lake
STAFF = 17 1/16

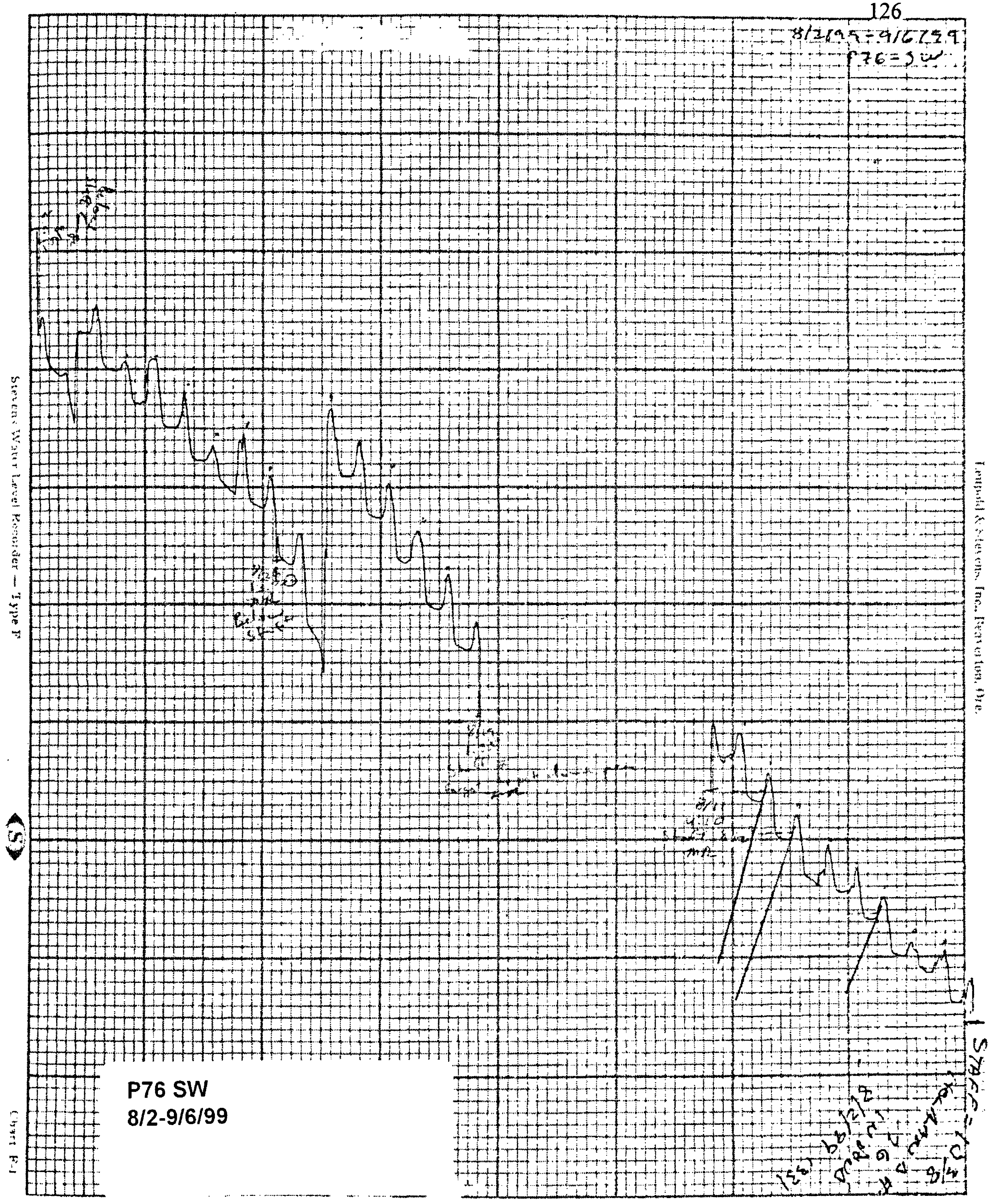
6/28

SW
7/6
6:20
staff 17 1/16

P76 SW
6/17-7/6/99

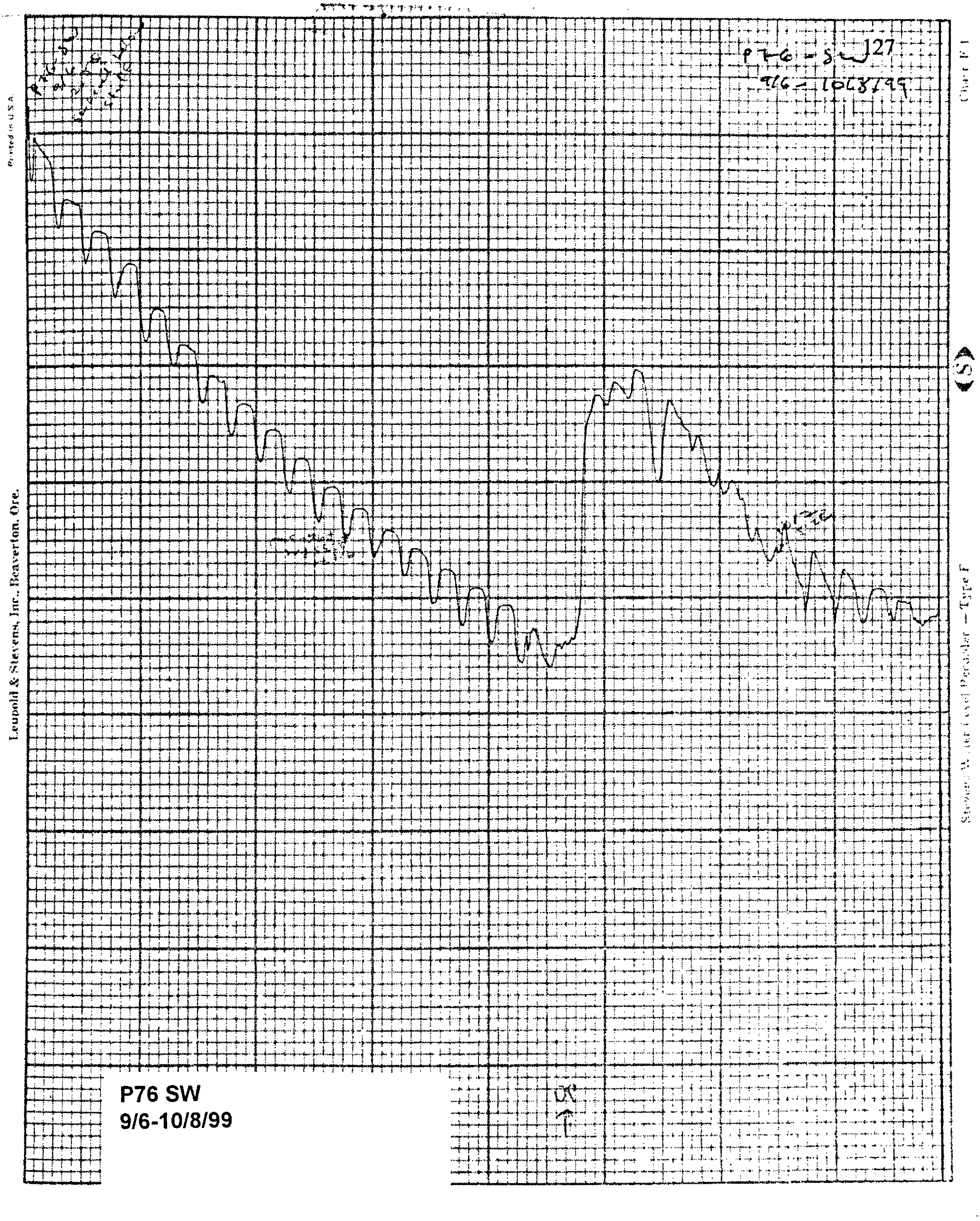


P76 SW
7/6-8/2/99



8/2/99 = 9/6/99
P76 = SW

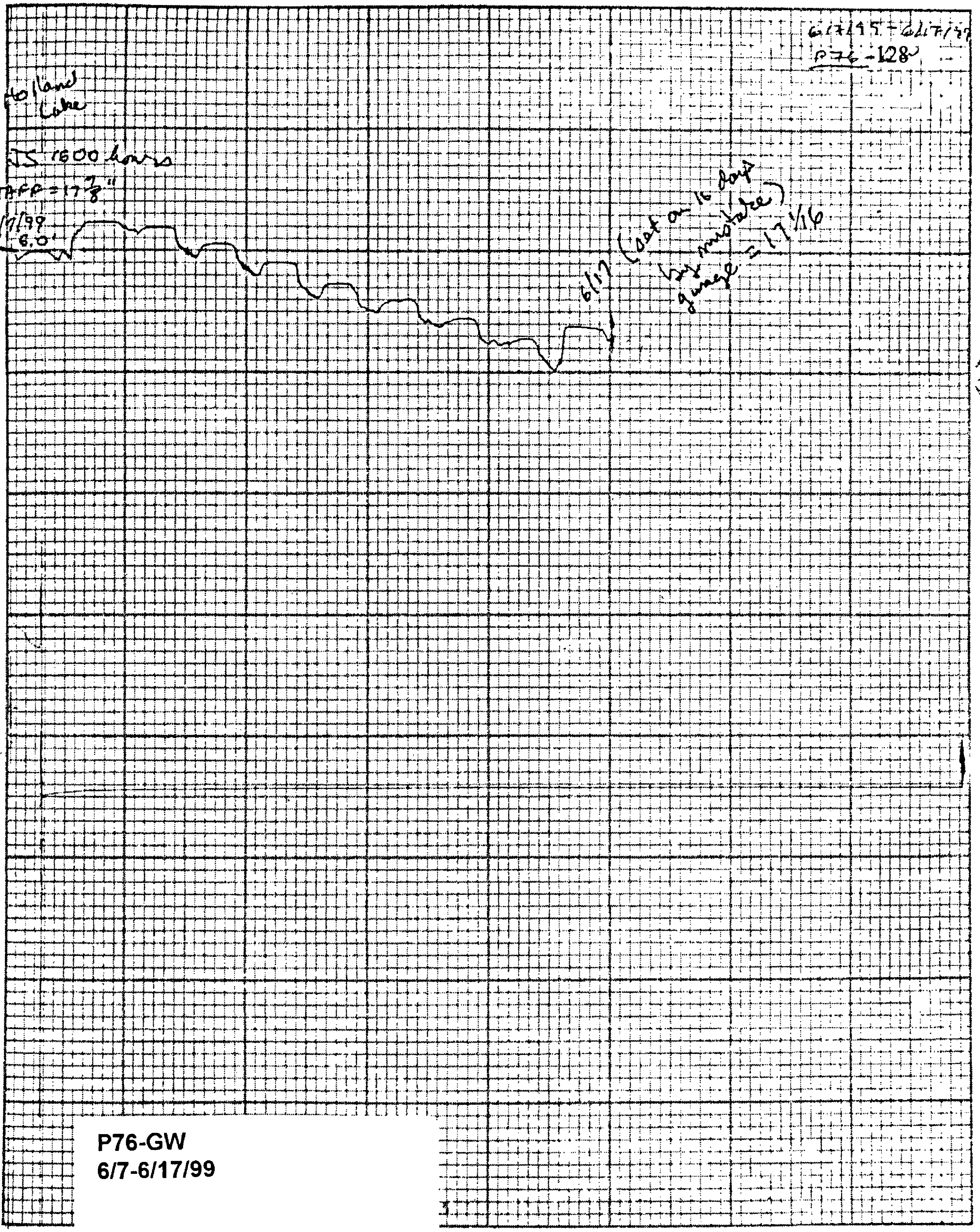
P76 SW
8/2-9/6/99



P76-SW 127
9/6-10/8/99

P76 SW
9/6-10/8/99

6/7/99 - 6/17/99
P76-128



Holland Lake

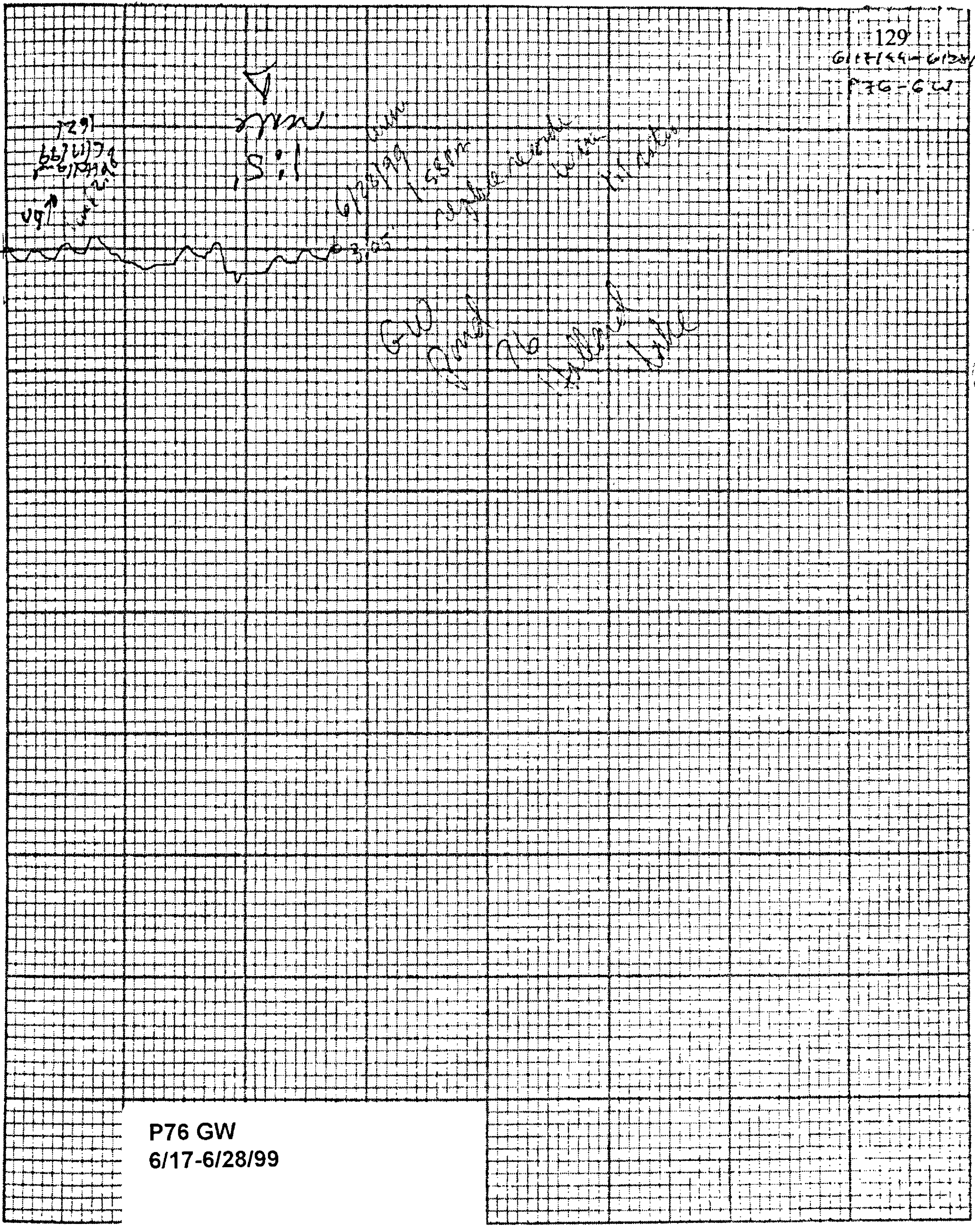
JS 1600 hours

STAFF = 17 7/8"

6/17/99
6.0'

6/17 (set on 16 days by mistake) gauge = 17 1/16

P76-GW
6/7-6/17/99



129
6/17/99 – 6/28/99
P76 - GW

129
6/17/99
P76 GW

up

1.5'

3.05

6/28/99 1450 replace with new Chart

GW Pond 76 Holland Lake

P76 GW
6/17-6/28/99

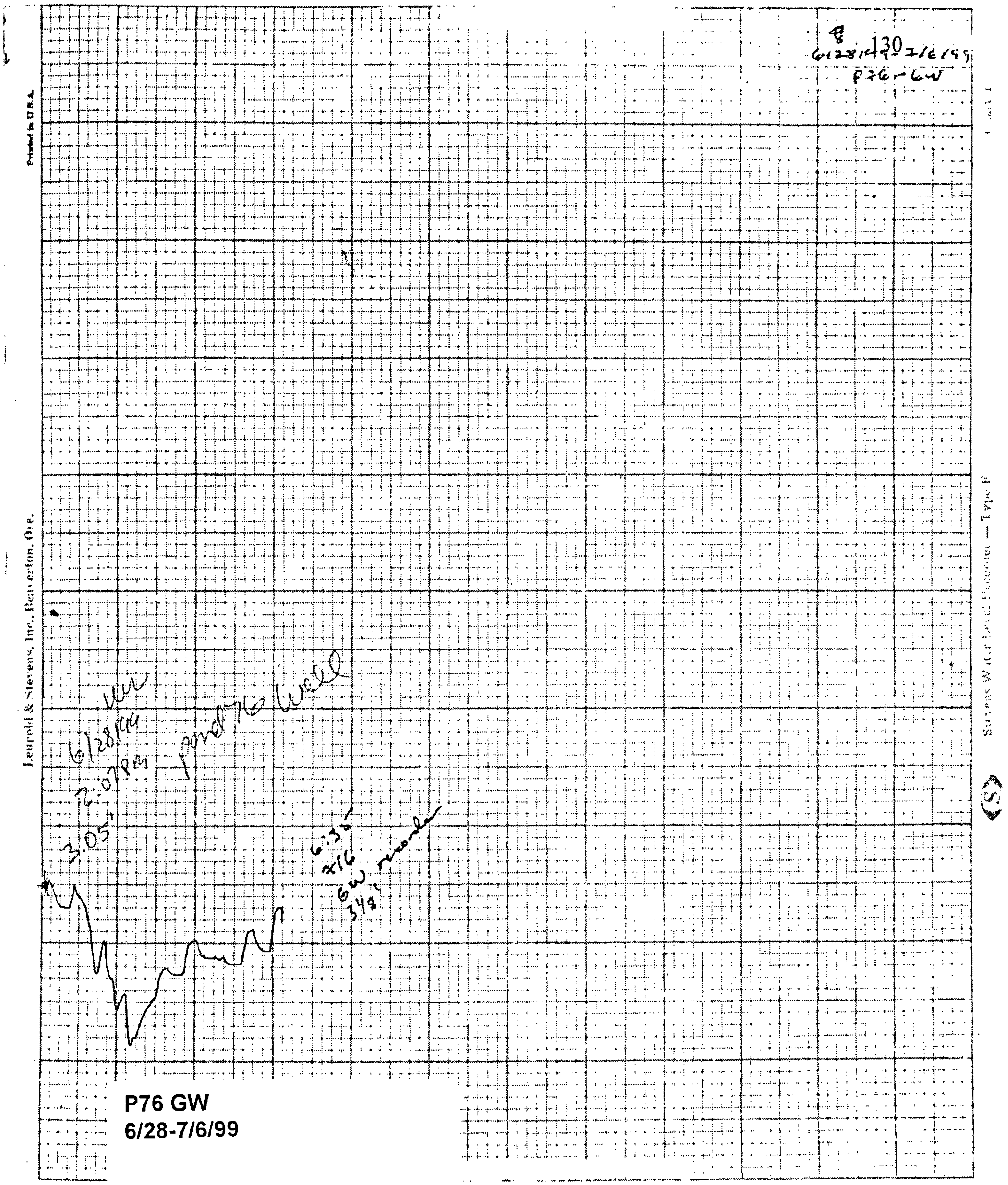
Printed in U.S.A.

Leupold & Stevens, Inc., Beaverton, Ore.

Chart F1

Stevens Water Level Recorder — Type F

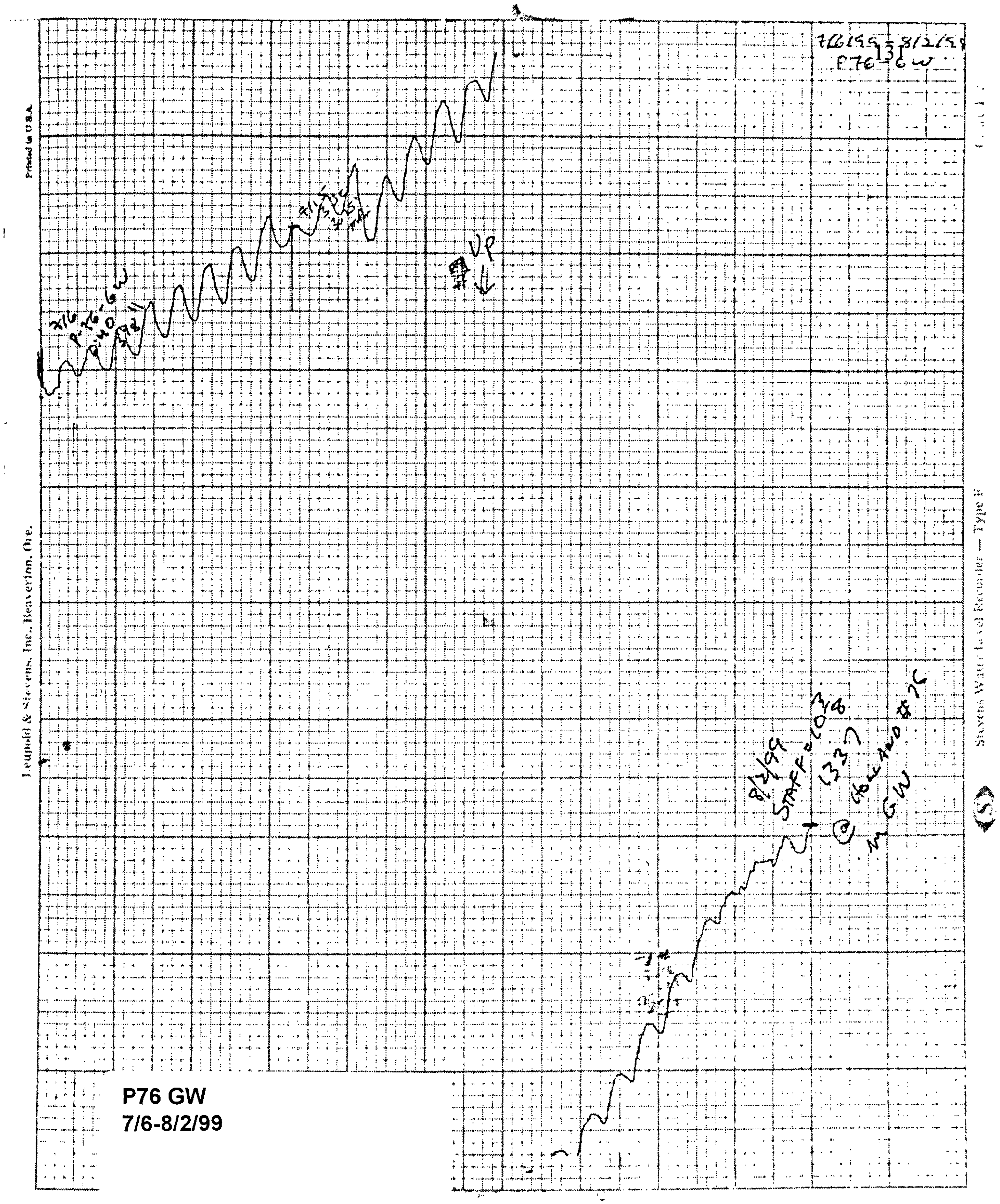
6/28/99-7/6/99
P76-GW



6/28/99 WW
2:07pm
3.05' — pond 76 well

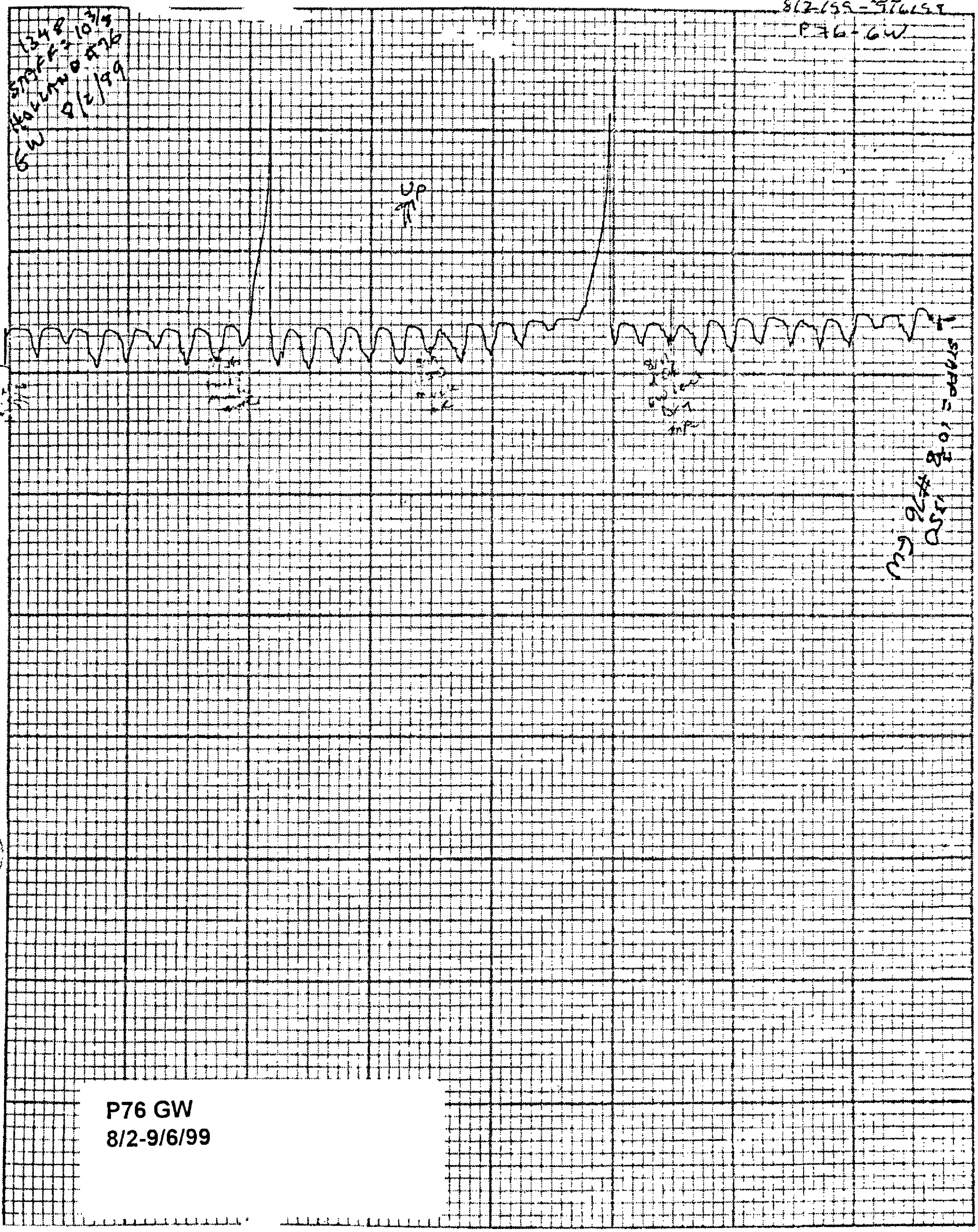
6:35
7/6
GW reader
3.48'

P76 GW
6/28-7/6/99



P76 GW
7/6-8/2/99

8/2/99 - 9/6/99
P76-GW



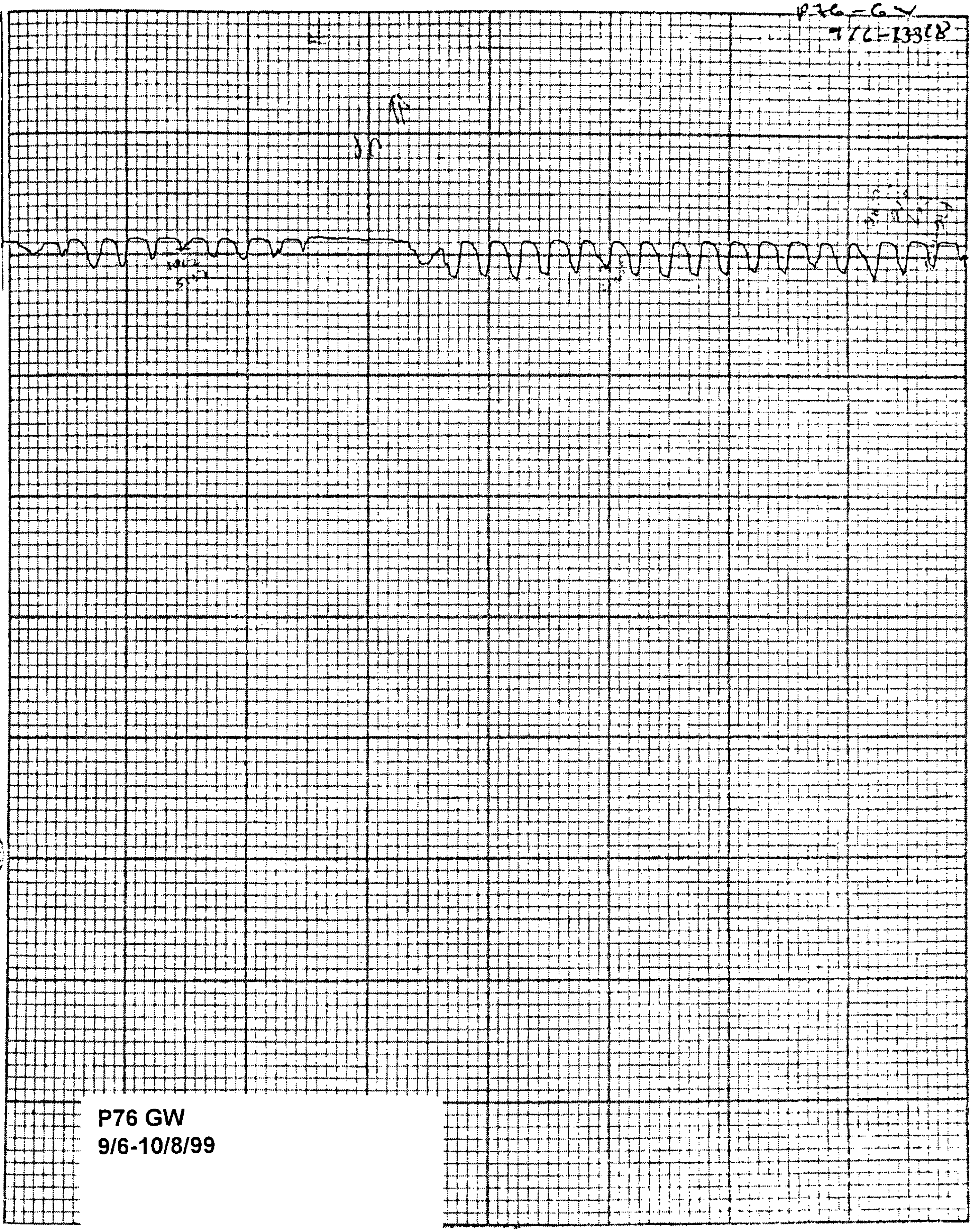
P76 GW
8/2-9/6/99

Stevens Water Level Recorder — Type F

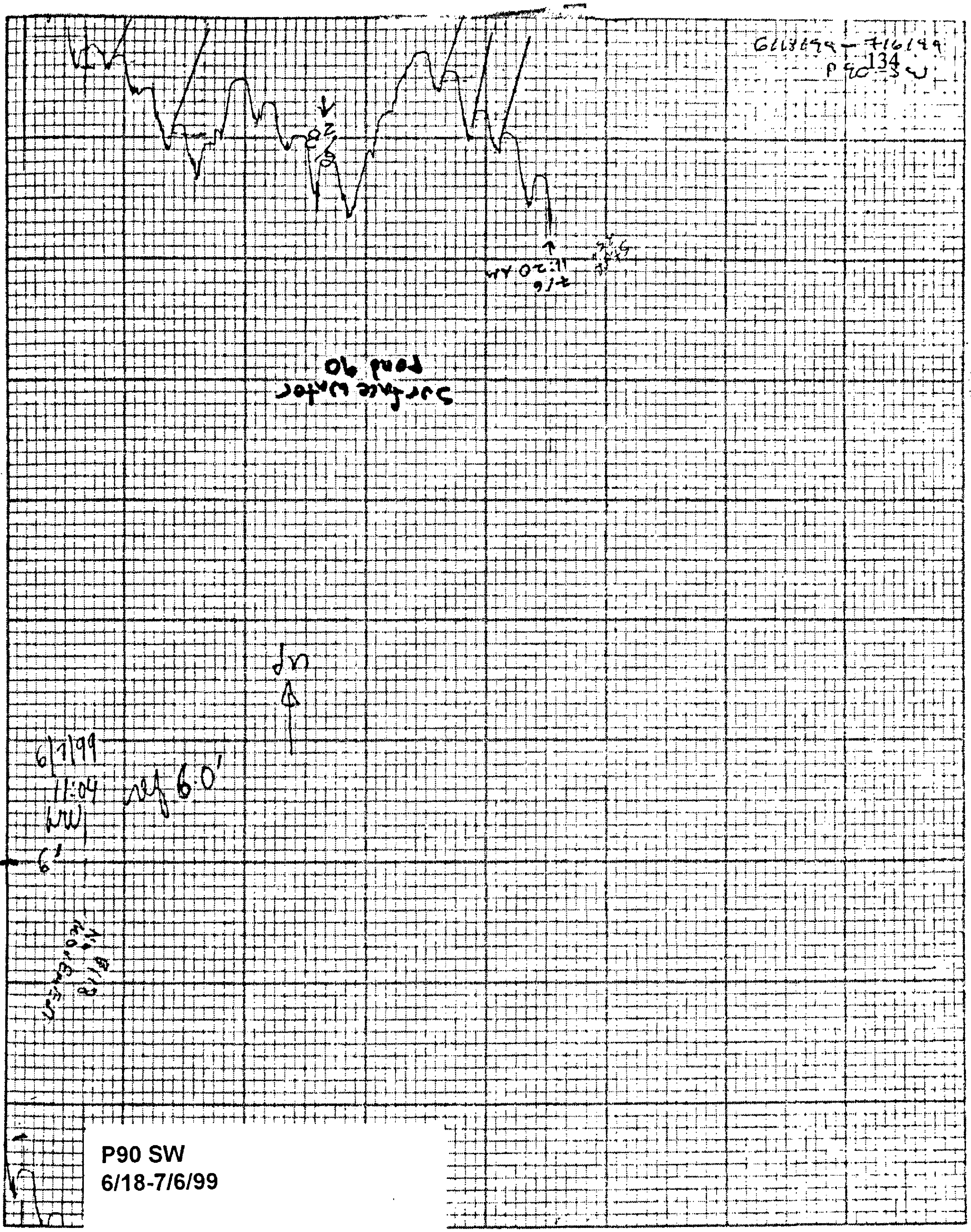
Leupold & Stevens, Inc., Beaverton, Ore.

Chart F-1

P76-GW
776-13318

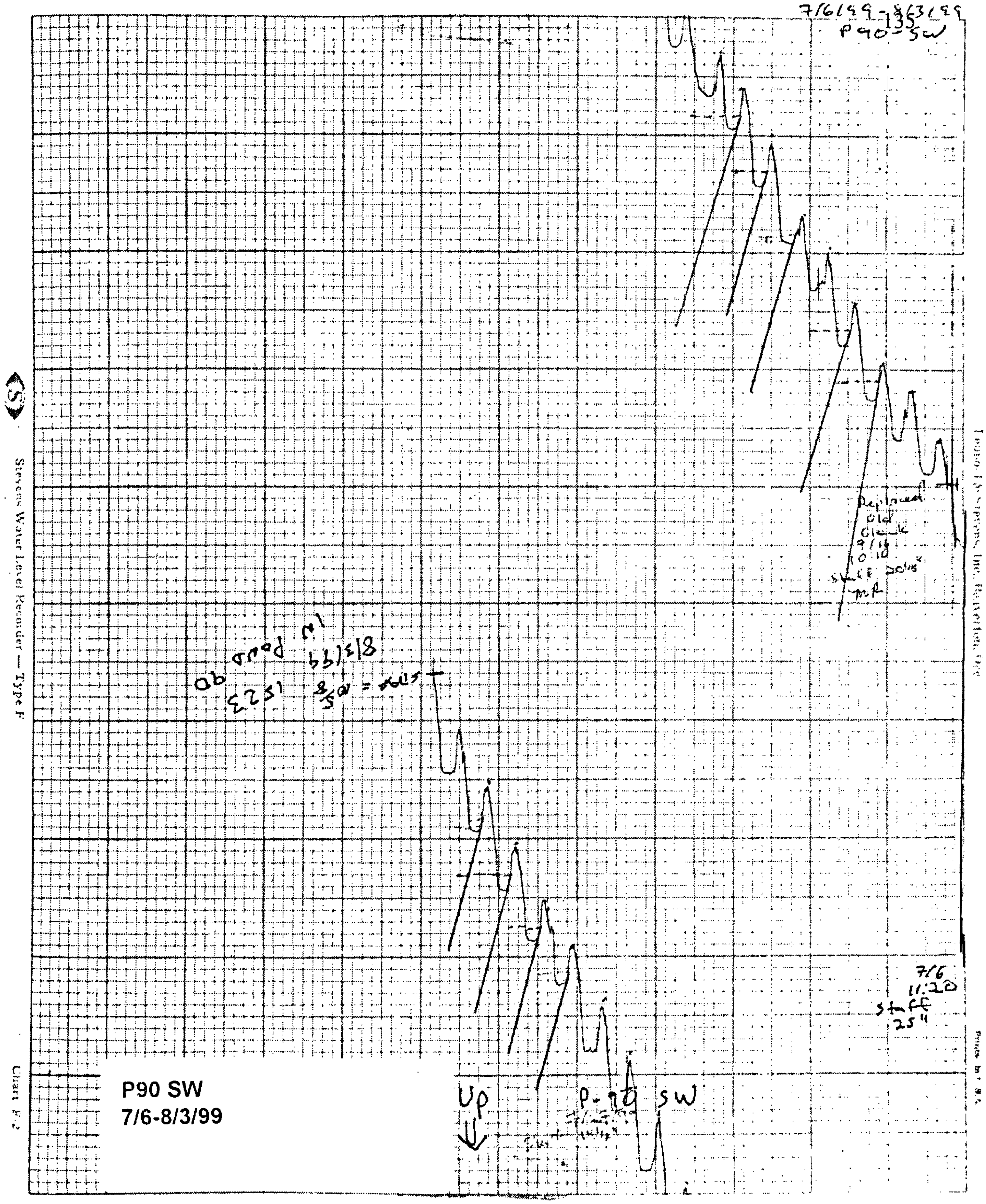


P76 GW
9/6-10/8/99



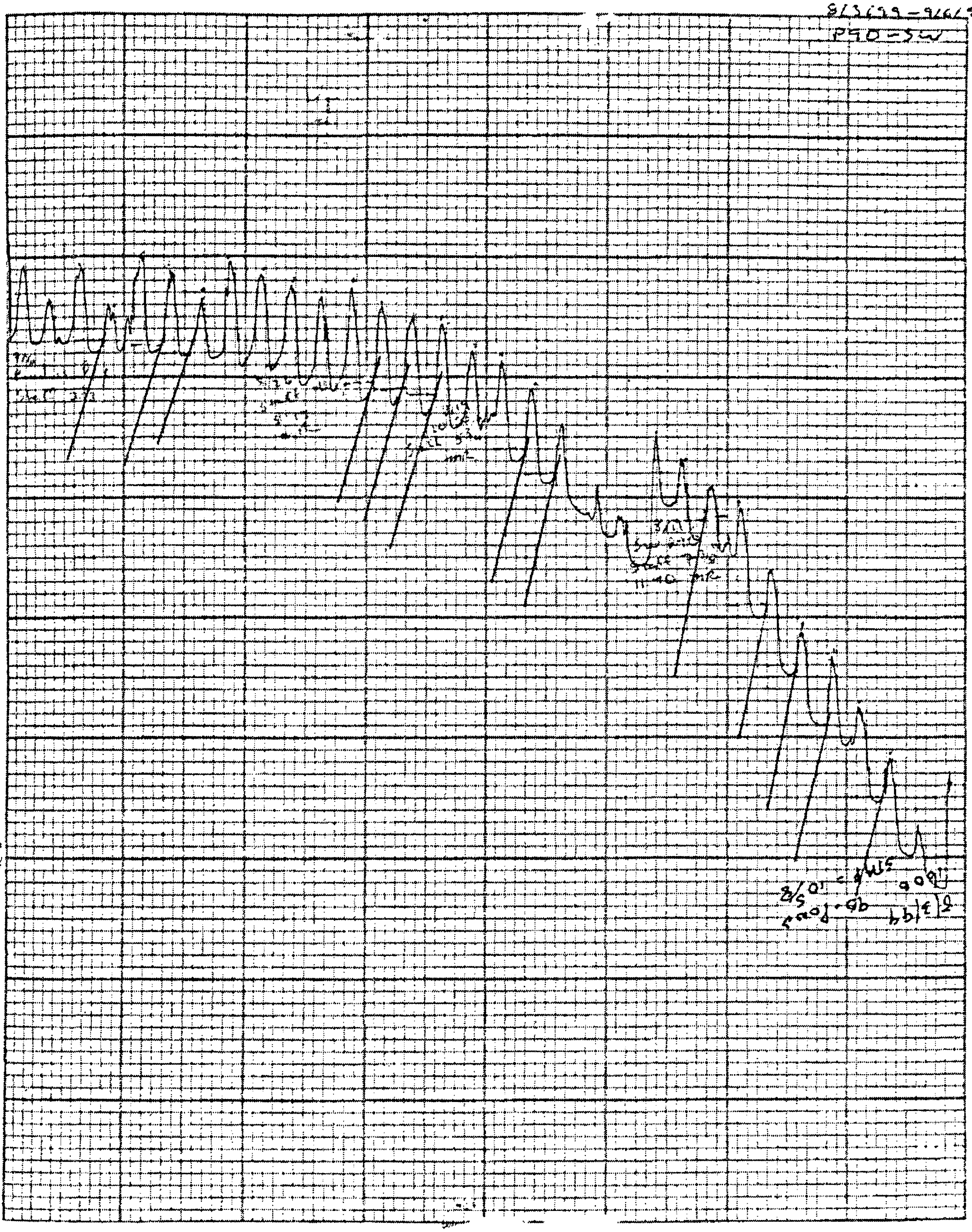
P90 SW
6/18-7/6/99

135



P90 SW
7/6-8/3/99

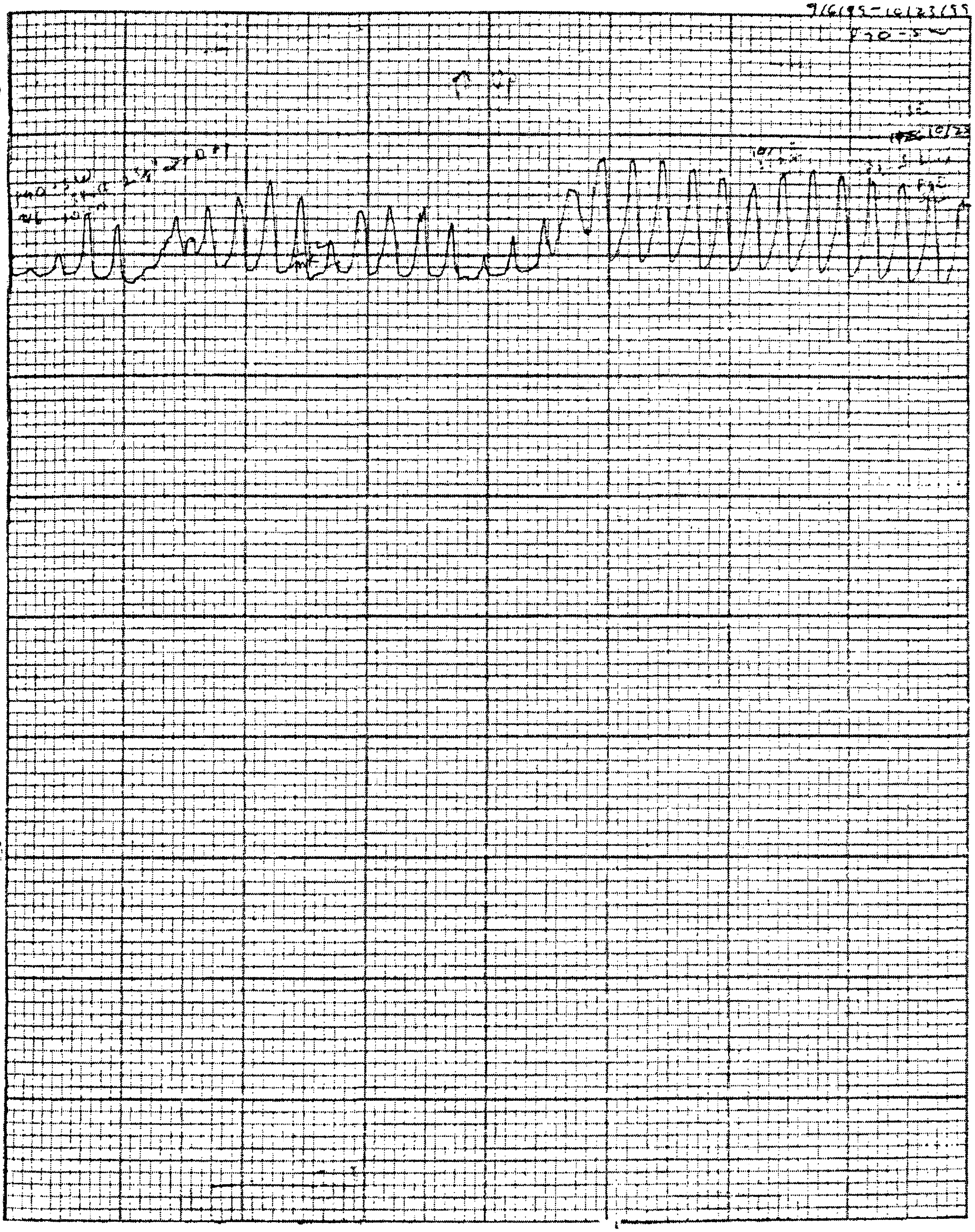
8/3/99 – 9/6/99
P90 – SW



Stevens Water Level Recorder — Type F

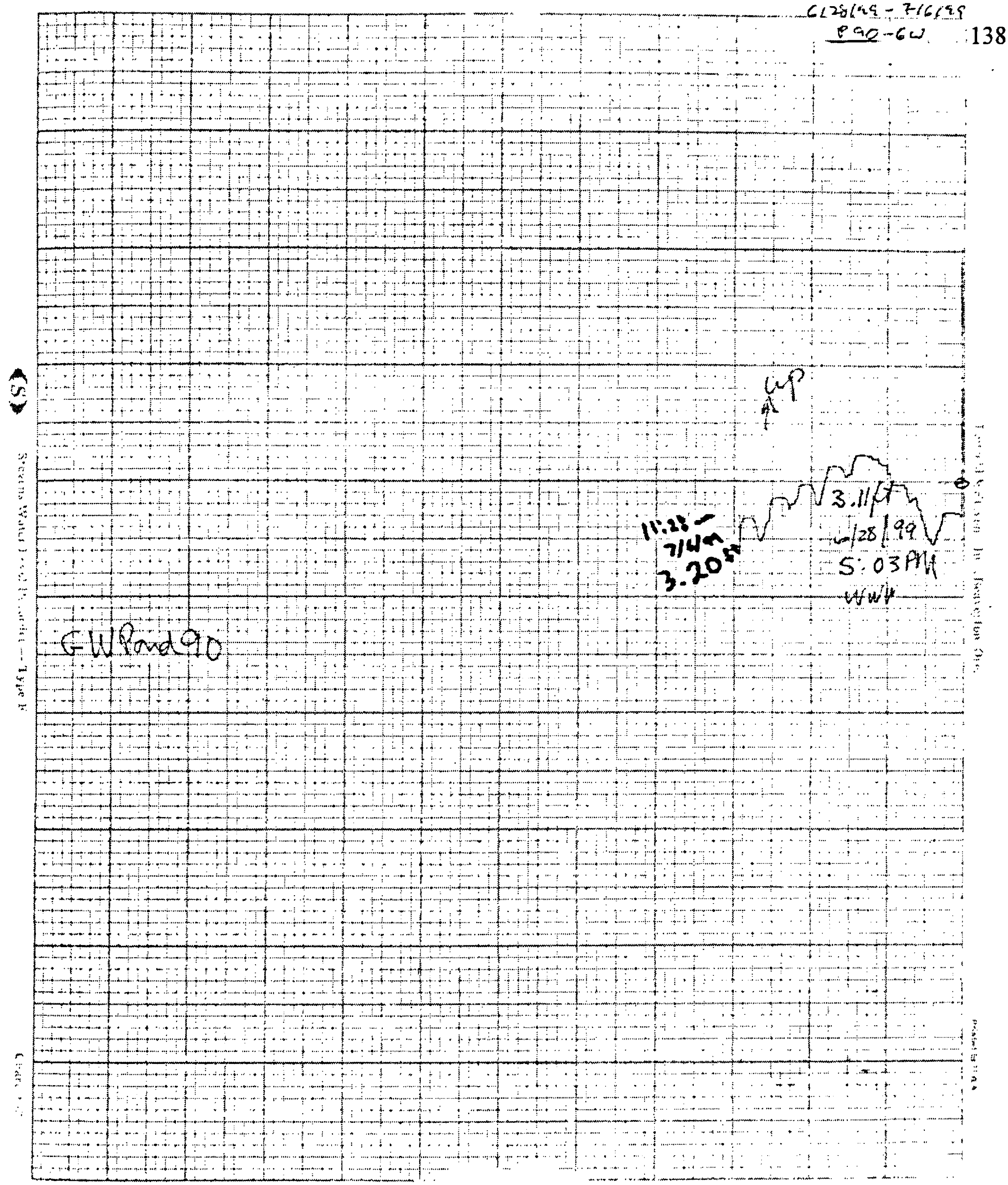
Leupold & Stevens, Inc., Beaverton, Ore.

P90 SW
8/3-9/6/99

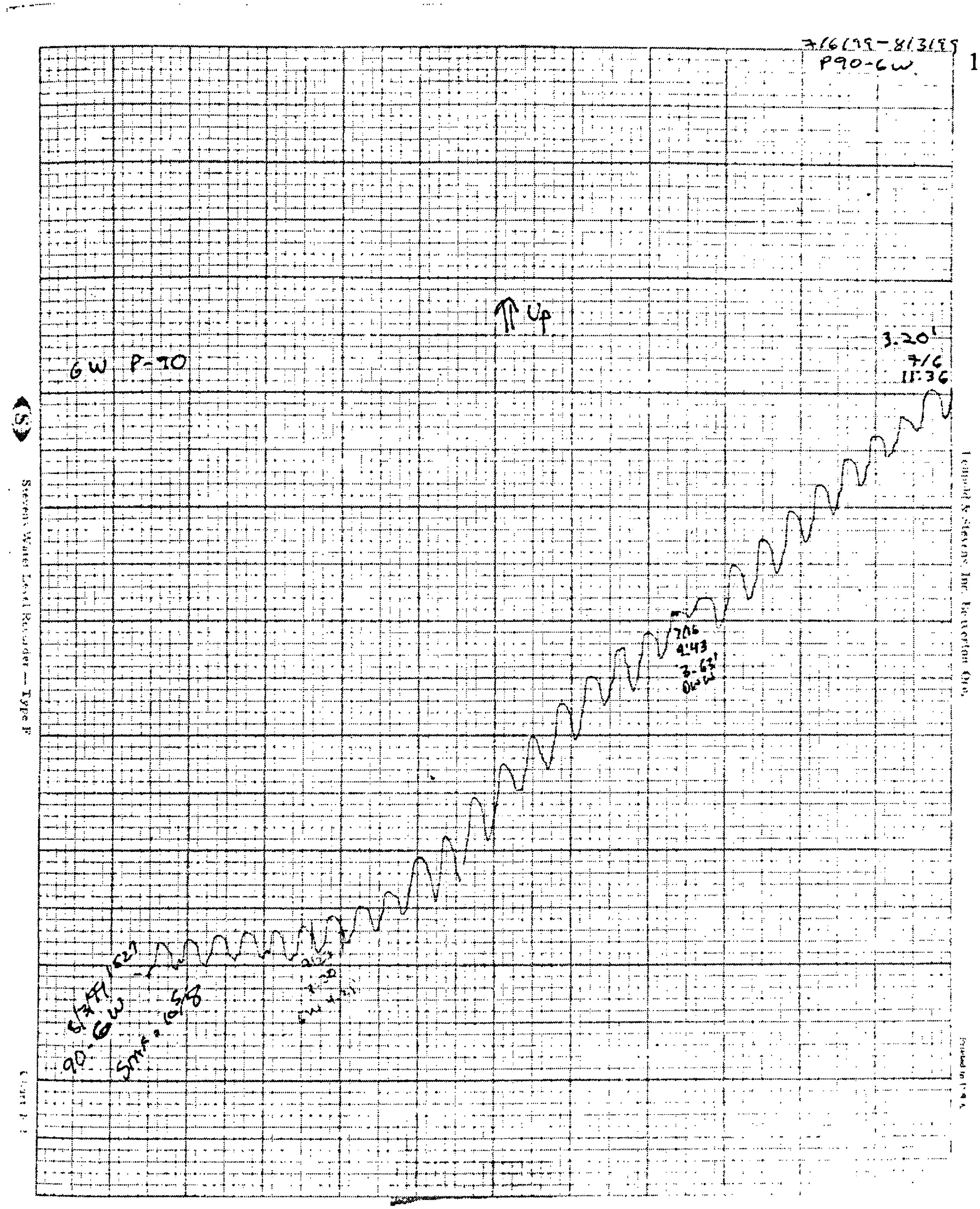


P90 SW
9/6-10/23/99

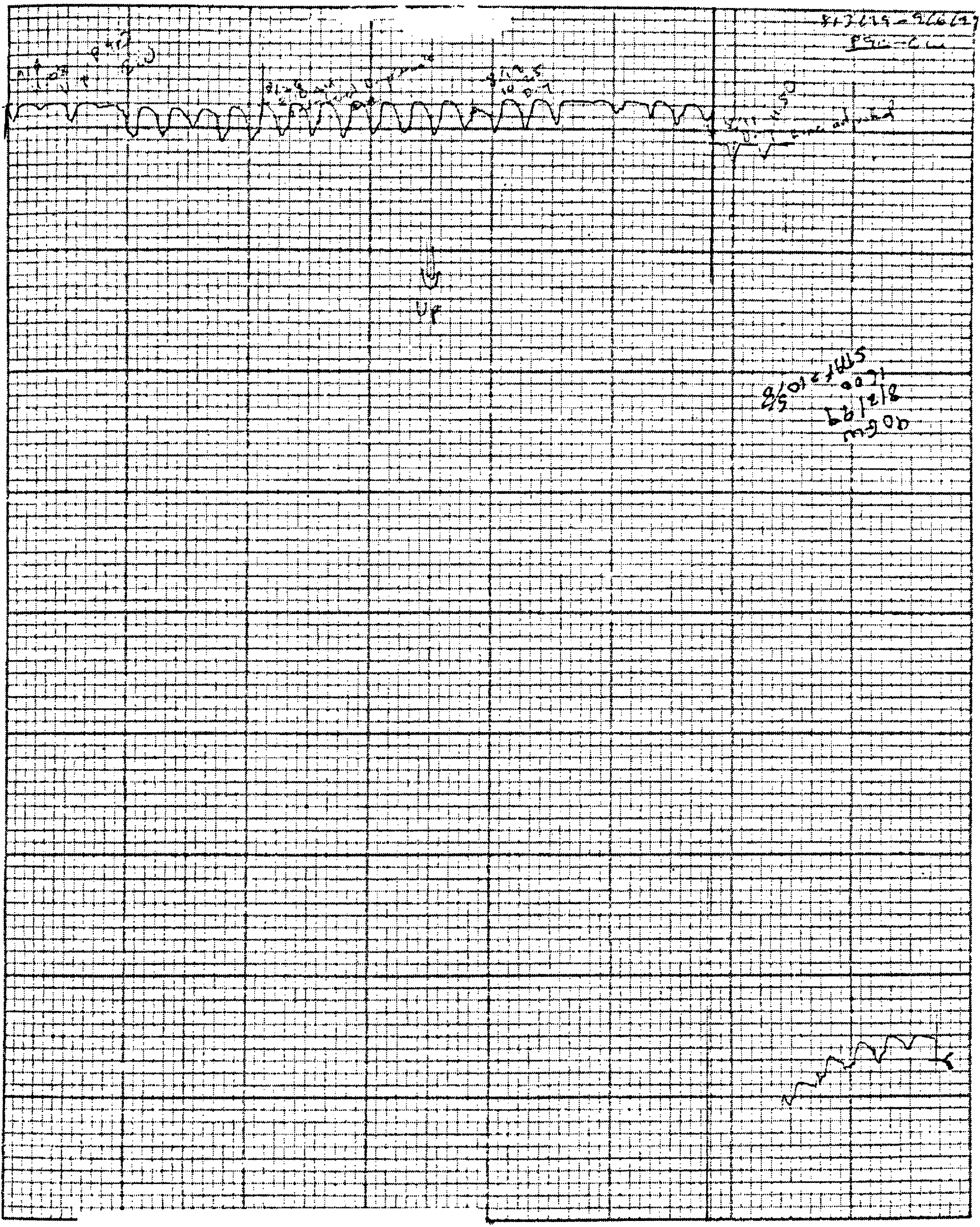
6/28/99 - 7/6/99
P90-GW



P90 GW
6/28-7/6/99

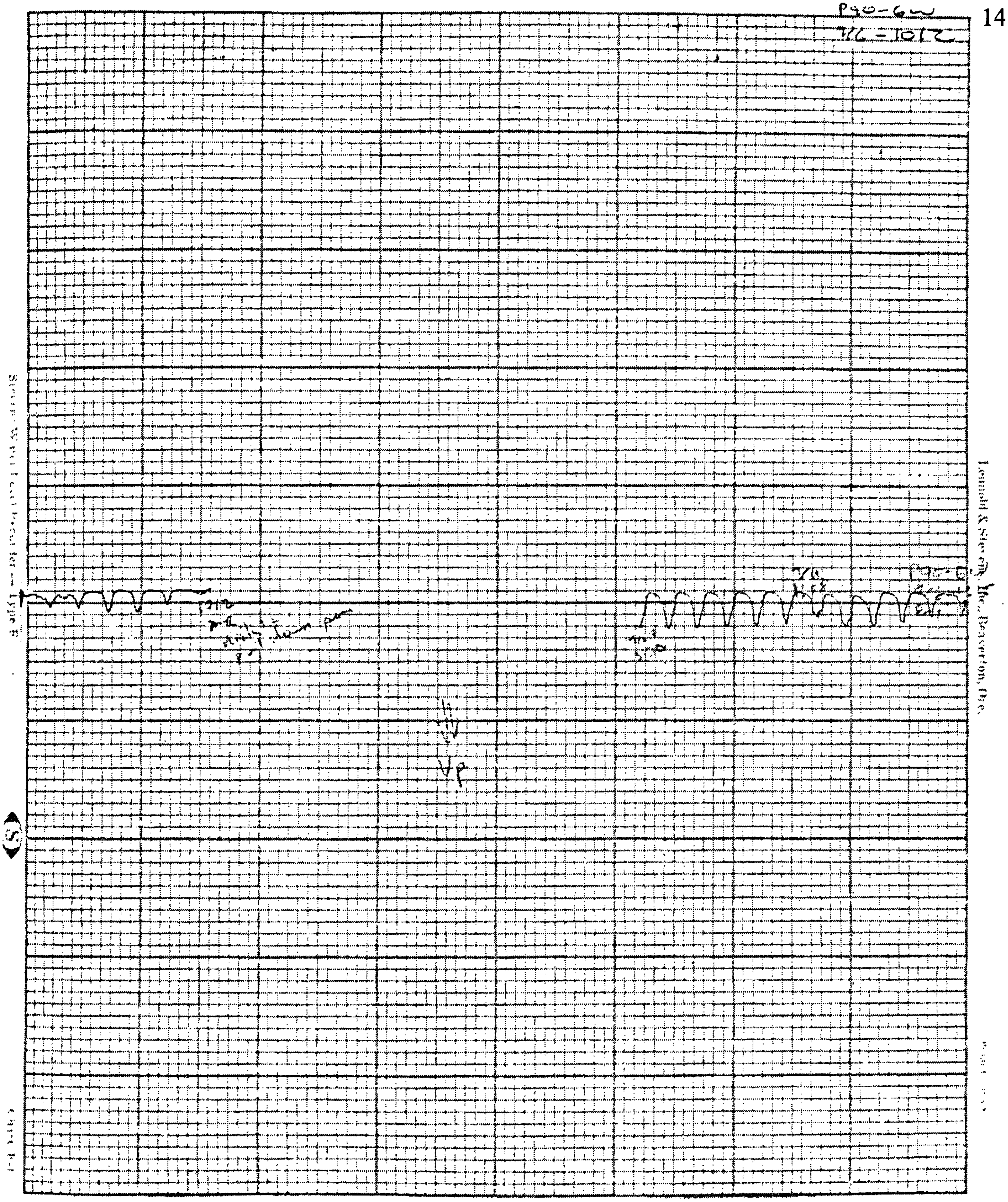


P90 GW
7/6-8/3/99



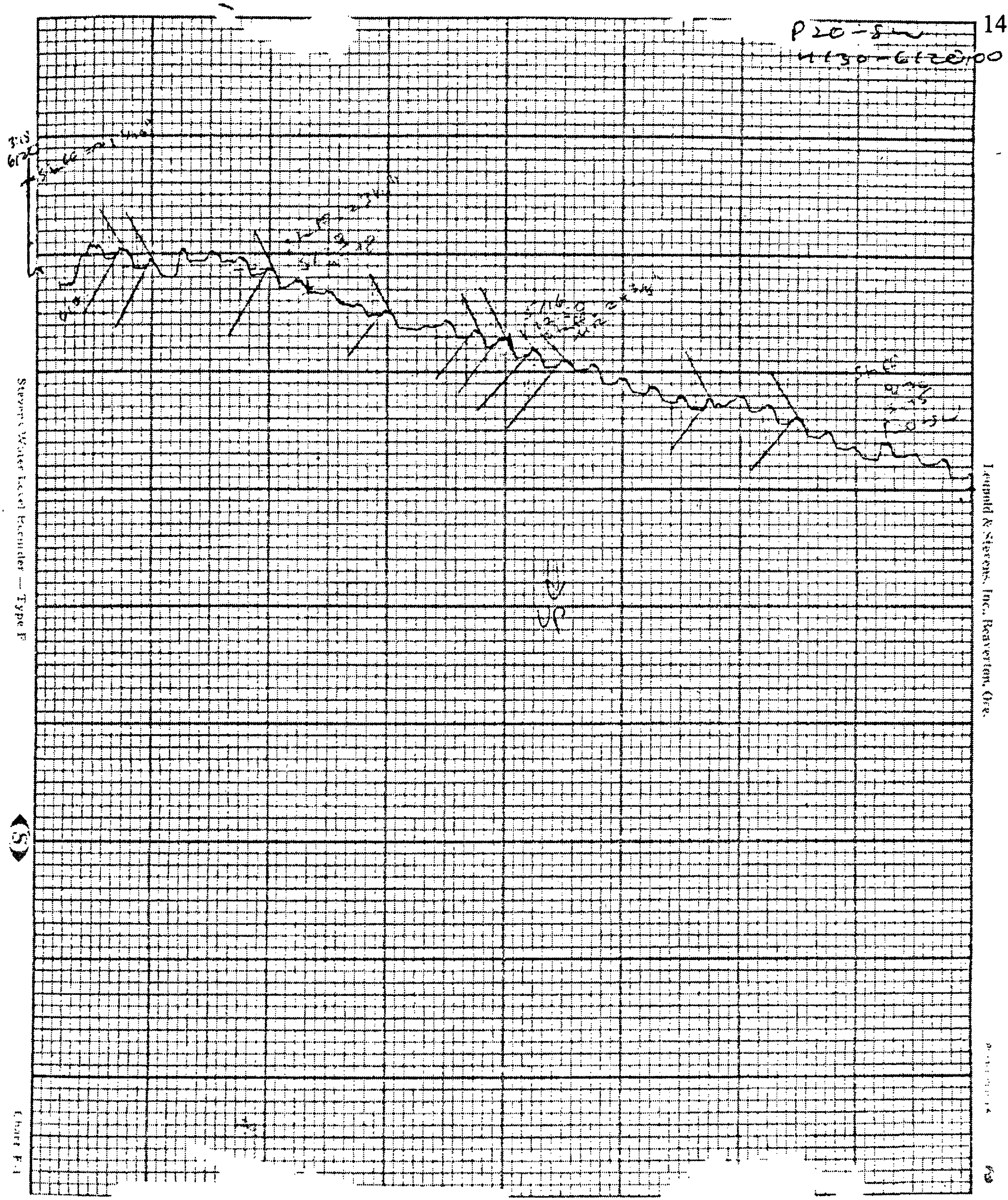
P90 GW
8/3-9/6/99

P90-GW
9/6 - 10/2

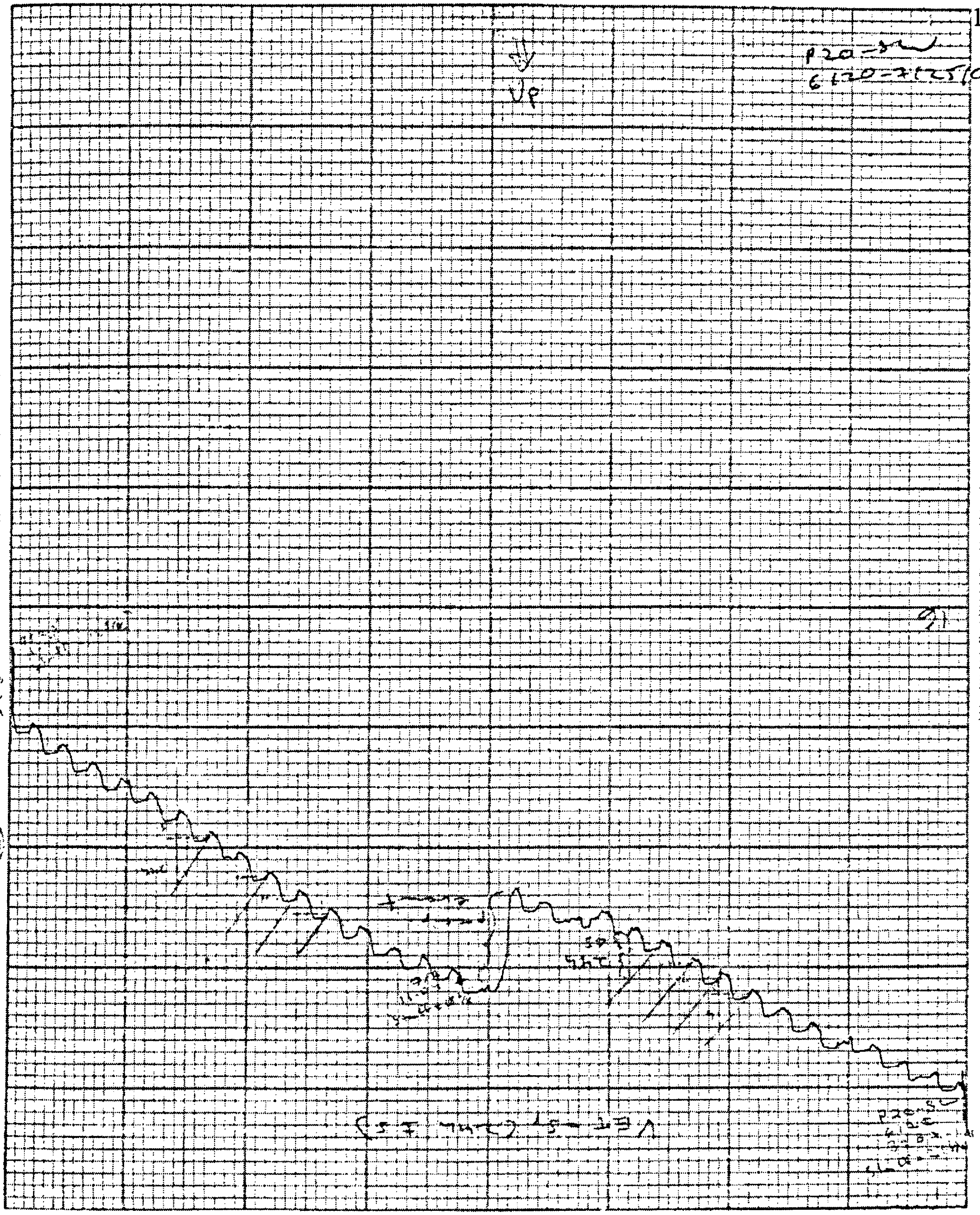


P90 GW
9/6-10/2/99

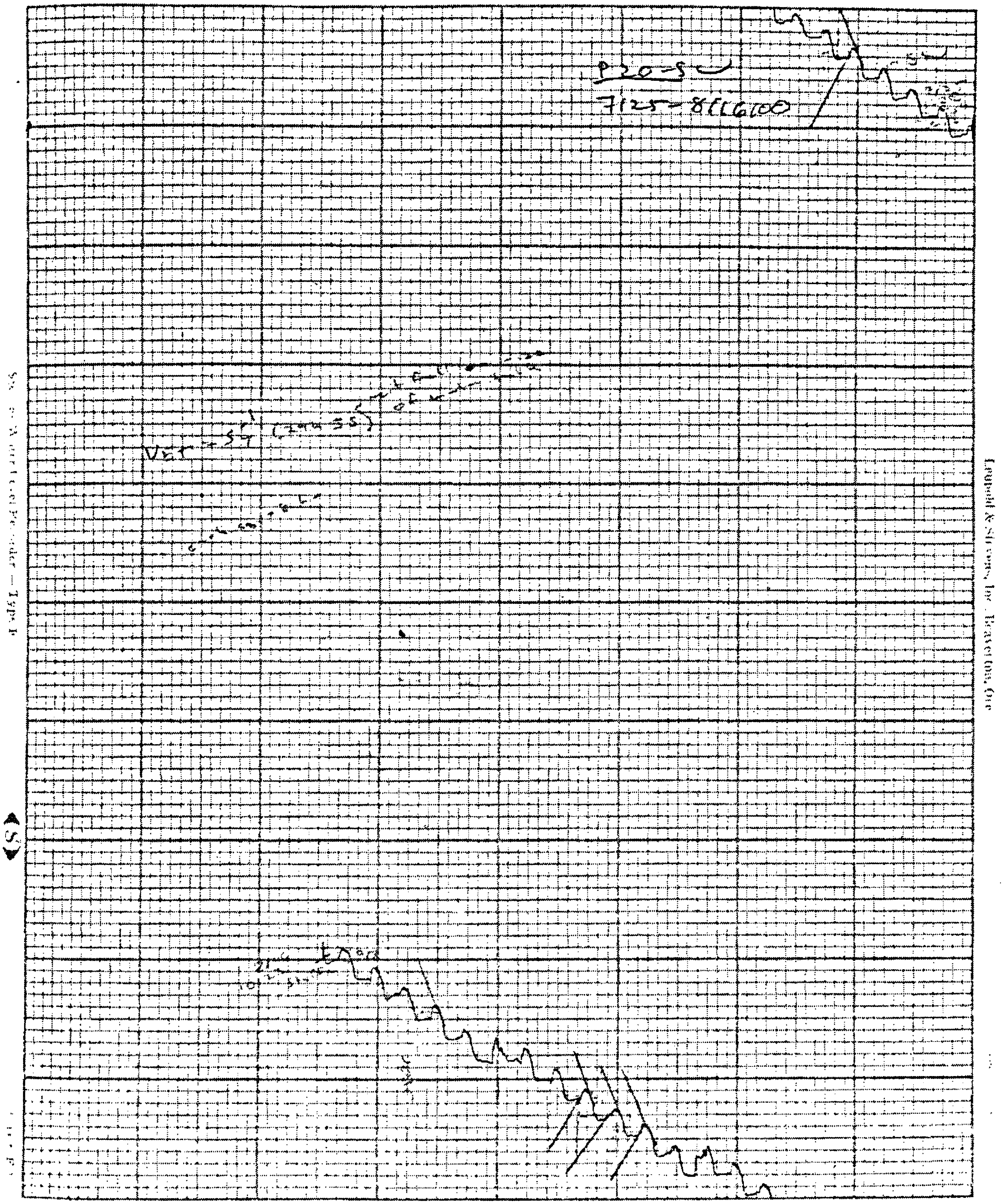
2000 Field Season Hydrographs



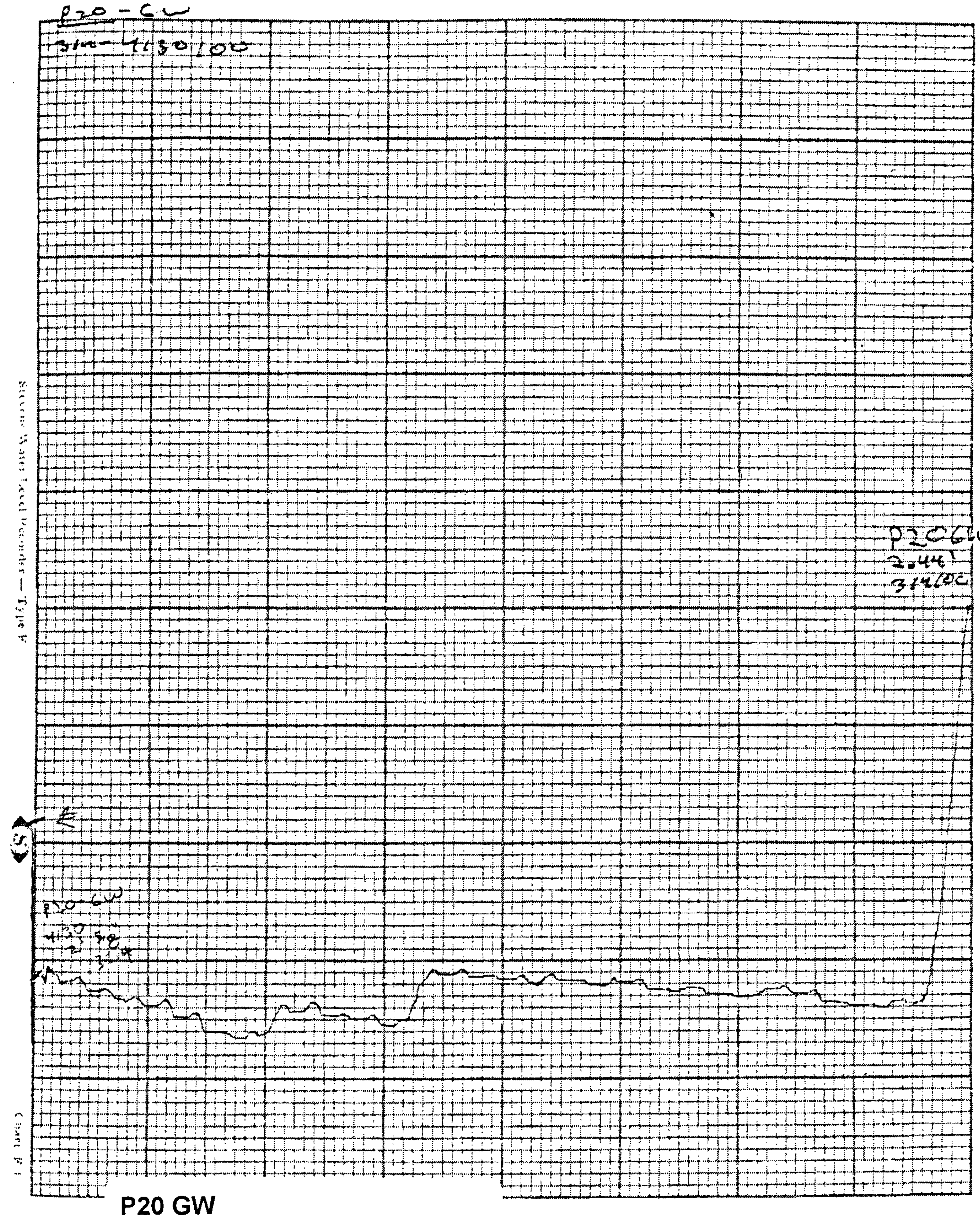
P20 SW
4/30-6/20/00



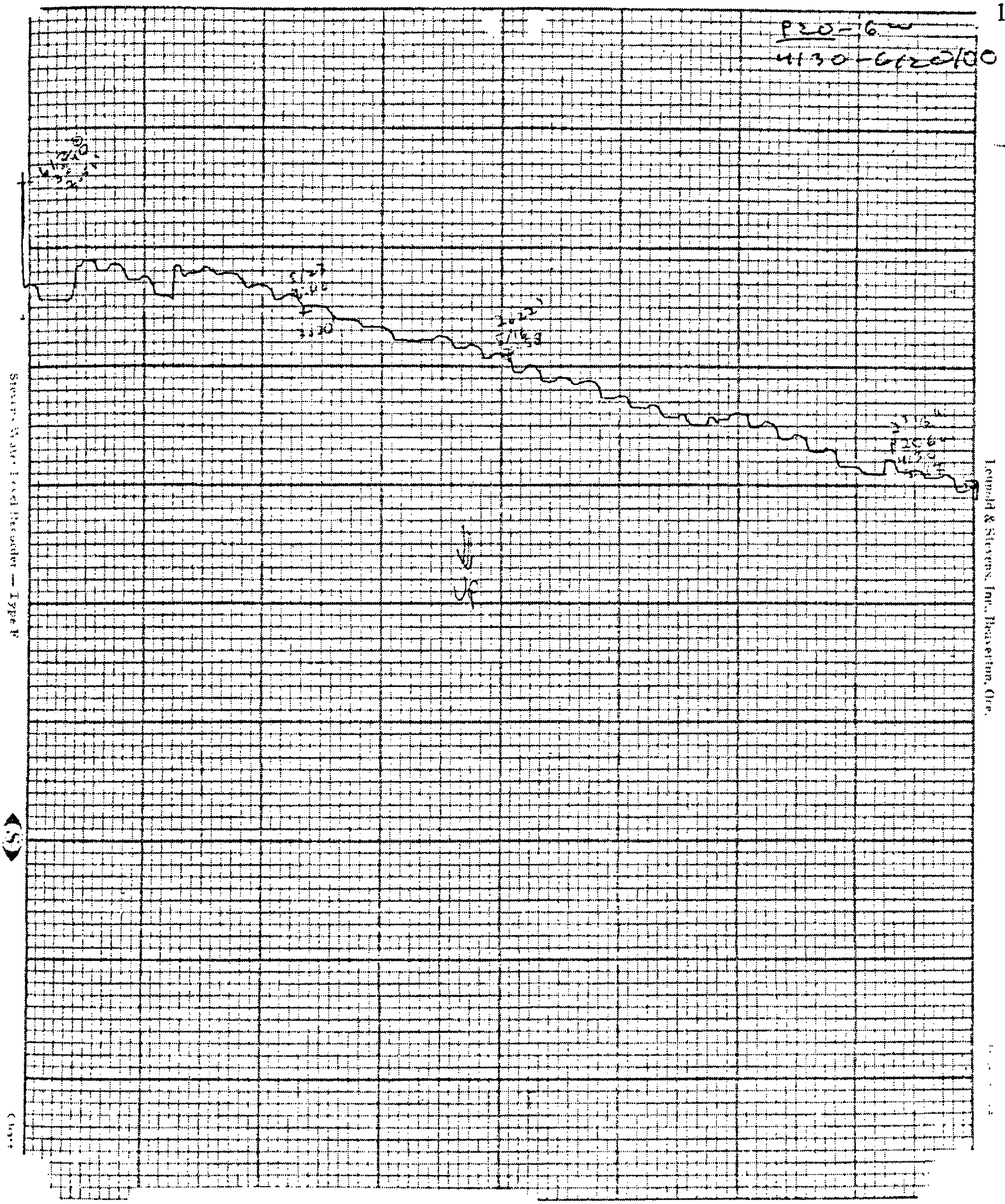
P20 SW
6/20-7/25/00



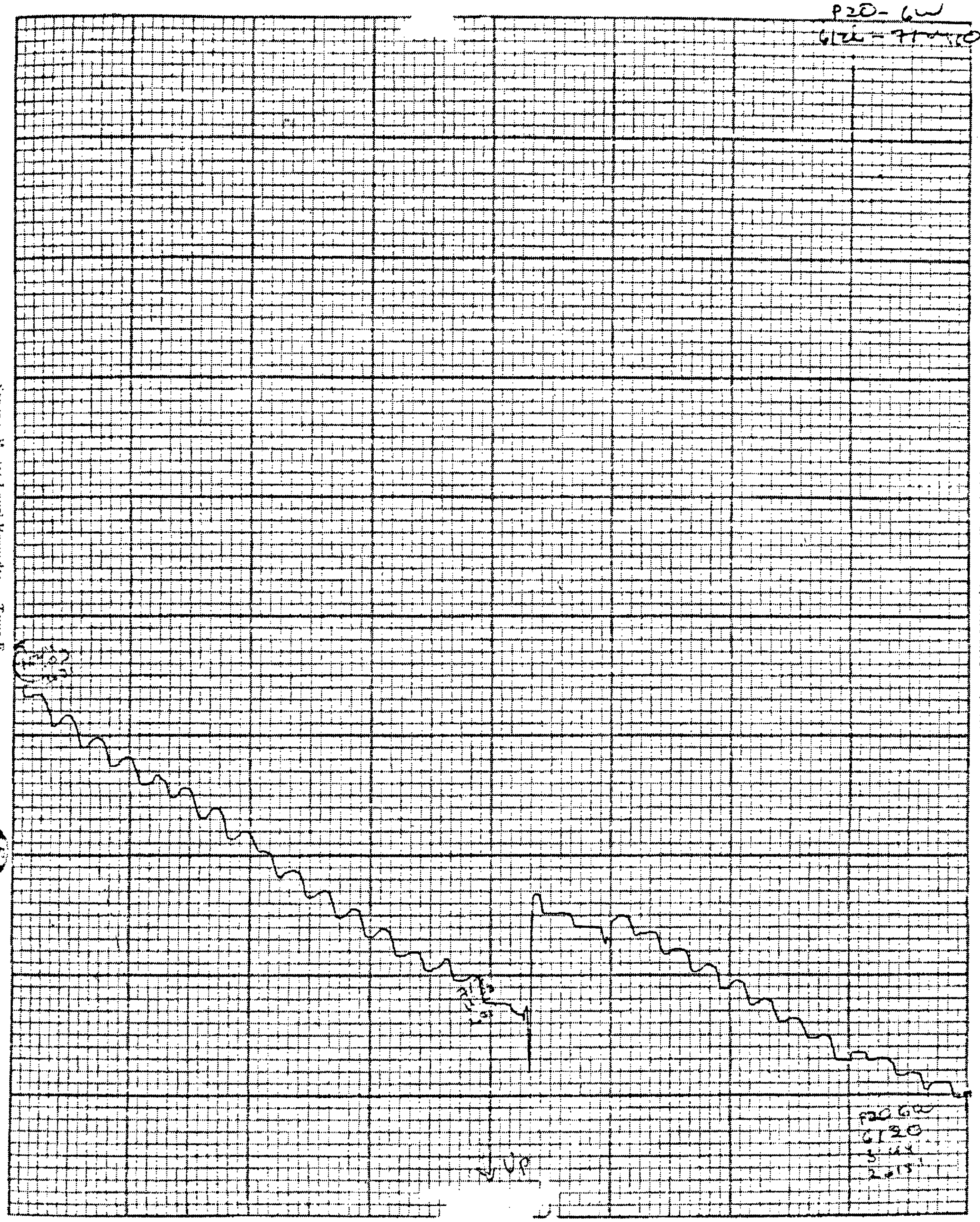
P20 SW
7/25-8/16/00



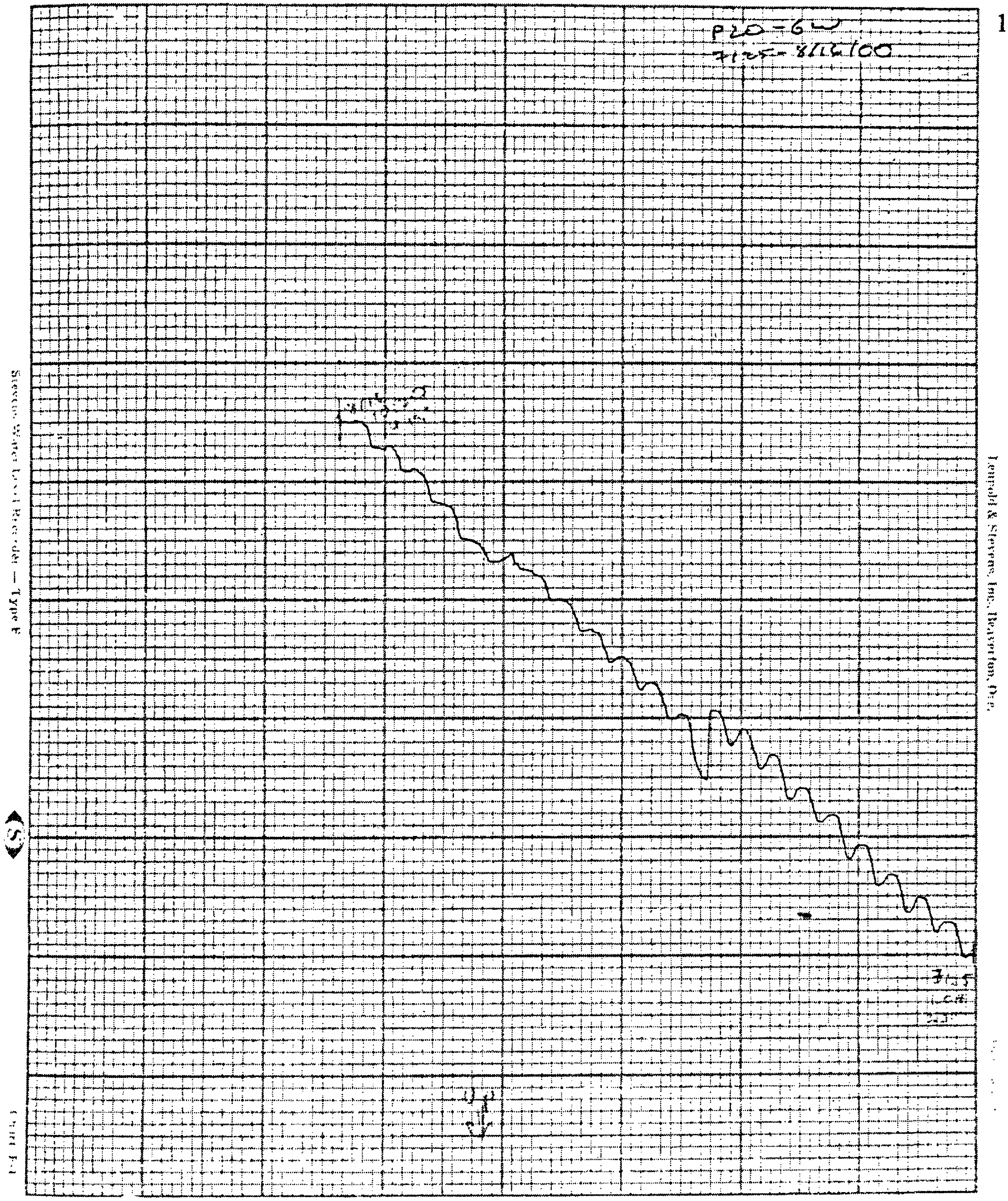
P20 GW
3/4-4/30/00


P20-6
4/30-6/20/00

P20 GW
4/30-6/20/00

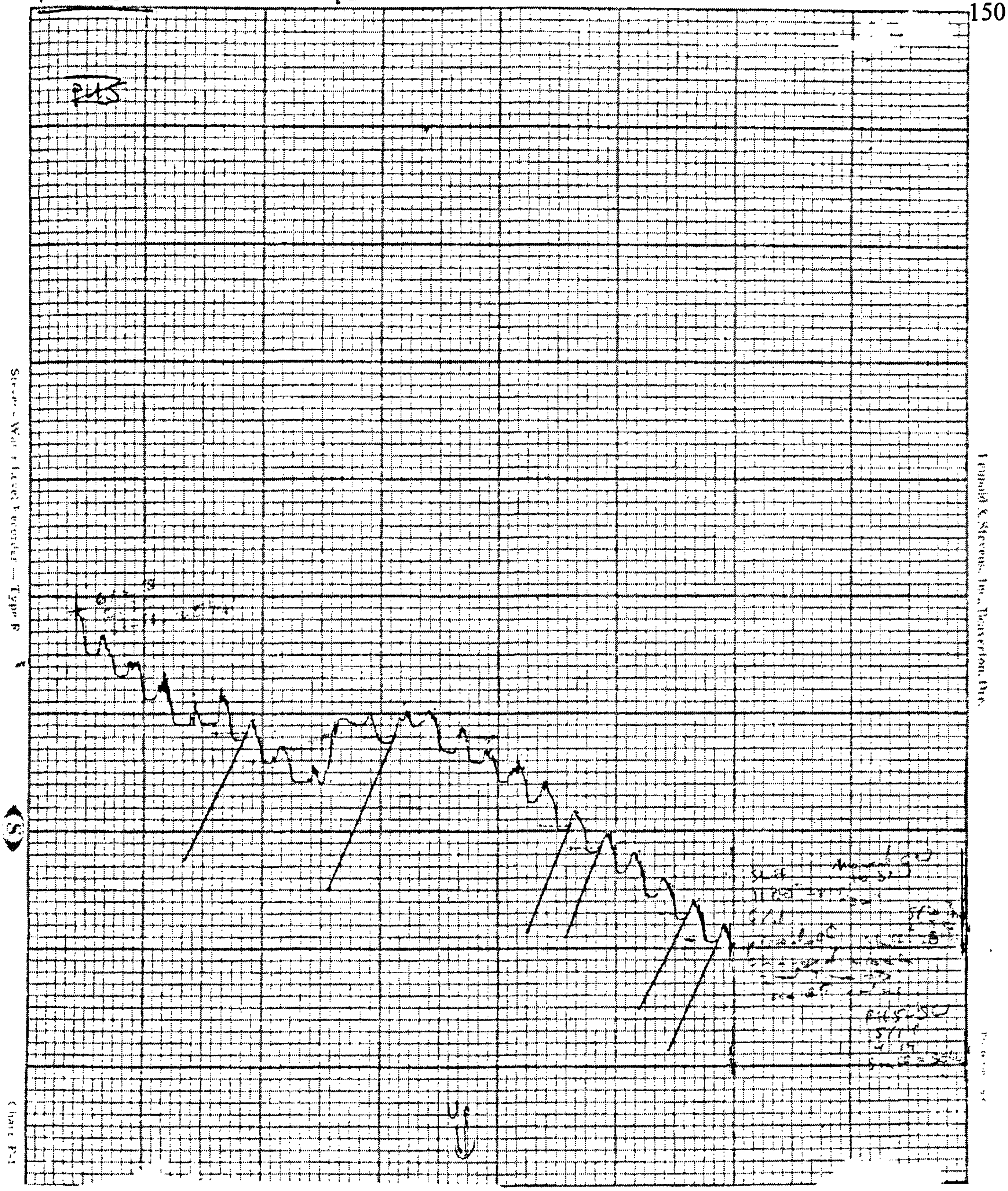


P20 GW
6/20-7/24/00

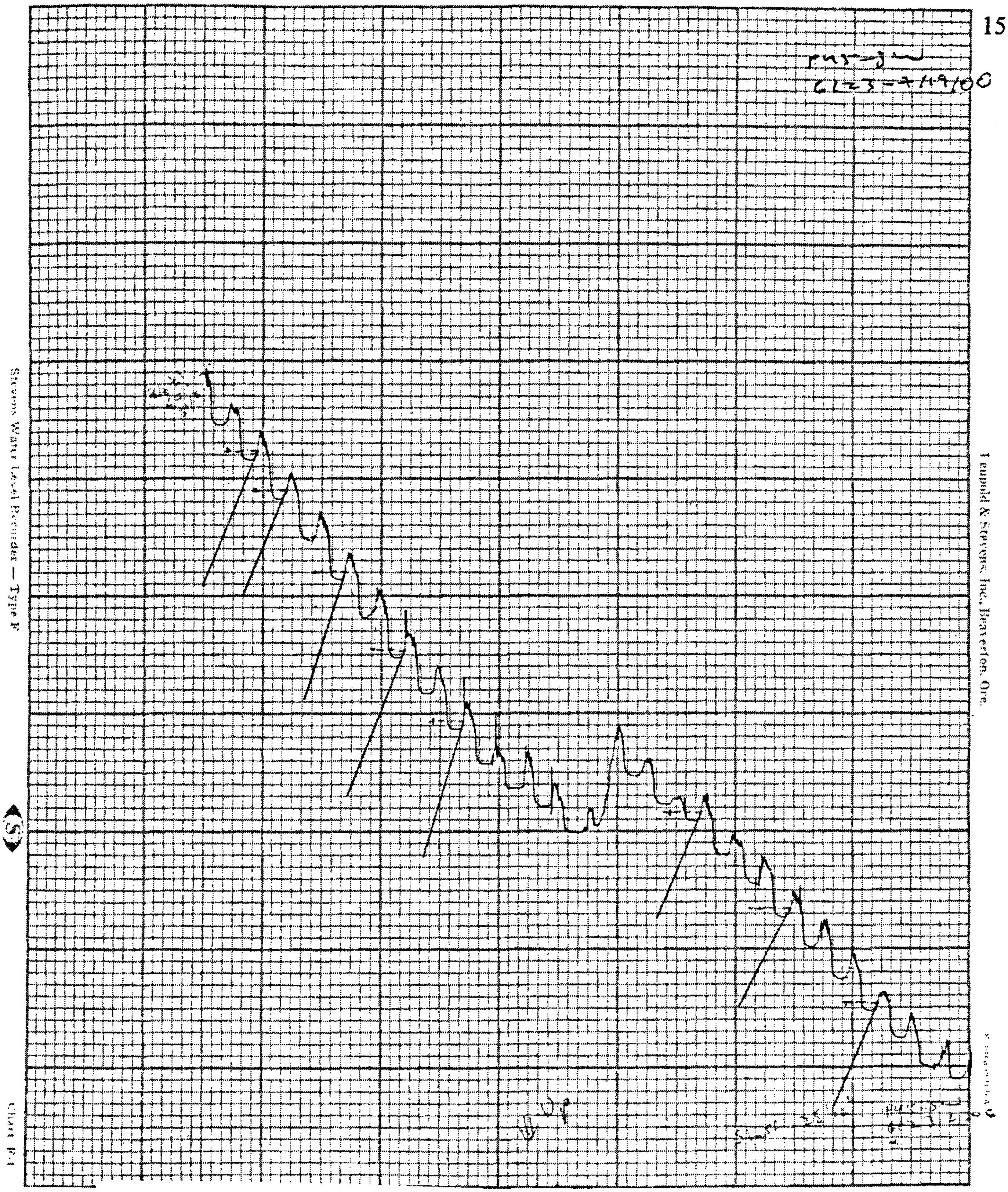


P20 GW
7/25-8/16/00

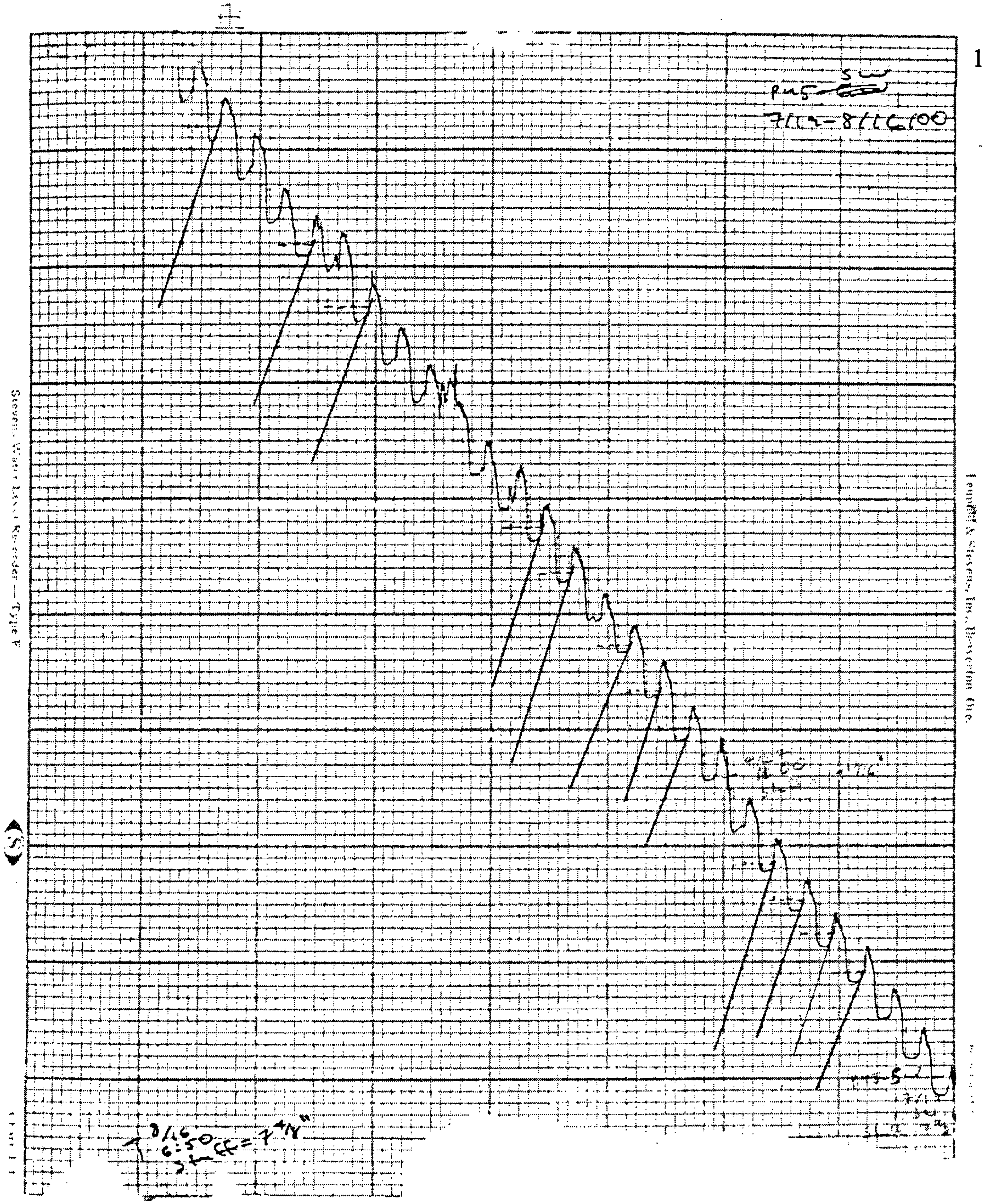
P45-SW 6/1 - 6/23/00



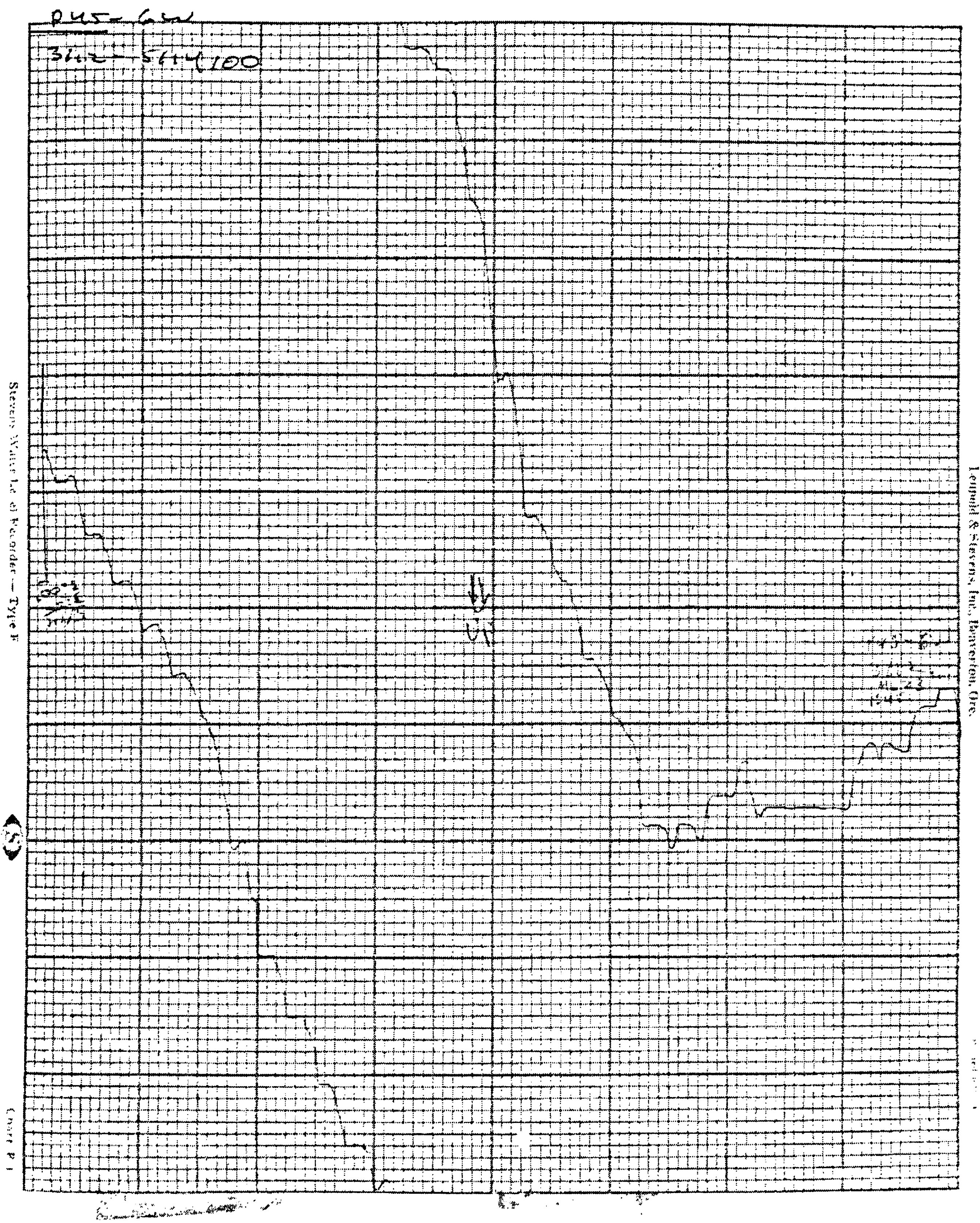
P45 SW
6/1-6/23/00



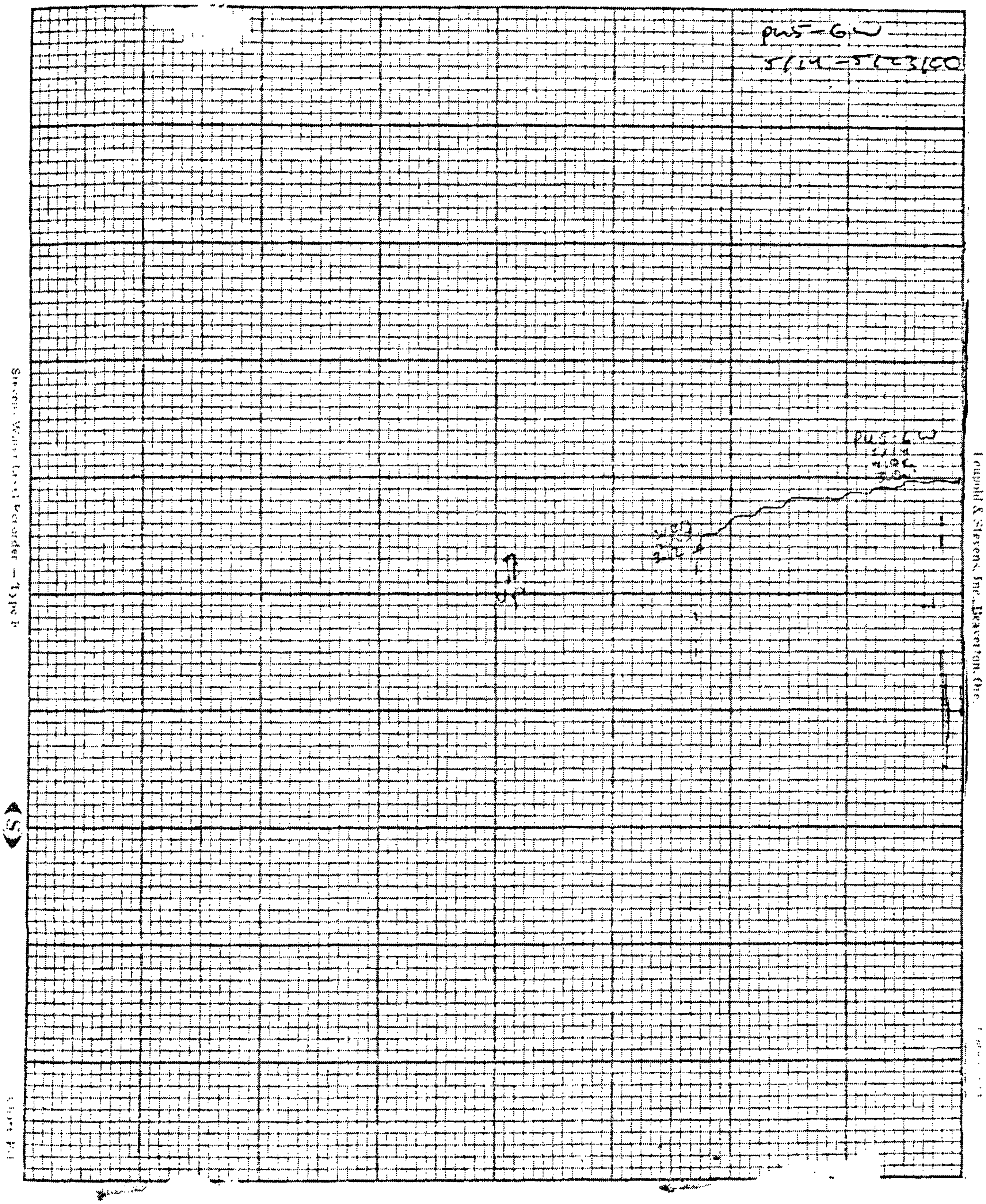
P45 SW
6/23-7/19/00



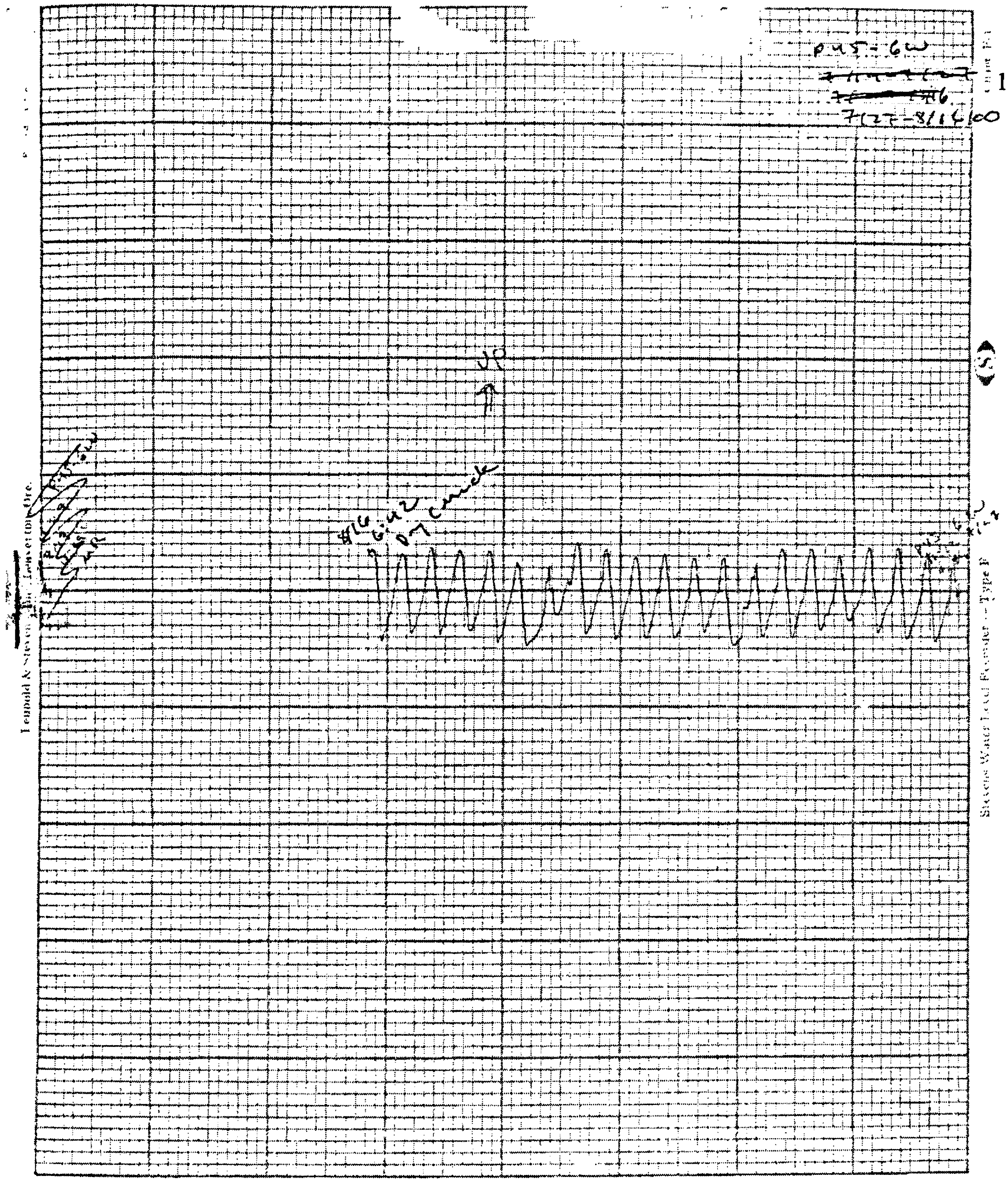
P45 SW
7/19-8/16/00



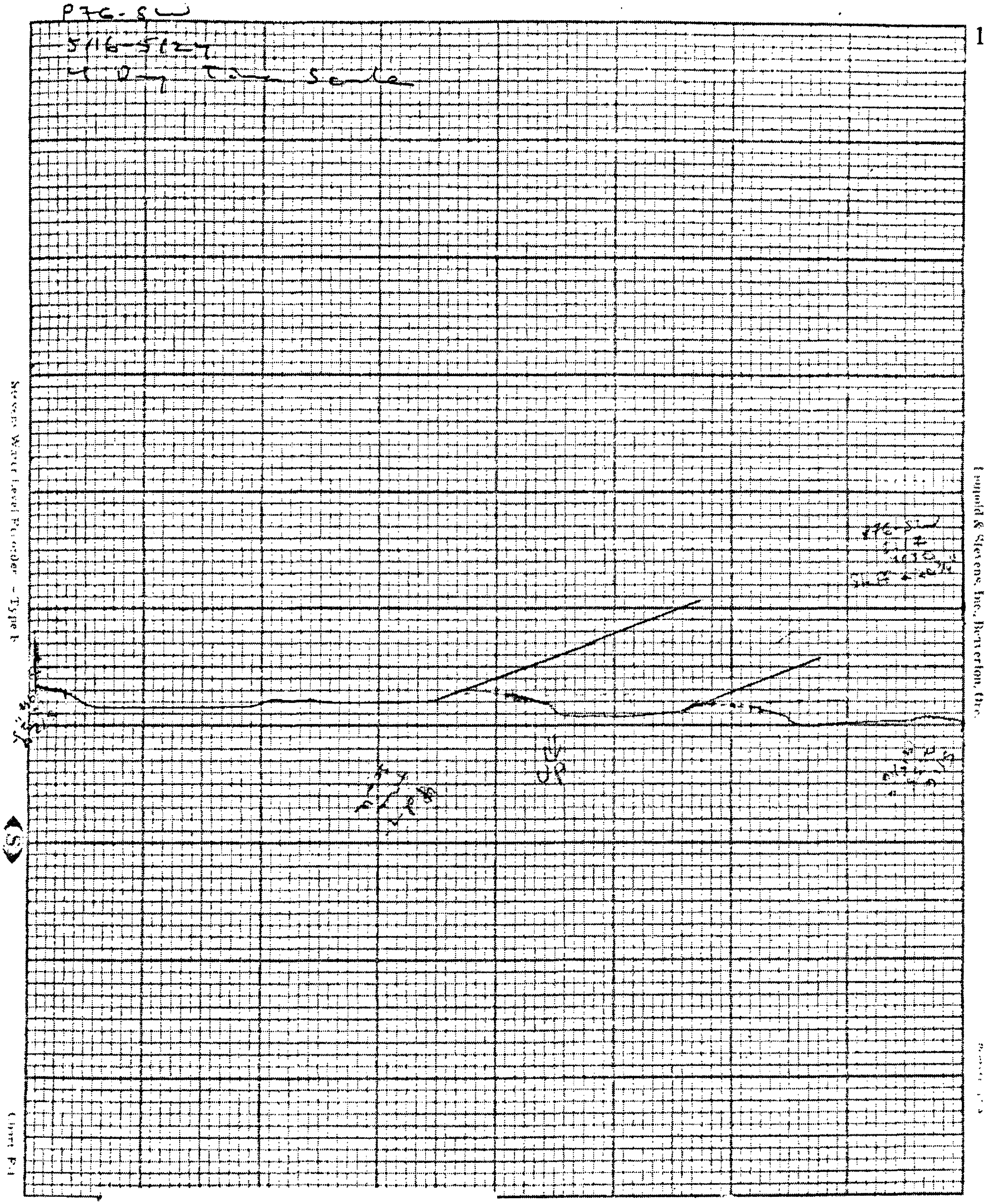
P45 GW
3/12-5/14/00



P45 GW
5/14-5/23/00

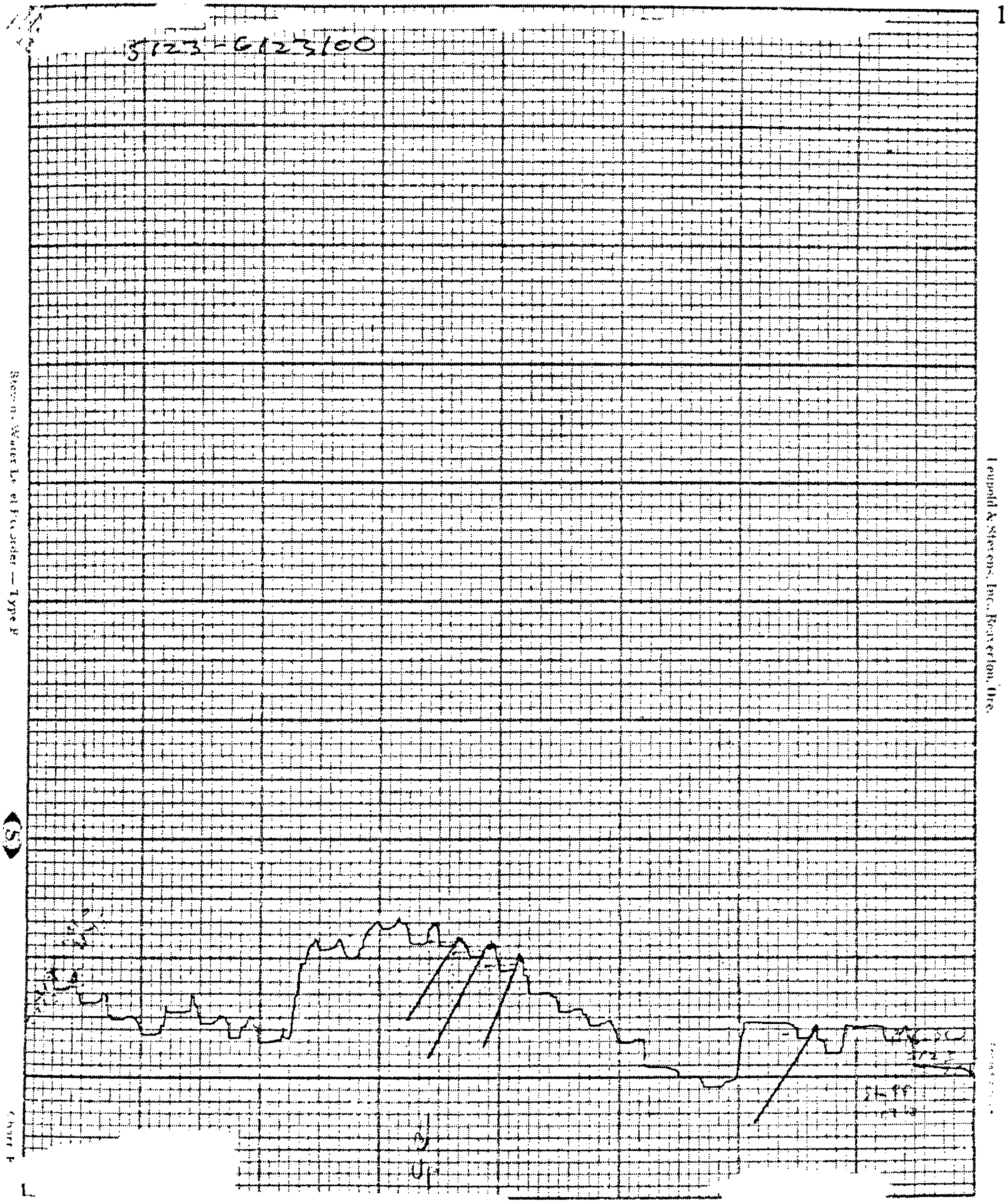


P45 GW
7/27-8/16/00

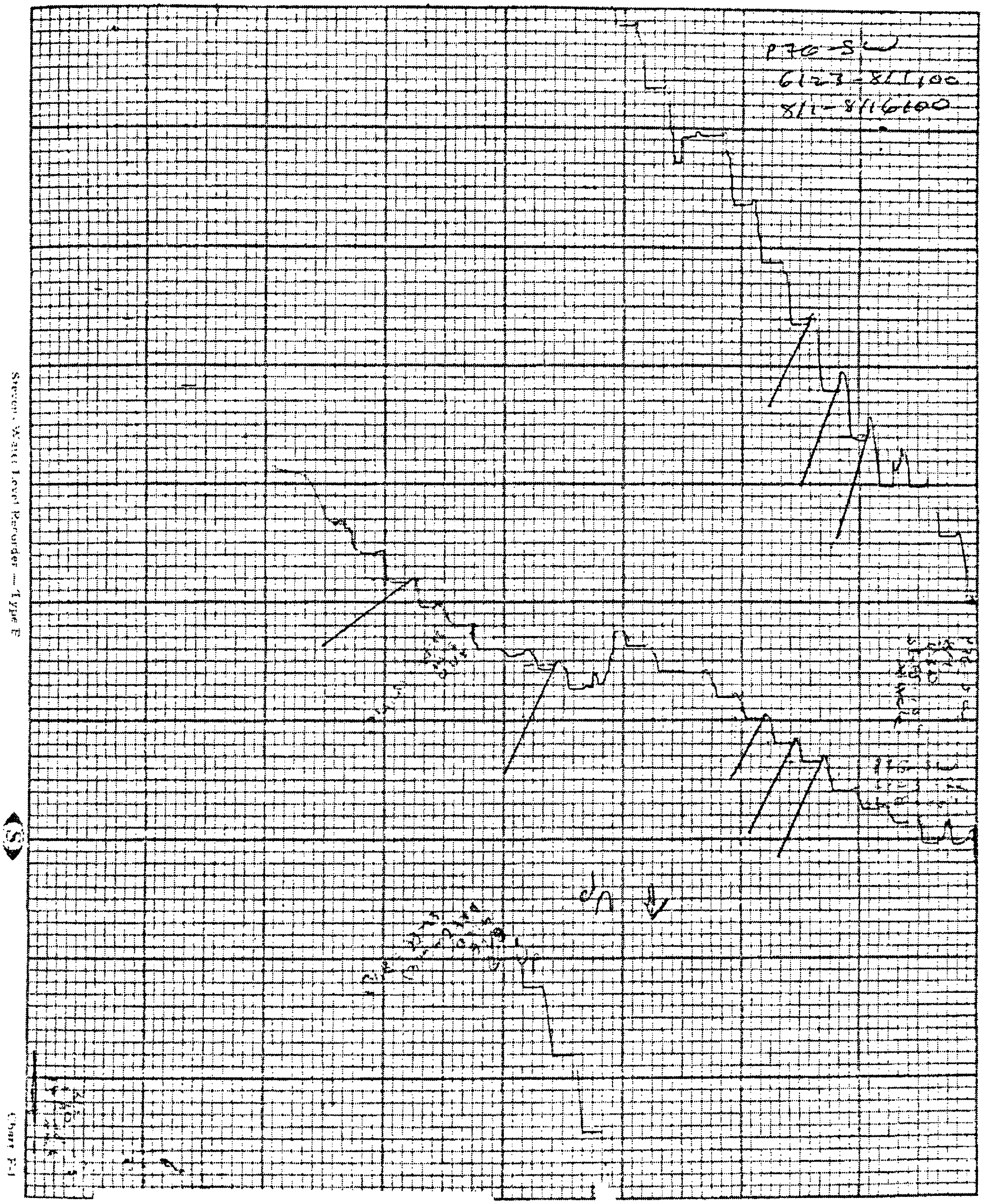


P76 SW
5/16-5/24/00

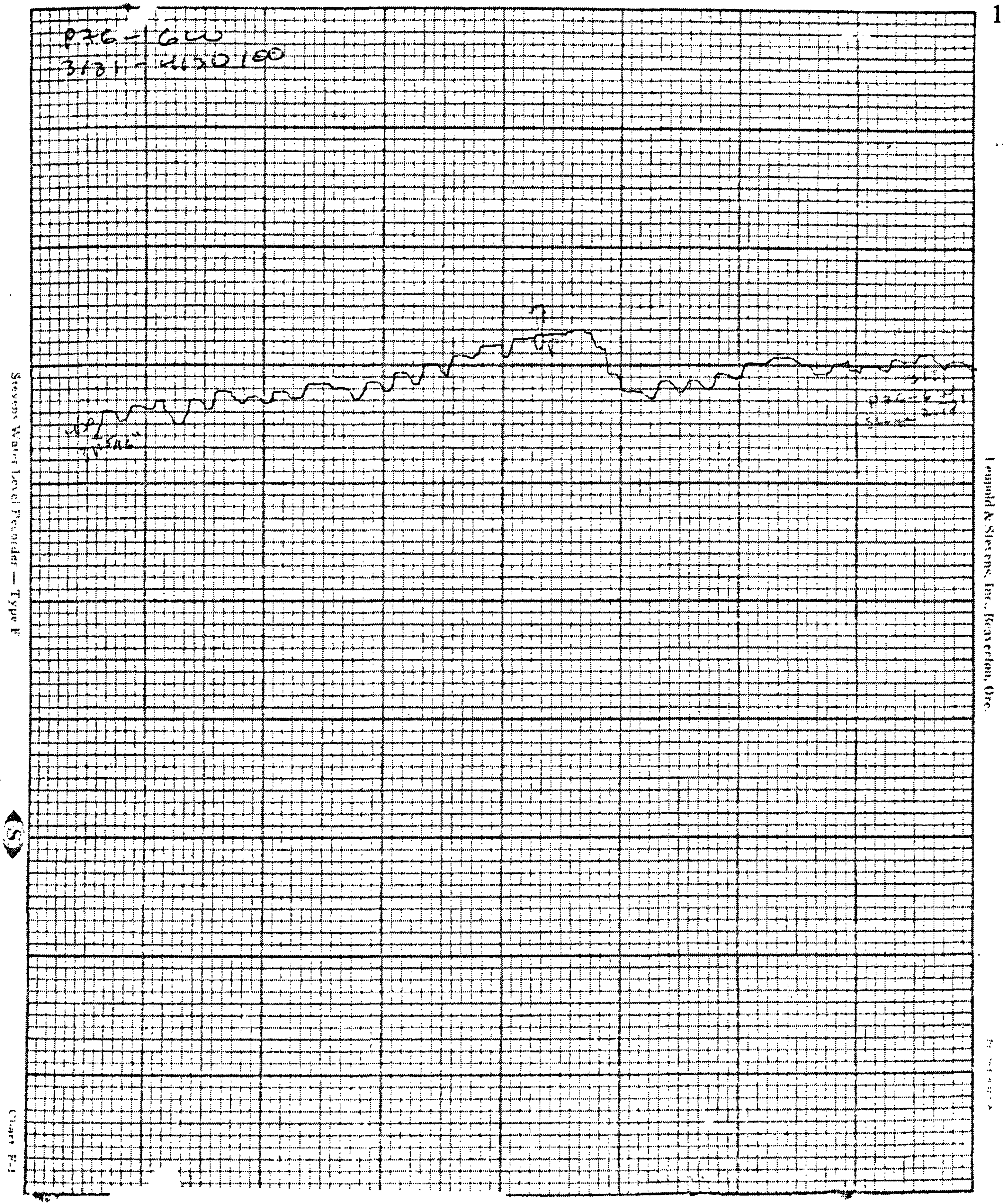
P76-SW



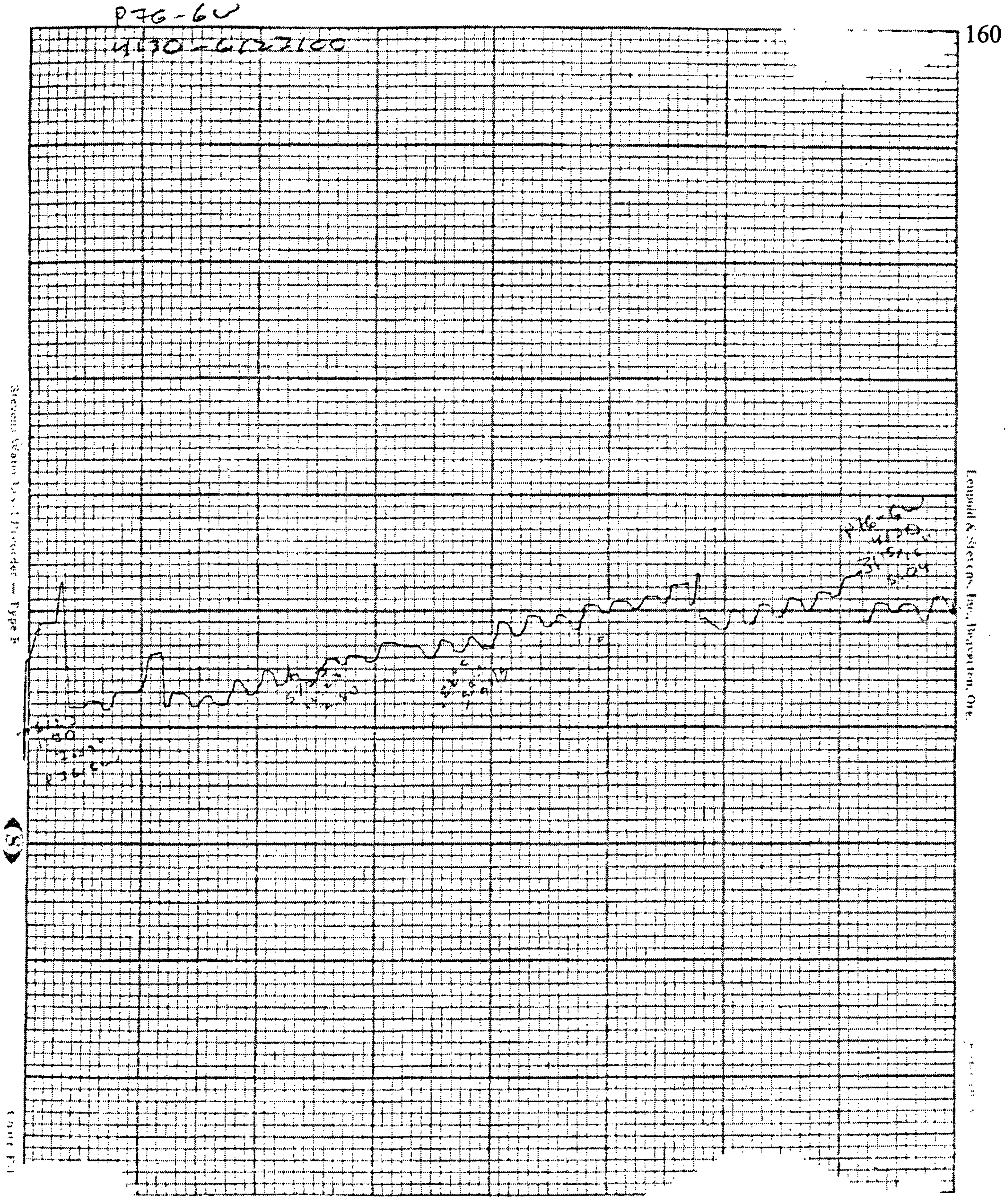
P76 SW
5/23-6/23/00



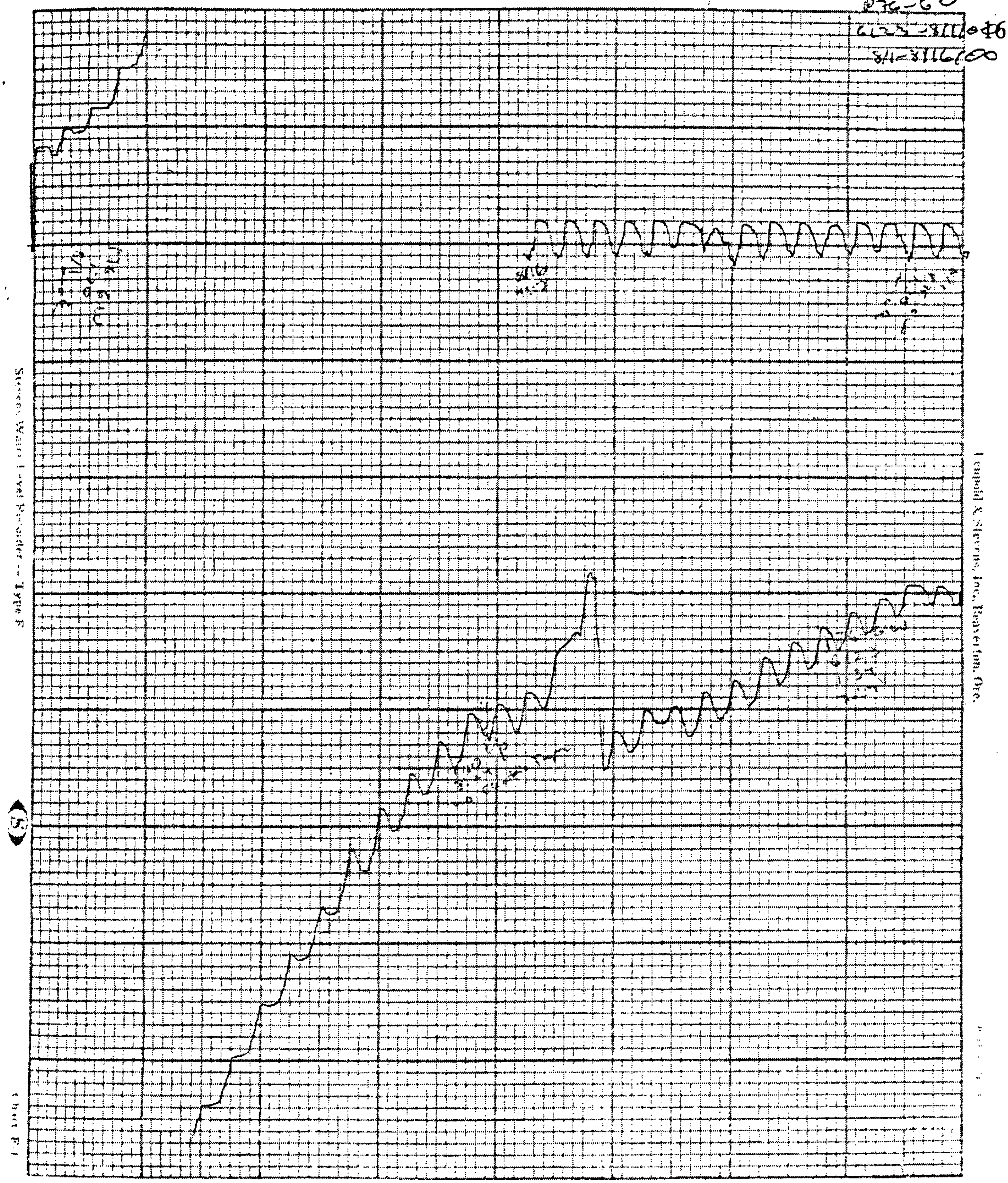
P76 SW
6/23-8/1/00
8/1-8/16/00



P76 GW
3/31-4/30/00

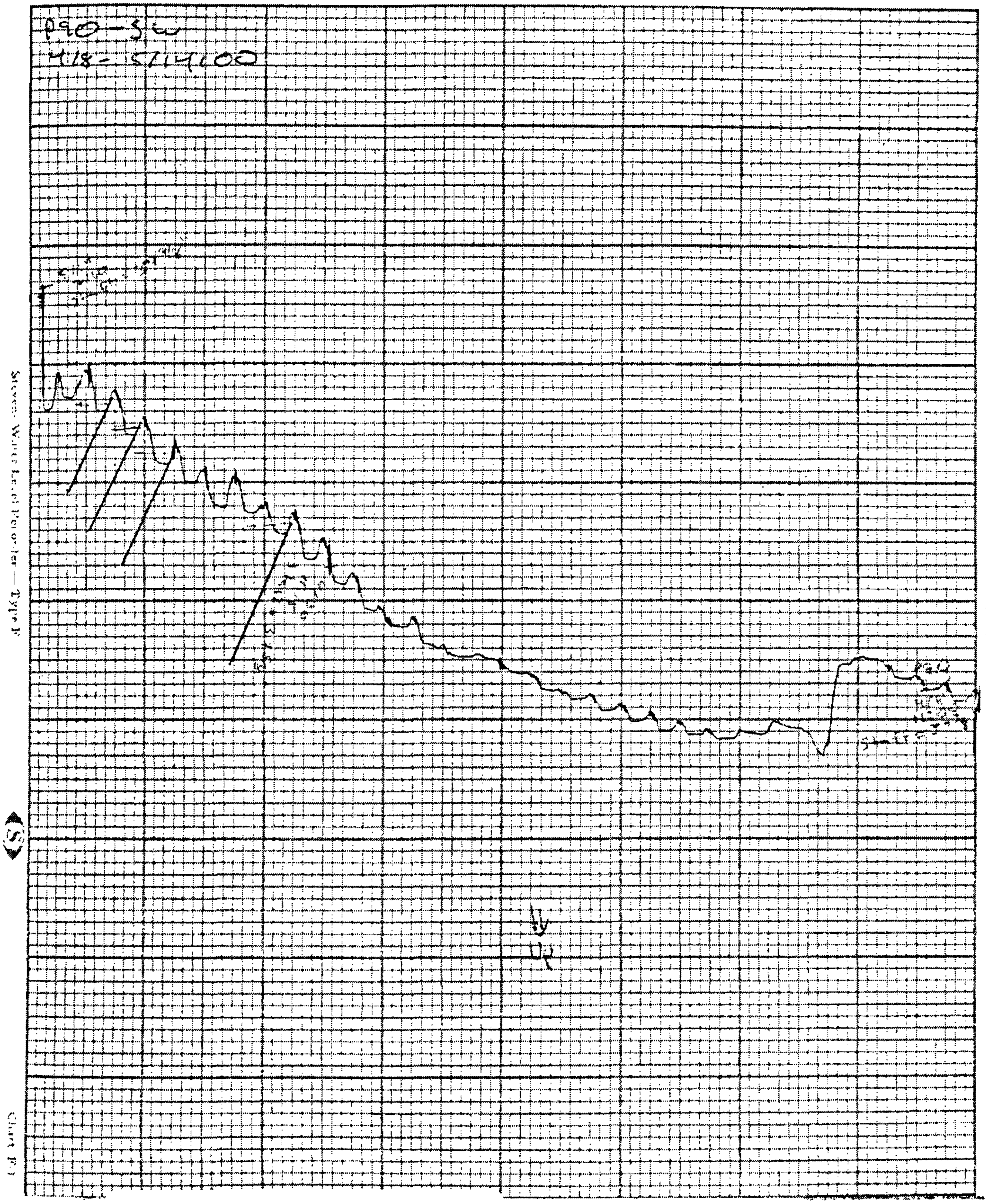


P76 GW
4/30-6/23/00



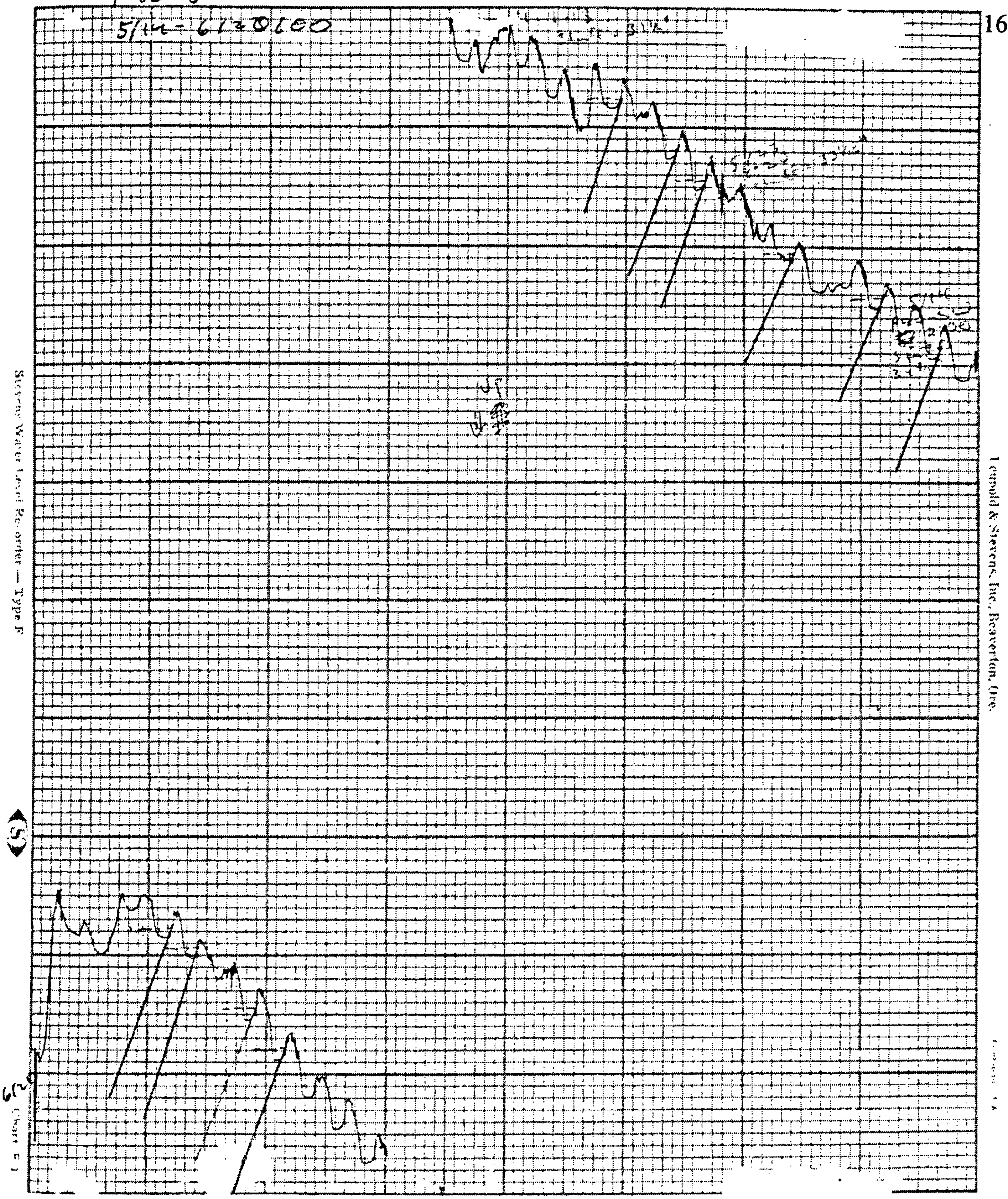
P76-GW
6/23-8/1/00 461
8/1-8/16/00

P76 GW
6/23-8/1/00
8/1-8/16/00

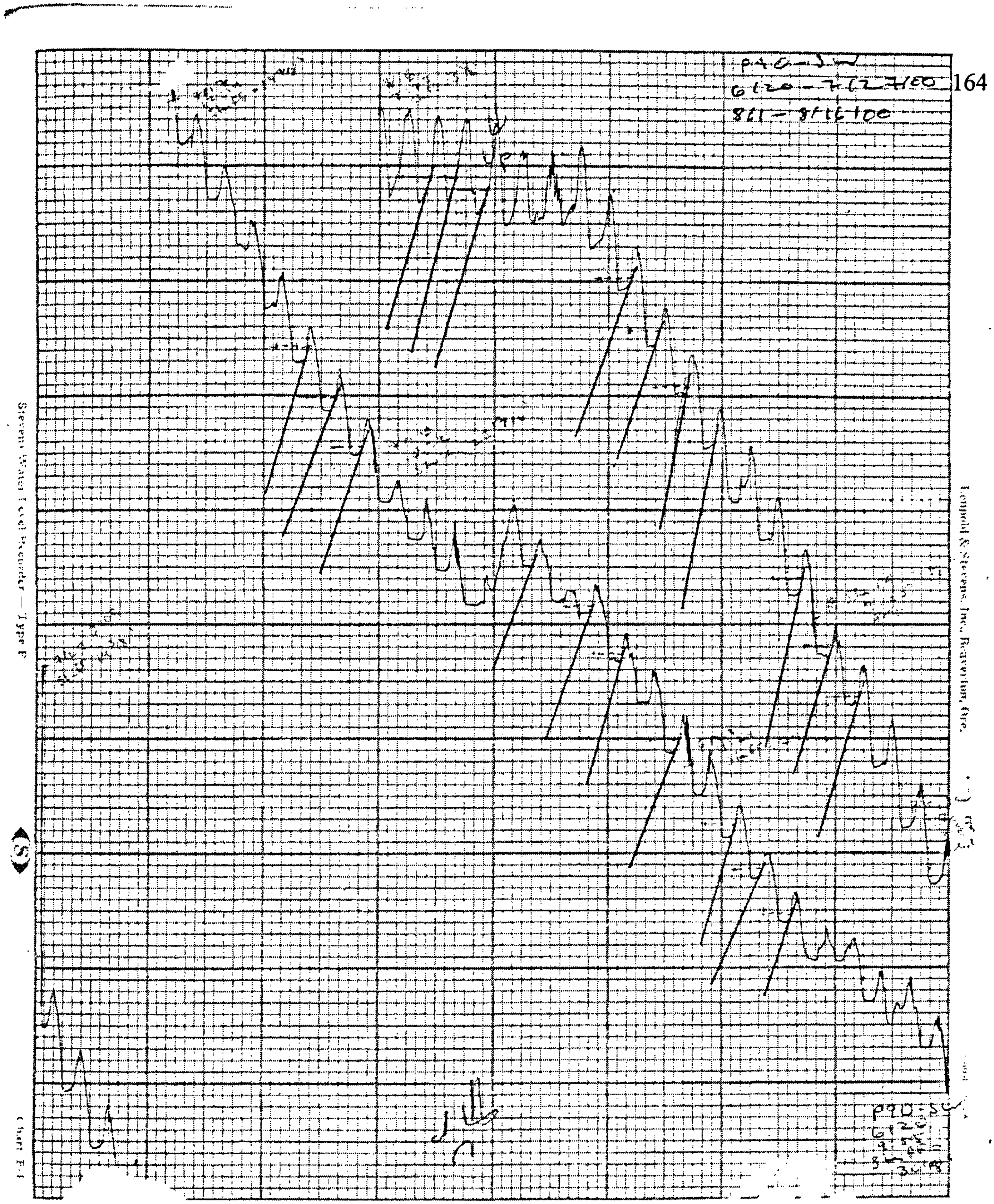


P90 SW
4/8-5/14/00

P90-SW

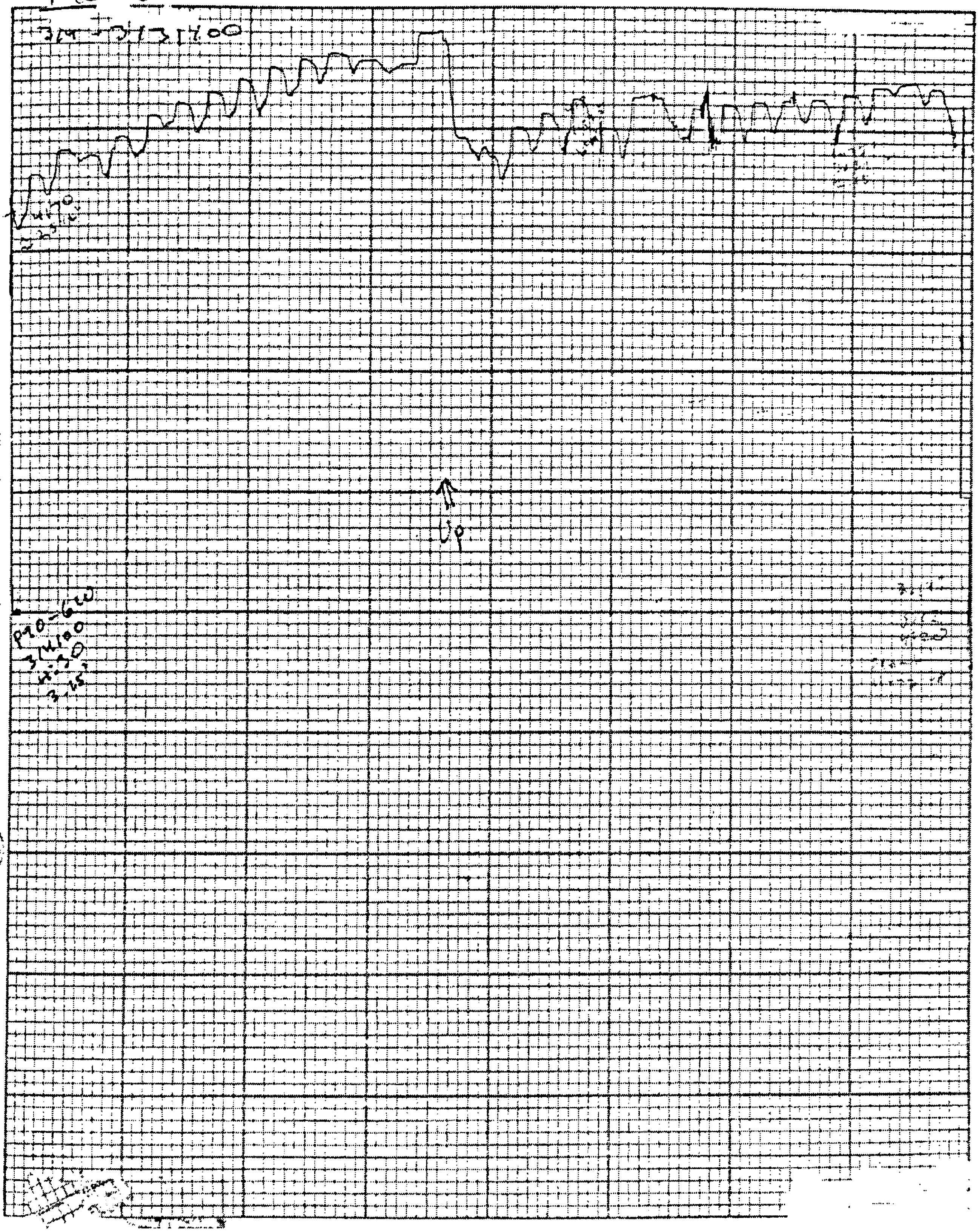


P90 SW
5/14-6/20/00



P90 SW
6/20-7/27/00
8/1-8/16/00

P90-GW
3/4-3/31/00

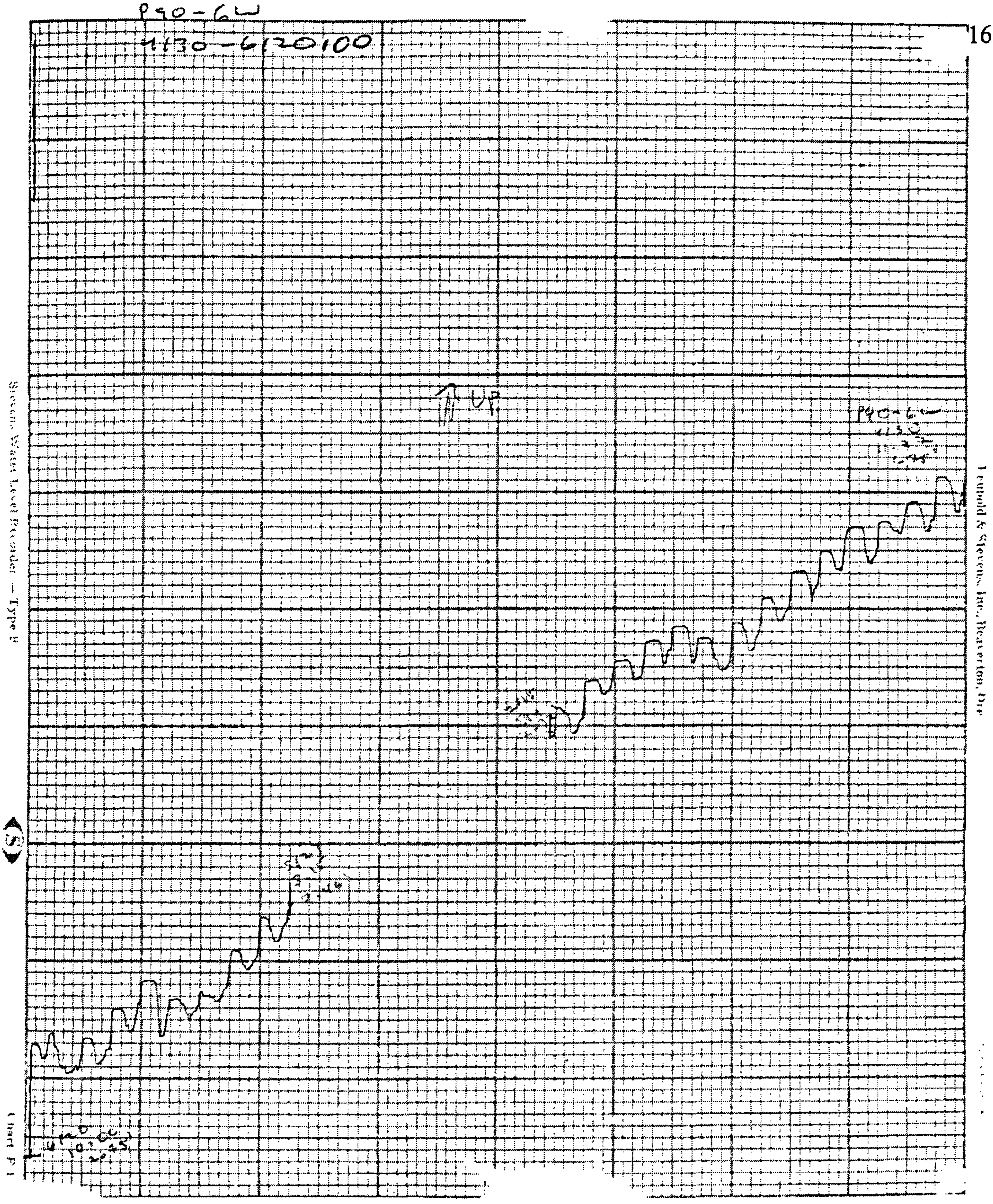


Up

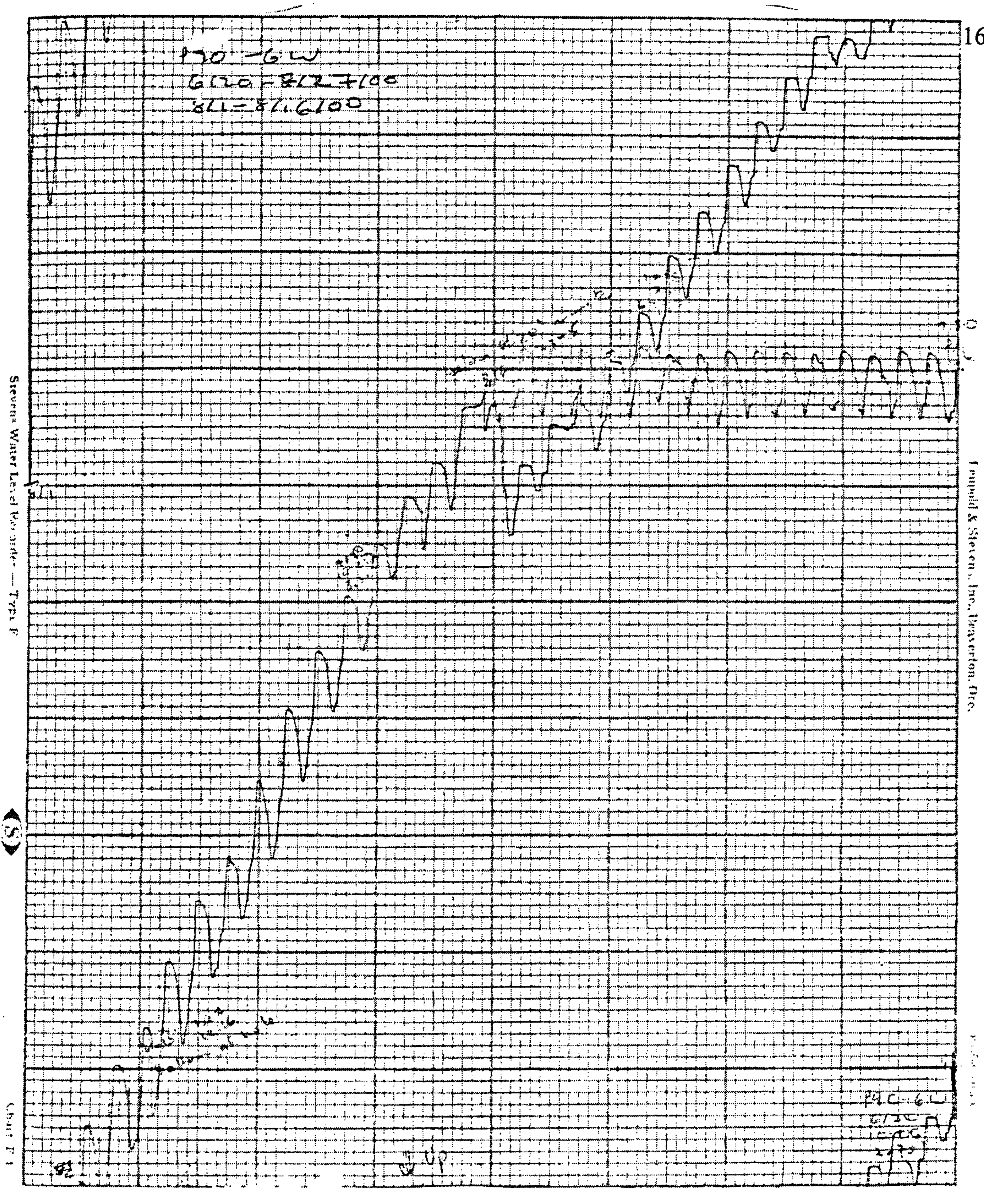
P90-GW
3/4/00
4:30
3.15'

P90 GW
3/4-3/31/00

P90-6W
4/30-6/20/00



P90 GW
4/30-6/20/00



P90 GW
6/20-7/27/00
8/1-8/16/00

APPENDIX D

WATER LEVELS AND WELL SPECIFICATIONS

Topo:	Condon Quad SW 1/4, Sec. 18, T21N, R16W
Latitude:	N47' 35"
Longitude:	W 1 1 3 ' 42.5"
Elevation:	~3720'-3760'
Aerial:	8/31/1992 2:12 USDA-F 611100 1492-172
Access:	Forest Service Road 9815

Pond Key

P20	Main Pond/Fully Instrumented
P21	Downgradient from P20/Lilies
P22	Upgradient from P20
P23	Visible from Road/Upgradient from P20

Data from Shapley, 1998

P20

Outlet Stream	Yes
Hypsometric Class	1
Basin Form Class	elongate

3/4" Steel Pipe Well Specifications

Well No.	Top of Well to Line (in.)	Total Above Ground (in.)	Sections of Pipe (3' lengths)	Total Well Length (in.)	Adjusted Well Length (datum) (in.)
W20-1SS	15.25	32.00	1	60	44.75
W20-1S	21.50	36.50	2	72	50.50
W20-1D	22.31	35.38	3	108	85.69
W20-2S	15.56	35.00	2	72	56.44
W20-2D	21.38	42.63	3	108	86.63
W20-3S	15.50	37.50	2	72	56.50
W20-3D	8.75	26.75	3	108	99.25

1/2" Electrical Conduit Piezometer Specifications

Piezometer No.	Length Above Sediment (in.)
MP-20-1A	39.38
MP-20-Bs	41.00
MP-20-Bd	42.88
MP-20-Cs	37.00
MP-20-Cd	29.75
MP-20-D	35.13
MP-20-E	39.69

3/4" PVC Monitoring Well Specificaitons

Well No.	Depth to Filter Pack (ft.)	Thickness of Filter Pack (ft.)	Length Below Ground (ft.)	Total Well Length (ft.)
MW20-1	2.45	5.75	8.20	10.00
MW20-2	1.90	12.30	14.20	16.00
MW20-3	6.10	4.15	10.25	12.20

P21-P23 3/4" Steel Well Specifications

	Total Above Ground (in.)	Sections of Pipe	Total Well Length (in.)
P21-S	33.00	1	60
P21-D	32.13	2	72
P22-S	39.38	1	60

all these wells are dry, no GW data, no longer used

P22-D	33.13	2	72
P23-S	40.00	1	60
P23-D	32.25	2	72

Wells drilled w/ Geoprobe on 6/4/00

Well No.	Depth to Filter Pack (ft.)	Thickness of Filter Pack (ft.)	Length Below Ground (ft.)	Total Well Length (ft.)
MW20-1	7.33	6.29	13.63	15.13
MW20-2	land surface	6.00	6.00	7.50
MW20-3	3.00	13.25	16.25	18.00
MW20-4	2.58	8.92	11.50	13.17
MW20-5	2.45	5.75	8.20	10.00

MW20-5 was formerly designated MW20-1 in 1999 water level data

P45-Beaver Creek

Topo: Cygnet Lake Quad
~SE 1/4, Sec. 18, T19N, R16W
Latitude: N47' 23"
Longitude: W113' 40'
Elevation: 4240'-4260'
Aerial: line 46, 197-172
Access: Forest Service Road 9563

3/4" Steel Pipe Well Specifications

Well No.	Top of Well to Line (in.)	Total Above Ground (in.)	Sections of Pipe (3' lengths)	Total Well Length (in.)	Adjusted Well Length (datum) (in.)
W45-1SS	20.25	34.94	1	60	39.75
W45-1S	23.50	36.38	2	72	48.50
W45-1D	3.00	11.25	2	72	69.00
W-45-2S	10.63	36.75	2	72	61.38
W45-2D	21.75	48.25	3	108	86.25
W45-3S	0.00	0.00	1	36	36.00
W-45-3D	48.50	48.50	2	108	59.50

1/2" Electrical Conduit Piezometer Specifications

Piezometer No.	Length Above Sediment (in.)
MP-45-1As	37.88
MP-45-1Ad	
MP-45-B	37.38
MP-45-C	31.44
MP-45-Ds	35.00
MP-45-Dd	33.50
MP-45-Es	39.00
MP-45-Ed	25.50
MP-45-F	37.25

3/4" PVC Monitoring Well Specificaitons

Well No.	Depth to Filter Pack (ft.)	Thickness of Filter Pack (ft.)	Length Below Ground (ft.)	Total Well Length (ft.)
MW45-1	3.5	3.5	7.00	8.10
MW45-2	3.2	4.1	7.30	8.20
MW45-3	6.3	4.31	10.61	11.93

MW45-4	3.87	6.03	9.90	11.49	
MW45-5	3	8.89	11.89	14.00	
MW45-6	na	na	2.70	9.00	steel black pipe installled on 7/19/00

P76-Holland Lake

Topo:	Holland Lake Quad SE 1/4, Sec. 34, T20N, R16W
Latitude:	N47' 26"
Longitude:	W113' 37.5"
Elevation:	~4080'
Aerial:	line 48, 197-210

Data from Shapley, 1998

P76

Outlet Stream	No
Hypsometric Class	3
Basin Form Class	complex

3/4" Steel Pipe Well Specifications

Well No.	Top of Well to Line (in.)	Total Above Ground (in.)	Sections of Pipe (3' lengths)	Total Well Length (in.)	Adjusted Well Length (datum) (in.)
W-76-1SS	20.75	40.50	1	60	39.25
W-76-1S	19.63	32.25	2	72	52.38
W-76-1D	2.88	15.38	3	108	105.13
W-76-2S	15.63	35.00	2	72	56.38
W-76-2D	11.50	30.38	3	108	96.50
W-76-3S	16.25	35.50	2	72	55.75
W-76-3D	15.38	33.75	3	108	92.63

1/2" Electrical Conduit Piezometer Specifications

Piezometer No.	Length Above Sediment (in.)
MP-76-1As	20.38
MP-76-1Ad	22.25
MP-76-B	21.38
MP-76-C	31.00
MP-76-D	34.00
MP-76-Es	31.00
MP-76-Ed	15.50
MP-76-F	28.50

3/4" PVC Monitoring Well Specificaitons

Well No.	Depth to Filter Pack (ft.)	Thickness of Filter Pack (ft.)	Length Below Ground (ft.)	Total Well Length (ft.)
MW76-1	6.1	2.7	8.80	10.00
MW76-2	6.9	3.2	10.10	10.79
MW76-3	8.19	4.47	12.66	13.50

Topo: Salmon Prairie Quad

SE 1/4, Sec. 18, T22N, R17W
Latitude: N47' 40"
Longitude: W113' 50"
Elevation: ~3520'
Aerial: line 42, 697-34

Pond Key

P90	Main Pond/Fully Instrumented
P91	Upgradient from P90

Data from Shapley, 1998

P90

Outlet Stream	Yes
Hypsometric Class	1
Basin Form Class	equidimensional

3/4" Steel Pipe Well Specifications

Well No.	Top of Well to Line (in.)	Total Above Ground (in.)	Sections of Pipe (3' lengths)	Total Well Length (in.)	Adjusted Well Length (datum) (in.)
W90-1SS	20.25	34.94	1	60	39.75
W90-1S	23.50	36.38	2	72	48.50
W90-1D	3.00	11.25	2	72	69.00
W-90-2S	10.63	36.75	2	72	61.38
W90-2D	21.75	48.25	3	108	86.25
W90-3S	0.00	0.00	1	36	36.00
W-90-3D	48.50	48.50	3	108	59.50

1/2" Electrical Conduit Piezometer Specifications

Piezometer No.	Length Above Sediment (in.)
MP-90-1As	37.88
MP-90-1Ad	
MP-90-B	37.38
MP-90-C	31.44
MP-90-Ds	35.00
MP-90-Dd	33.50
MP-90-Es	39.00
MP-90-Ed	25.50
MP-90-F	37.25

4-6 Additional wells in watershed installed (all initially had water (4/8-4/30))

Water Levels-P20 Condon Group

Date	Time Since 5/27/99	P20 Staff	W20-1SS	W20-1S	W20-1D	W20-2S	W20-2D	W20-3S	W20-3D	MW20-1	MW20-2	MW20-3	MW20-4
	(days)	(ft.)	(ft.)	(ft.)	(ft.)	(ft.)	(ft.)	(ft.)	(ft.)	(ft.)	(ft.)	(ft.)	(ft.)
05/27/99	0	3717.09											
6/7/99	11	3716.60	3714.62										
6/17-6/18/99	21	3716.42	3714.62	3716.47	3714.22	3716.62	3716.50	3714.95	3716.62				
6/28-6/29/99	32	3716.31	3714.84	3716.07	3716.00	3716.45	3716.54	3716.53	3716.59				
7/6-7/7/99	39	3716.37	3714.93	3716.17	3712.99	3716.45	3716.52	3716.49	3716.45				
7/15-7/16/99	47	3716.07	3715.26	3715.97	3715.81	3716.21	3716.29	3716.43	3716.25				
7/27-7/28/99	59	3715.85	3715.32	3715.42	3715.33	3715.83	3715.86	3715.92	3715.84				
8/2-8/3/99	65	3715.52	3715.27	3715.13	3715.06	3715.76	3715.62	3715.83	3715.67				
08/11/99	74	3715.27	3715.16	3714.73	3714.47	3715.30	3715.27	3715.57	3715.49				
08/19/99	82	3715.12	3715.10	3714.30	3714.22	3715.17	3715.07	3715.35	3715.23				
08/26/99	89	3714.87	3714.74	3713.94	3713.85	DRY	3714.71	3715.07	3715.02				
09/06/99	100	3714.85	DRY	DRY	3713.04	DRY	3714.02	3714.74	3714.71				
09/11/99	105	3714.85	DRY	DRY	3712.71	DRY	3713.60	3714.58	3714.50				
09/17/99	111	3714.85	DRY	DRY	3712.71	DRY	3713.27	3712.78	3714.32				
10/02/99	126	3714.85	DRY	DRY	DRY	DRY	DRY	DRY	3713.89				
11/21/99	176	3714.85	DRY	3714.24	3713.90	3715.02	DRY	DRY	DRY				
03/04/00	280	3716.85	3714.97	3716.40	3716.17	3716.92	3716.75	3717.05	3717.18				
05/16/00	354	3716.88	3716.27	3716.69	3716.85	3716.50	3717.55	3717.08	3717.17				
05/23/00	361	3716.79	3716.38	3716.63	3716.87	3716.89	3716.88	3716.99	3716.94				
06/20/00	388	3716.61	3716.36	3716.39	3716.41	3716.83	3716.79	3716.81	3716.76	3702.02	3702.76	3689.06	3701.53
07/07/00	405	3716.42	3716.38	3716.63	3716.87	3716.89	3716.88	3716.99	3716.94	3701.46	3703.11	3688.72	3701.68
07/25/00	423	3715.90	3715.91	3715.71	3715.52	3717.73	3717.02	3716.12	3716.97	3700.76	3702.77	3688.47	3701.51
08/16/00	445	3715.26	3715.12	3714.74	3714.37	3715.35	3715.62	3715.40	3715.42	3699.28	3702.05	3687.85	3700.88
09/30/00	489	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	3702.47	3686.45	DRY	DRY

P21-Partially Instrumentated

Date	Time since 5/27/99	P21-Staff	W21-S	W21-D
	(days)	(ft.)	(ft.)	(ft.)
06/07/99	11	3706.31	3706.09	no data
6/17-6/18/99	21	3706.35	no data	no data
6/28-6/29/99	32	3706.28	3706.28	no data
7/6-7/7/99	39	3706.30	3705.54	3704.76
7/15-7/16/99	47	3706.14	3705.80	3705.03
7/27-7/28/99	59	3705.89	no data	no data
8/2-8/3/99	65	no data	3705.91	3705.50
08/11/99	74	3705.62	3705.96	3705.60
08/19/99	82	DRY	3706.02	3705.74
08/26/99	89	DRY	3705.86	3705.63
09/06/99	100	DRY	3705.63	3705.52
10/02/99	126	DRY	3705.55	3705.29
10/16/99	140	DRY	3705.31	3705.05
11/14/99	169	DRY	3705.03	3704.82
11/21/99	176	DRY	DRY	DRY
05/16/00	354	3706.57	3706.82	3706.87
05/23/00	361	3706.52	3706.79	3706.84
06/20/00	388	3706.52	3706.94	3706.86
07/07/00	405	3706.43	3706.80	3706.75
07/27/00	425	3706.04	3706.49	3706.48
08/16/00	445	3705.56	3706.05	3706.04

P22-Partially Instrumentated

Date	Time since 5-27/99	P22-Staff	W22-S	W22-D
	(days)	(ft.)	(ft.)	(ft.)
06/07/99	11	3720.23	3720.45	
6/17-6/18/99	21	3719.92	3720.01	
6/28-6/29/99	32	3719.92	3719.74	3719.56
7/6-7/7/99	39	3719.56	3719.55	3719.65
7/15-7/16/99	47	3719.28	3719.24	3719.24
7/27-7/28/99	59	3718.80	no data	no data
8/2-8/3/99	65	3718.58	DRY	3718.61
08/11/99	74	DRY	DRY	3718.22
08/19/99	82	DRY	DRY	3717.87
08/26/99	89	DRY	DRY	3717.32
09/06/99	100	DRY	DRY	DRY
10/02/99	126	DRY	DRY	DRY
10/16/99	140	DRY	DRY	DRY
11/14/99	169	DRY	DRY	DRY
11/21/99	176	DRY	DRY	DRY
05/16/00	354	3721.17	3722.15	3720.25
05/23/00	361	3720.94	3720.94	3721.20
06/20/00	388	3720.27	3720.48	3720.29
07/07/00	405	3719.91	3719.92	3719.95
07/27/00	425	3719.20	DRY	3719.78
08/16/00	445	DRY	DRY	3718.43

P23-Partially Instrumentated

Date	Time since 5/27/00	P23	W23-S	W23-D
	(days)	(ft.)	(ft.)	(ft.)
06/07/99	11	3705.30		
6/17-6/18/99	21	3704.83		
6/28-6/29/99	32	3704.41	3704.41	3701.94
7/6-7/7/99	39	3704.23	3704.46	3703.28
7/15-7/16/99	47	3703.72	DRY	3702.28
8/2-8/3/99	65	DRY	DRY	3702.36
08/11/99	74	DRY	DRY	3702.22
08/19/99	82	DRY	DRY	3702.18
08/26/99	89	DRY	DRY	3702.23
06/20/00	388	3706.68	no data	no data
07/07/00	405	3706.04	no data	no data
07/27/00	425	3704.94	no data	no data
08/16/00	445	3703.49	DRY	DRY

P45-Beaver Creek

Date	Time since 5/27/99	P45-Staff	W45-1SS	W45-1S	W45-1D	W45-2S	W45-2D	W45-3S	W45-3D	MW45-1	MW45-2	MW45-3	MW45-4	MW45-5	MW45-6
	(days)	(ft.)	(ft.)	(ft.)	(ft.)	(ft.)	(ft.)	(ft.)	(ft.)	(ft.)	(ft.)	(ft.)	(ft.)	(ft.)	(ft.)
05/27/99	0	4241.29													
06/07/99	11	4241.21	4241.51												
6/17-6/18/99	21	4241.09	4241.73	4241.14	4241.17	4239.06	4238.35								
6/28-6/29/99	32	4240.97	4241.25	4240.99	4241.09	4241.17	4240.73								
7/6-7/7/99	39	4240.94	4241.23	4240.97	4241.19	4241.13	4241.09	4240.62	4240.51						
7/15-7/16/99	47	4240.69	4241.02	4240.66	4240.74	4240.87	4240.85	4240.13	4240.13						
7/27-7/28/99	59	4240.44	4240.84	4240.17	4240.17	4240.68	4240.67	4239.74	4239.76	4225.09	4220.09	4215.41	4228.45	4228.83	
8/2-8/3/99	65	4240.25	4240.61	4239.72	4239.41	4240.63	4239.34	4237.37	4237.45	4224.39	4219.11	4215.04	4222.95	4228.33	
08/11/99	74	4240.02	DRY	4239.26	4239.26	4240.13	4240.08	DRY	4238.80	4223.54	4218.86	4214.35	4216.80	4227.72	
08/19/99	82	4239.92	DRY	4239.06	4239.09	4240.01	4240.07	DRY	4238.57	4223.16	4218.73	4213.99	4210.34	4227.42	
08/26/99	89	4239.74	DRY	DRY	4238.77	4239.78	4239.75	DRY	4238.02	4222.70	4218.63	4213.46	4203.44	4226.99	
09/06/99	100	4239.60	DRY	DRY	4238.44	4239.63	4239.49	DRY	DRY	DRY	4218.06	4212.80	4195.91	4226.71	
09/17/99	111	4238.45	DRY	DRY	4237.89	4239.03	4239.35	DRY	DRY	DRY	4218.18	4212.46	4188.03	no data	
10/02/99	126	4238.45	DRY	DRY	4237.53	DRY	4239.40	DRY	DRY	DRY	4218.05	4212.11	4179.41	4226.35	
11/21/99	176	4238.45	DRY	DRY	4238.22	4239.36	4239.37	DRY	DRY	DRY	4217.80	4211.27	4170.41	4225.99	
03/11/00	287	4240.11	DRY	4240.25	4240.21	4240.27	no data	no data	4240.03	DRY	4217.99	4211.15	4160.92	4225.62	
05/14/00	352	4241.47	4241.62	4241.53	4241.53	4241.77	4241.68	4241.18	4240.18	4227.88	4223.75	4240.59	4230.56	4231.89	
05/23/00	361	4241.36	4241.56	4241.40	4241.41	4241.58	4241.99	4241.05	4241.07	4227.68	4224.03	4240.90	4230.07	4230.54	
06/01/00	369	4241.32	4241.10	4241.36	4241.41	4241.51	4241.53	4241.00	4240.97	4227.49	4223.80	4240.44	4230.01	4230.64	
06/23/00	391	4241.04	4241.20	4241.06	4241.07	4241.24	4241.20	4240.80	4240.78	4227.13	4222.93	4240.11	4229.68	4230.08	
07/19/00	417	4240.44	4240.65	4240.26	4240.11	4240.68	4240.54	4239.65	4239.75	4224.51	4220.69	4239.45	4228.26	4228.49	
07/27/00	425	4240.18	4240.36	4239.53	4239.56	4240.31	4240.29	4239.14	4239.14	4223.73	4219.81	4239.20	4227.64	4227.93	4236.47
08/16/00	445	4239.61	DRY	DRY	4238.39	4239.50	4239.56	DRY	DRY	DRY	4218.54	4238.47	4225.88	4226.47	4237.62
09/21/00	481	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	4236.87	4223.68	4224.50	4236.96
09/30/00	490	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	4236.63	4223.35	4223.99	4236.96

P76-Holland Lake

Date	Time since 5/27/99	P76-Staff	W76-1SS	W76-1S	W76-1D	W76-2S	W76-2D	W76-3S	W76-3D	MW76-1	MW76-2	MW76-3
	(days)	(ft.)	(ft.)	(ft.)	(ft.)	(ft.)	(ft.)	(ft.)	(ft.)	(ft.)	(ft.)	(ft.)
05/27/99	0	4294.66										
06/07/99	11	4294.66	4293.57									
6/17-6/18/99	21	4294.58	DRY	4294.45			4294.29					
6/28-6/29/99	32	4294.57	DRY	4294.88	4292.35	4294.27	4294.42	4294.41	4290.54			
7/6-7/7/99	39	4294.58	DRY	4294.68	4290.83	4295.34	4294.42	4294.49	4290.72			
7/15-7/16/99	47	4294.41	4293.57	4294.55	4291.85	4294.17	4294.30	4294.50	4291.40			
7/27-7/28/99	59	4294.16	4294.32	4293.71	4292.65	4293.95	4293.83	4294.10	4292.12	4289.47	4286.10	4270.59
8/2-8/3/99	65	4294.02	4293.73	4293.34	4293.15	4293.65	4293.66	4293.93	4292.34	4289.49	4285.80	4271.76
08/11/99	74	4293.85	4293.73	4292.98	4292.87	4293.38	4293.34	4293.65	4292.65	4290.10	4285.96	4274.33
08/19/99	82	4293.74	4293.70	4292.86	4292.94	4293.18	4293.17	4293.64	4292.99	4289.75	4285.73	4273.51
08/26/99	89	DRY	DRY	4292.72	4292.86	4292.90	4292.82	4293.32	4292.92	4291.82	4285.54	4274.95
09/06/99	100	DRY	DRY	4292.43	4292.66	4292.58	4292.54	4293.06	4292.87	4289.75	4285.49	4276.41
09/11/99	105	DRY	DRY	DRY	4292.58	4292.27	4292.17	4293.97	4292.90	4289.57	4285.06	4276.72
09/17/99	111	DRY	DRY	DRY	4289.56	DRY	4291.89	DRY	4292.97	4289.09	4285.11	4277.01
10/02/99	126	DRY	DRY	DRY	4289.86	DRY	4292.05	DRY	4290.50	4289.00	4284.75	4276.65
11/21/99	176	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	4288.71	4284.10	4275.75
03/04/00	280	4294.65	DRY	4294.88	4294.42	4294.30	4294.39	4294.49	4294.34	4289.26	4287.98	no data
03/31/00	307	4294.99	4293.95	4295.11	4294.73	4294.72	4294.70	4294.93	4294.60	4294.54	4288.13	4279.47
05/16/00	354	4294.89	4293.72	4294.94	4293.34	4294.54	4294.56	4294.77	4292.19	4292.01	4287.33	4276.86
05/23/00	361	4294.82	no data	no data	no data	4294.51	4294.56	4294.71	4292.64	4291.80	4287.00	4277.85
06/23/00	391	4294.75	4294.11	4294.80	4294.48	4294.41	4294.50	4294.63	4294.05	4291.28	4286.52	4278.56
07/17/00	415	4294.66	4294.15	4293.90	4294.53	4294.27	4294.34	4294.37	4294.19	4290.93	4286.17	4278.80
08/01/00	430	4294.47	DRY	4293.06	4292.68	4293.51	4293.45	4293.90	4292.63	4290.68	4285.89	4275.60
08/16/00	445	4293.99	DRY	4292.56	4292.07	4292.40	4292.61	4292.92	4291.37	4290.34	4285.46	4275.34
09/13/00	473	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	4289.71	4284.74	4275.82
09/29/00	489	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	4289.26	4284.66	4277.20

P90-Piper Creek

Date	Time Since 5-27/99	P90-Staff	W90-1SS	W90-1S	W90-1D	W90-2S	W90-2D	W90-3S	W90-3D	MW90-1
	(days)	(ft.)	(ft.)	(ft.)	(ft.)	(ft.)	(ft.)	(ft.)	(ft.)	(ft.)
05/27/99	0	3521.08								
06/07/99	11	3521.01								
6/17-6/18/99	21	3520.74	3520.87	3520.96	3519.87	3519.773	3520.65			
6/28-6/29/99	32	3520.55	3520.76	3520.78	3520.78	3520.703	3520.7		3520.7	
7/6-7/7/99	39	3520.51	3520.63	3520.65	3521.27	3520.703	3520.7	3520.57	3520.6	
7/15-7/16/99	47	3520.11	3520.20	3520.29	3520.21	3520.283	3520.28	3520.06	3520.09	
8/2-8/3/99	65	3519.32	DRY	3519.02	3519.34	3519.133	3519.29	3518.87	3518.93	
08/11/99	74	3519.04	DRY	DRY	3518.27	3521.533	3518.29	3515.7	3519.05	
08/19/99	82	3518.91	DRY	DRY	3517.87	DRY	3518.84	DRY	3518.07	
08/26/99	89	3518.81	DRY	DRY	3517.02	DRY	3517.61	DRY	3517.36	
09/06/99	100	3518.76	DRY	DRY	DRY	DRY	DRY	DRY	DRY	
09/17/99	111	3518.43	DRY	DRY	DRY	DRY	DRY	DRY	DRY	
10/02/99	126	3518.43	DRY	DRY	DRY	DRY	DRY	DRY	DRY	
11/21/00	176	3518.43	DRY	DRY	3519.00	DRY	3516.67	DRY	DRY	
03/04/00	280	3520.47	3520.59	3520.59	3519.83	3520.61	3520.62	no data	3520.77	
03/11/00	287	no data	3521.40	3521.48	3521.44	3521.42	3521.42	no data	3521.49	
03/31/00	307	3521.72	3521.88	3521.98	3521.94	3521.99	3521.93	no data	3521.94	
04/30/00	337	3521.57	3521.87	3521.67	3521.75	3521.82	3521.85	no data	3521.64	
05/14/00	352	3521.34	3521.48	3521.54	3521.65	3521.65	3521.66	no data	3521.56	
05/23/00	361	3521.19	3521.31	3521.33	3521.36	3521.37	3521.34	no data	3521.31	
06/01/00	369	3521.06	3521.18	3521.18	3521.22	3521.22	3521.26	no data	3521.22	
06/20/00	388	3520.94	3521.04	3521.06	3521.21	3521.12	3521.19	3520.92	3521.05	3510.84
06/29/00	397	3520.68	3520.79	3520.82	3520.89	3520.85	3521.22	3520.74	3520.86	3510.67
07/17/00	415	3520.09	3520.13	3520.12	3520.11	3520.94	3520.19	3519.98	3520.11	3508.44
08/01/00	430	3519.39	3519.28	3519.28	3519.26	3519.323	3519.42	3518.98	3519.07	3505.84
08/16/00	445	3518.73	DRY	DRY	DRY	DRY	3517.76	DRY	3517.51	DRY

APPENDIX E

WATER CHEMISTRY

Quality Assurance/Quality Control Water Sampling Procedure for Water Samples taken from Wetlands and Surrounding Flow Systems Containing Water Howellia

Water samples will be taken from 3 sources for Howellia project:

1) surface-water from wetland

2) 3/4" black steel well nests on shoreline

3) 3/4" pvc wells drilled in surrounding flow system w/ a Geoprobe Rig

All wells were developed after installation using a peristalic pump and plastic tubing

Water Sampling

1) All wells prior to having water extracted for chemical analysis will be purged at 1 week prior to sampling. This is done to ensure a sample that is representative of the groundwater chemistry and to eliminate any chemical reactions with the groundwater and the well that may alter ionic concentrations. The reason for the 1 week time period between purging the wells and sampling is due to the low hydraulic conductivity of the glacial till. It takes at least a 7 days for the water level in the wells to recover after being pumped.

2) All samples are taken using a peristalic pump with plastic tubing to bring the water from the well to the surface. All samples will be filtered in the field using a new 0.45 micron filter for each sample. Filtering will result with a sample containing only dissolved constituents less than 0.45 micrometers. Between each sample the plastic tubing will be rinsed using Milli-Q water to avoid cross contaminating samples. A blank sample consisting of Milli-Q water run through the tubing will give a background

concentration of the Milli-Q water and any contamination of the sample by the plastic tubing.

3) Samples from the same sampling location will be put into separate containers (bottles) depending on what type of analyses is desired. The cations will be acidified with nitric acid (HNO_3) to avoid any chemical reactions that will alter the results of the analysis. All samples will be put in a clean cooler filled with ice to minimize any reactions involving organics that may occur between the time the sample was collected and the transport time to the laboratory. All samples will be analyzed in a time allowance that will not exceed the holding time for any test.

4) All analyses of water samples from each wetland and groundwater from wells located on shore and the pvc wells in the surrounding flow system will be analyzed for major cations and anions, alkalinity, organic carbon, and inorganic carbon. All analyses will be performed at the Murdock Environmental Laboratory located on the third floor of the Science Complex on the campus of the University of Montana. Cations concentrations will be determined using ICP-ES (inductively coupled plasma emission spectroscopy). An automated ion chromatograph wil be used to analyze anions. Inorganic and organic carbon concentrations will be measured using a TOC carbon analyzer. All analyses of all water samples will be compared with standard concentrations with measured concentrations of standards to ensure quality assurance and quality control of all measured constituents. At least one sample site will be have 3 samples collected in order

to check for error in methodology. Results from all analyses will be statistically measured for error in both methology of the collection of the water samples and the instrumentation error.

pH data and trends
1999 Field Season

	Time Since								
	27-May								
Date	(days)	Pond 45	Pond 76	Pond 20	Pond 21	Pond 22	Pond 23	Pond 90	Pond 91
5/27/99	0	No Geochemical measurements							
6/7/99	11	7.11	7.01	7.68	7.42	7.64	7.42	6.57	7.05
6/17-6/18/99	21	7.43	6.30	7.29	7.02	6.96	7.00	7.24	7.15
6/28-6/29/99	32	6.60	5.98	6.82	6.48	6.66	6.66	7.01	6.72
7/6-7/7/99	39	6.94	6.17	6.66	6.56	6.57	6.56	7.22	6.87
7/15-7/16/99	47	No Geochemical measurements							
7/19-7/20/99	51	6.77	6.20	ND	ND	ND	ND	ND	ND
7/27-7/28/99	59	6.75	6.07	6.72	6.39	6.60	DRY	6.94	6.72
8/2-8/3/99	65	6.60	5.97	6.41	6.30	6.44	"	7.19	ND
8/11/99	74	6.30	DRY	6.50	DRY	6.48	"	7.02	6.70
8/19/99	82	6.50	"	6.62	"	6.53	"	7.20	6.25
8/26/99	89	6.71	"	6.80	"	6.42	"	7.28	6.69
9/6/99	100	No Geochemical measurements-dead battery for pH meter/ conductivity meter not working							
9/11/99	105	ND	"		"	DRY	"	DRY	DRY
9/17/99	111	7.41	"	6.87	"	"	"	"	"

pH data and Trends
2000 Field Season

Date	Time Since 27-May (days)	Pond 45	Pond 76	Pond 20	Pond 21	Pond 22	Pond 23	Pond 90	Pond 91
03/04/00	0	no data	5.74	no data	no data	no data	no data	6.75	no data
03/11/00	7	5.62	no data	no data	no data	no data	no data	no data	no data
03/31/00	27	no data	5.55	no data	no data	no data	no data	6.09	no data
04/30/00	57	no data	6.03	no data	no data	no data	no data	6.78	no data
05/14/00	72	6.45	no data	no data	no data	no data	no data	6.48	no data
05/16/00	74	no data	no data	no data	no data	no data	no data	no data	no data
05/23/00	81	6.54	6.86	6.33	6.81	6.47	6.50	6.46	no data
06/01/00	89	7.36	no data	no data	no data	no data	no data	no data	no data
06/20/00	108	no data	no data	6.74	6.56	6.41	5.65	no data	no data
06/23/00	111	6.67	5.71	no data	no data	no data	no data	no data	no data
06/29/00	117	no data	no data	no data	no data	no data	no data	6.97	no data
07/07/00	125	no data	no data	6.35	6.44	6.42	6.68	no data	no data
07/10/00	128	no data	6.18	no data	no data	no data	no data	6.91	no data
07/17/00	135	no data	no data	no data	no data	no data	no data	6.78	no data
07/19/00	137	6.38	no data	no data	no data	no data	no data	6.38	no data
07/25/00	143	no data	no data	6.31	6.11	5.95	6.19	no data	no data
07/27/00	145	6.13	no data	no data	no data	no data	no data	7.04	no data
08/01/00	150	no data	6.22	no data	no data	no data	no data	6.54	no data
08/16/00	165	6.96	no data	7.41	6.41	6.80	6.88	7.71	no data
09/13/00	193	no data	DRY-no SW	no data	no data	no data	no data	DRY-no SW	DRY-no SW
09/21/00	201	DRY-no SW	no data	7.97	DRY-no SW	7.1	DRY-no SW	no data	no data

Specific Conductance Data
1999 and 2000 Field Seasons

	Time Since	Pond 45	Pond 76	Pond 20	Pond 21	Pond 22	Pond 23	Pond 90	Pond 91
Date	**27-May**	Conductance	Conductance	Conductance	Conductance	Conductance	Conductance	Conductance	Conductance
(mo/day/yr)	(days)	(micromhos/cm)	(micromhos/cm)	(micromhos/cm)	(micromhos/cm)	(micromhos/cm)	(micromhos/cm)	(micromhos/cm)	(micromhos/cm)
05/27/99	0	70	45	40	52	72	42	260	70
06/07/99	11	100	52	84	42	54	42	200	100
6/17/99	21	38	59	84	60	40	34	140	76
6/28/99	32	20	40	83	54	50	39	187	62
7/7/99	39	70	66	90	66	59	ND	160	ND
7/16/99	47	No Geochemical measurements							
7/19	51	92	64	ND	ND	ND	ND	NA	ND
7/28/99	59	64	24	86	82	18	DRY	180	92
8/2	65	74	93	80	64	49	"	200	ND
08/11/99	74	60	DRY	86	DRY	40	"	180	43
08/19/99	82	73	"	93	"	48	"	200	84
08/26/99	89	88	"	64	"	54	"	200	80
09/06/99	100	No Geochemical measurements-dead battery for pH meter/ conductivity meter not working							
09/11/99	105	ND	"	78	"	DRY	"	DRY	DRY
09/17/99	111	90	"	71	"	"	"	"	"
03/04/00	0	no data	52	56	no data	no data	no data	69	no data
03/11/00	7	32	no data	no data	no data	no data	no data	no data	no data
03/31/00	27	no data	38	no data	no data	no data	no data	86	no data
04/30/00	57	no data	46	58	no data	no data	no data	120	no data
05/14/00	72	76	no data	no data	no data	no data	no data	210	no data
05/16/00	74	no data	no data	no data	no data	no data	no data	no data	no data
05/23/00	81	92	92	73	68	26	53	200	no data
06/01/00	89	126	no data	no data	no data	no data	no data	no data	no data
06/20/00	108	no data	no data	66	60	50	40	180	no data

06/23/00	111	88	56	no data	no data	no data	no data	no data	no data
06/29/00	117	no data	no data	no data	no data	no data	no data	190	no data
07/07/00	125	no data	no data	70	54	45	42	no data	no data
07/10/00	128	no data	68	no data	no data	no data	no data	200	no data
07/17/00	135	no data	no data	no data	no data	no data	no data	180	no data
07/19/00	137	80	no data	no data	no data	no data	no data	no data	no data
07/25/00	143	no data	no data	50	66	45	42	no data	no data
07/27/00	145	93	no data	no data	no data	no data	no data	200	no data
08/01/00	150	no data	150	no data	no data	no data	no data	200	no data
08/16/00	165	84	DRY	92	80	50	38	236	105
09/13/00	193	no data	DRY-no SW	no data	no data	no data	no data	DRY-no SW	DRY-no SW
09/21/00	201	DRY-no SW	no data	93	DRY-no SW	39	DRY-no SW	no data	no data

geochemical measurements taken for P76 on 8/1 represent pore water concentrations since there was no standing free water

P20, P45, P76 Water Chemistry Results 8-19-99

Sample Name	Ca	K	Mg	Mn	Na	S	F	Cl	SO4
PQL	0.07	0.1	0.05	0.003	0.18	0.007	0.1	0.05	0.5
Field Blank	0.6708	0.199	0.1679	0.0049	0.2809	0.0158	<PQL	1.50	<PQL
P20-SW	6.296	2.45	2.433	0.0072	1.856	0.2023	<PQL	0.99	<PQL
P45-SW	9.082	0.7645	3.049	0.0051	1.36	0.33	<PQL	0.24	<PQL
W45-1D	12.26	0.1934	4.464	0.1125	1.827	0.3049	0.12	0.66	<PQL
MW45-3	41.38	1.415	12.01	0.1769	1.797	0.5889	0.16	0.62	2.42
MW45-4	44.84	3.065	14.04	0.3612	2.625	0.5886	0.12	1.45	2.34
W76-2D	74.66	0.7812	15.3	0.6902	6.625	0.19	0.30	1.53	<PQL
MW76-2	40.49	3.387	15.86	1.418	35.95	0.5001	0.31	1.39	2.13

P20 Water Chemistry Results 6/19/00

Sample Name	Al	Ca	K	Mg	Mn	Na	S	F	Cl	SO_4	Alkalinity	Specific	
Practical Quantifiable Limit (mg/L)	*0.007*	*0.07*	*0.1*	*0.05*	*0.0003*	*0.18*	*0.007*	0.1	0.1	0.5	(mg/l) $CaCO_3$	Conductance	pH
BLANK 1	BPQL	BPQL	BPQL	BPQL	0.0009	BPQL	0.012	BMDL	BMDL	BMDL		(micromhos/cm)	
BLANK 2	0.018	BPQL	BPQL	BPQL	0.0015	BPQL	0.013	BMDL	BMDL	BMDL			
P21-SW	0.028	6.46	1.3	2.79	0.0068	1.35	0.211	BMDL	BMDL	BMDL	28	68	6.81
P22-SW	0.180	5.22	1.5	1.80	0.0179	1.35	0.258	BMDL	0.45	0.26	22	26	6.47
P23-SW	0.081	4.05	1.8	1.47	0.0054	1.22	0.413	BMDL	0.36	0.93	21	53	6.50
P20-SW1	0.048	7.36	1.1	2.49	0.0184	1.34	0.213	BMDL	0.37	BMDL	32	62	6.78
P20-SW1	0.051	7.22	1.0	2.45	0.0202	1.17	0.211	BMDL	0.42	BMDL	31	62	6.66
W20-1SS	BPQL	8.01	1.0	2.88	0.3427	2.38	2.818	BMDL	1.24	11.20	44	91	6.85
W20-1S	BPQL	7.35	0.5	2.92	0.3799	1.70	0.771	0.17	0.63	2.49	38	87	6.93
W20-1D	BPQL	6.52	0.8	2.31	0.3584	1.05	0.672	0.18	0.65	1.98	32	67	6.83
W20-2S	BPQL	7.91	1.1	3.31	0.6206	2.04	1.146	BMDL	1.06	3.61	40	82	6.45
W20-2D	BPQL	11.73	1.6	4.30	0.3705	2.35	0.944	0.10	0.85	2.69	62	150	6.64
W20-3S	BPQL	5.13	1.3	2.02	0.6387	1.56	0.358	0.22	0.82	0.84	30	83	6.45
W20-3D	BPQL	4.41	0.7	1.93	0.4607	1.29	0.172	BMDL	0.47	BMDL	22	no data	no data

P45 Water Chemistry Results 6/12/00

Sample Name	Al	Ba	Ca	Fe	K	Mg	Mn	Na	S	F	Cl	SO_4	Alkalinity	Specific	
Practical Quantifiable Limit (mg/L)	*0.007*	*0.0002*	*0.07*	*0.005*	*0.1*	*0.05*	*0.0003*	*0.18*	*0.007*	*0.1*	*0.1*	*0.5*	(mg/l) CaCO3	Conductivity	pH
BLANK 1	BPQL	0.0003	0.07	BPQL	BPQL	BPQL	0.0014	0.19	0.012	BMDL	BMDL	BMDL		(micromhos/cm)	
P45-SW	0.019	0.0359	10.81	0.041	1.1	3.25	0.0154	0.81	0.369	BMDL	0.42	BMDL	50	66	7.36
W45-1S	0.122	0.0572	11.20	35.270	0.2	3.70	0.3424	1.91	0.286	0.10	0.71	BMDL	102	160	6.33
W45-1D	0.022	0.0470	9.89	18.030	0.1	3.24	0.3398	1.25	0.329	BMDL	0.51	BMDL	68	110	6.59
W45-2S	BPQL	0.1356	41.87	1.334	1.6	13.32	2.0090	1.68	1.062	0.28	1.48	1.68	162	280	6.98
W45-2D	BPQL	0.1351	35.11	0.020	1.4	12.54	0.8165	1.31	1.039	0.32	0.67	2.14	137	250	7.55
W45-3S	BPQL	0.0382	13.58	0.028	0.3	7.61	0.4173	2.73	0.887	BMDL	0.87	2.35	76	160	7.44
W45-3D	BPQL	0.0626	23.39	8.908	0.9	10.56	0.6101	2.76	0.495	BMDL	1.01	0.55	128	230	6.71
MW45-1	0.029	0.0510	14.65	0.037	1.1	4.79	0.0068	4.93	0.784	BMDL	0.51	1.90	84	140	7.07
MW45-2	BPQL	0.1080	41.08	0.005	3.2	12.06	0.0323	4.19	2.697	BMDL	0.54	7.53	164	300	7.38
MW45-3	BPQL	0.1239	40.36	BPQL	0.7	12.30	0.0056	0.53	1.068	BMDL	0.29	2.15	152	280	7.68
MW45-4	BPQL	0.1450	50.17	BPQL	1.4	14.61	0.0138	0.70	1.310	BMDL	0.25	2.85	180	360	7.75
MW45-5	BPQL	0.1942	73.34	0.024	2.1	22.43	0.9109	2.05	1.186	0.30	1.03	1.52	258	520	7.57

P76 Water Chemistry Results 5/23/00

Sample Name	**Ca**	**K**	**Mg**	**Mn**	**Na**	**S**	**F**	**Cl**	**SO_4**	**Alkalinity**	**Specific**	
Practical Quantifiable Limit (mg/L)	*0.07*	*0.1*	*0.05*	*0.0003*	*0.18*	*0.007*				**(mg/l) CaCO3**	**Conductance**	**pH**
BLANK 1	BPQL	BPQL	BPQL	0.0009	BPQL	0.012	BPQL	BPQL	BPQL		(micromhos/cm)	
BLANK 2	BPQL	BPQL	BPQL	0.0015	BPQL	0.013	BPQL	BPQL	BPQL			
P76-SW	6.04	3.3	1.70	0.0146	1.64	0.288	BMDL	0.73	BMDL	36	58	6.86
W76-1S	13.58	0.8	2.83	0.2996	2.39	0.622	0.20	1.42	1.48	58	98	6.84
W76-1D	36.58	0.9	9.73	0.6720	6.95	0.405	0.86	0.63	BMDL	147	220	7.03
W76-2S	18.79	0.4	5.02	0.3860	6.22	0.762	BMDL	0.78	1.43	76	160	6.86
W76-2D	73.74	0.4	16.17	0.8087	6.07	1.075	0.21	1.14	BMDL	230	540	6.66
W76-3S	16.87	0.8	5.89	0.3923	8.97	1.203	BMDL	0.99	3.42	100	200	6.98
MW76-1	11.52	1.3	4.67	0.0168	32.33	0.680	1.15	1.24	1.69	139	280	7.71
MW76-2	30.51	1.5	12.26	1.1890	23.68	0.571	0.13	0.57	0.96	182	350	7.03
MW76-3	25.82	1.3	7.62	0.2555	60.88	0.605	0.32	1.38	0.61	182	440	7.25

P90 Water Sampling Results 4-30-00

Sample Name	Al	Ca	K	Mg	Mn	Na	S	F	Cl	SO_4	Alkalinity	Specific
Practical Quantifiable Limit (mg/L)	*0.007*	*0.07*	*0.1*	*0.05*	*0.0003*	*0.18*	*0.007*	0.10	0.10	0.50	**(mg/l) CaCO3**	**Conductance**
BLANK 1 043000	BPQL	BPQL	BPQL	BPQL	BPQL	BPQL	0.007	BMDL	BMDL	BMDL		(micromohs/cm)
W90-BLANK 2 043000	BPQL	0.43	BPQL	0.07	0.0047	0.18	0.024	BMDL	BMDL	BMDL		
P90-SW2 043000	0.017	26.22	1.2	3.71	0.0117	0.74	0.527	BMDL	0.33	0.75	92	160
P90-SW2 DUP 043000	0.018	25.75	1.2	3.71	0.0110	0.67	0.516	BMDL	0.32	0.77	53	160
W90-1SS 043000	BPQL	21.45	1.2	4.60	0.1031	2.22	1.406	BMDL	1.98	4.24	97	no data
W90-1S 043000	BPQL	42.50	0.7	6.96	0.1901	2.46	1.441	0.16	1.15	3.41	85	280
W90-1D 043000	BPQL	26.74	1.7	6.95	0.3081	2.56	1.107	BMDL	1.11	2.76	192	200
W90-2S 040200	BPQL	28.58	0.8	5.34	0.3371	1.60	0.768	BMDL	0.61	1.38	109	200
W90-2D 043000	BPQL	37.16	0.9	6.13	0.4431	1.56	0.825	BMDL	0.52	1.37		360
W90-3D 043000	BPQL	36.84	1.3	3.88	0.1429	2.33	1.056	BMDL	1.10	2.20	123	225
W-SW OUT 043000	BPQL	16.85	4.2	2.75	1.3220	1.96	0.922	BMDL	1.56	1.78		150

P20 Water Chemistry Results 8/16/00

Sample Name	Ca	K	Mg	Mn	Na	S	F	Cl	SO_4	Alkalinity (mg/l)$CaCO_3$	Specific Conductance	pH
Practical Quantifiable Limit (mg/L)	*0.07*	*0.1*	*0.05*	*0.0003*	*0.18*	*0.007*	0.1	0.1	0.5			
Field Blank	<0.05	<0.5	<0.1	0.0014	<0.05	0.0037	<0.1	<1	<0.5		(micromhos/cm)	
P20-SW	9.822	2.626	3.193	0.0277	1.779	0.234	<0.1	1.01444	<0.5	87	92	7.41
P21-SW	3.603	2.342	2.278	0.0158	1.085	0.2454	<0.1	<1.0	<0.5	31	80	6.41
P22-SW	4.306	2.446	1.221	0.008	0.9931	0.241	<0.1	<1.0	<0.5	33	50	6.80
W20-1D	4.521	0.8689	1.438	0.3833	1.143	0.2591	<0.1	<1.0	<0.5	35	110	6.73
W20-2D	7.144	1.463	1.909	0.635	1.496	0.1946	0.68780	1.42728	<0.5	47	110	6.75
W20-3S	6.242	1.172	2.322	1.401	1.188	0.2205	0.42397	<1.0	<0.5	47	120	6.36
W20-3D	8.565	1.092	3.382	0.3192	1.75	0.2614	<0.1	<1.0	<0.5	53	120	5.84
MW20-1	62.94	11.16	20.01	1.703	8.245	2.264	0.89	4.13	1.93	265	520	7.25
MW20-2	77.34	7.281	29.25	5.497	13.21	2.671	0.29	4.26	5.07	255	520	7.43
MW20-3	61.69	10.11	18.25	0.6658	10.62	4.646	0.69	6.18	5.38	317	600	7.35

P45 Water Chemistry Results 8/16/00

Sample Name	Al	Ca	K	Mg	Mn	Na	S	F	Cl	SO_4	Alkalinity (mg/l) CaCO3	Specific Conductance (micromhos/cm)
Practical Quantifiable Limit (mg/L)	0.007	0.070	0.100	0.050	0.000	0.180	0.007	0.10	0.10	0.50		
Field Blank	<0.005	<0.05	<0.5	<0.1	0.0014	<0.05	0.0037	<0.1	<1	<0.5		
P45-SW	0.051	10.770	1.326	3.739	0.007	1.264	0.452	<0.1	<1.0	0.50	47	84
Seepage Meter 45-5	0.017	11.06	0.809	3.52	0.0015	1.073	0.2746	<0.1	<1.0	<0.5	64.4	100
W45-1D	0.170	13.150	<0.5	4.657	0.175	1.725	0.467	0.37	1.07	<0.5	80	180
W45-2D	0.002	19.77	1.900	7.897	0.7483	2.465	0.3915	0.6878	1.42728	<0.5	100.8	200
MW45-3 8/16/00	<0.005	40.38	0.963	11.45	0.1412	1.378	1.121	0.1085	<1.0	2.5358	152.4	300
MW45-4 8/16/00	<0.005	46.24	1.512	13.67	0.0749	1.827	1.194	0.2636	<1.0	2.6468	184.4	320
MW45-5 6/18/00	<0.005	75.01	2.336	22.39	0.7841	3.821	0.919	0.3282	1.6380	0.8133	268.8	500
MW45-6 8/16/00	<0.005	19.250	4.475	5.479	0.402	2.182	2.187	<0.1	1.6827	5.4503	103.2	240
Beaver Creek	0.011	11.730	<0.5	4.579	0.001	1.272	0.358	<0.1	<1.0	0.8215	n/a	n/a
DW-1	0.0019	11.88	2.126	19.92	0.0007	3.784	0.6782	0.3005	1.1613	2.0469	125	240
DW-2	<0.005	37	1.102	15.39	0.0114	7.344	0.7454	0.1637	<1	1.7431	185	350
DW-3	0.0005	40.38	1.571	24.95	0.0004	5.853	1.122	0.1701	1.0996	2.9515	245	420

P76 Water Chemistry Results 8/16/00

Sample Name	Ca	K	Mg	Mn	Na	S	F	Cl	SO_4	Alkalinity (mg/l) $CaCO_3$	Specific Conductance (micromhos/cm)	pH
Practical Quantifiable Limit (mg/L)	*0.07*	*0.1*	*0.05*	*0.0003*	*0.18*	0.1	0.1	0.05				
FIELD BLANK	<0.05	<0.5	<0.1	0.001	<0.05	0.004						
W76-1D	47.1	2.446	15.31	0.8295	13.9	0.7888	1.20	2.65	0.85	198	400	7.16
W76-2D	82.93	<0.5	15.12	0.6549	8.164	1.349	0.33	3.42	<0.5	260	500	6.48
W76-3D	37.51	1.599	10.03	2.024	15.94	0.8724	0.71	1.89	1.31	153.6	200	6.95
MW76-1	39.74	2.03	14.8	0.2582	71.97	1.646	1.14	3.28	4.03	302.8	580	7.39
MW76-2	41.73	2.324	15.47	1.616	37.58	0.9137	0.316373	1.5575	1.96311	250.8	480	7.12
MW76-3	29.23	1.6	7.823	0.2448	70.14	0.4411	0.502568	1.753	0.700736	244	440	7.36
DW-4	38.5	0.5272	8.345	<0.0005	1.112	1.111	<0.1	<1	2.88487	175	260	7.41
DW-5	39.68	0.5748	8.813	<0.0005	1.242	1.09	0.107022	<1	2.77974	170	260	7.23

P90 Water Chemistry Results 8/16/00

Sample Name	Ca	K	Mg	Mn	Na	S	F	Cl	SO_4	Alkalinity (mg/l) $CaCO_3$	Specific Conductance	pH
Practical Quantifiable Limit (mg/L)	*0.07*	*0.1*	*0.05*	*0.0003*	*0.18*	0.1	0.1	0.05				
FIELD BLANK	<0.05	<0.5	<0.1	0.001	<0.05	0.004					(micromhos/cm)	
P90-SW	36.16	6.072	5.583	0.0039	2.219	0.5326	0.12215	1.19226	<0.5	117.6	220	7.25
P91-SW	15.02	3.836	3.078	0.0103	1.232	0.3322	<0.1	<1.0	<0.5	62.4	130	7.22
P90-Seepage Meter 10	76.26	18.38	10.66	0.0062	3.522	0.839	<0.1	3.80478	<0.5	no data	no data	no data
P90-Seepage Meter 11	69.66	19.55	9.815	0.0019	3.341	0.7364	0.1541	3.79202	<0.5	no data	no data	no data
W90-2D	93.93	0.9493	9.533	1.059	2.8	0.8575	0.32748	1.10978	<0.5	no data	500	7.03

APPENDIX F

WETLAND AND WATERSHED SEDIMENT PROPERTIES

Permeameter Tests

Sample	Length of Core (L)	Start Date	Start Time	End Date	End Time	Elapsed Time	Change in Head	Hydraulic Conductivity	Hydraulic Conductivity
	(cm)					(hrs)	(cm)	k = (d_{t2}L/$d_{c2)}$ln(ho/h) (Fetter, 1994) (cm/s)	(ft/d)
P20 Watershed	10.80	02/04/01	11:00	02/05/01	5:15	48.75	2.90	2.76E-06	7.8E-03
	10.80	02/05/01	5:15	02/07/01	7:30	50.25	3.81	3.04E-06	8.6E-03
P20 Wetland	38.42	could not seal permeameter-no data							
	38.42	could not seal permeameter-no data							
P45 Watershed	9.53	03/01/01	4:15	03/01/01	4:21	0.10	9.53	1.89E-03	5.30
	9.53	03/01/01	4:24	03/01/01	4:31	0.12	5.08	1.30E-03	3.70
P45 Wetland	44.13	03/07/01	3:30	03/12/01	8:00	16.50	16.19	6.21E-05	0.18
	44.13	03/12/01	8:00	03/13/01	8:00	24.00	1.91	1.81E-05	0.05
P76 Watershed	9.53	02/11/01	4:30	02/13/01	7:30	51.00	9.75	3.74E-06	1.1E-02
	9.53	02/28/01	4:30	03/01/01	4:00	23.50	19.37	9.86E-06	2.8E-02
P76 Wetland	37.15	03/13/01	8:00	03/17/01	2:30	90.50	13.34	9.03E-06	2.6E-02
	37.15	03/17/01	2:30	03/18/01	5:30	27.00	4.45	2.08E-05	5.9E-02
P90 Watershed	6.03	03/04/01	4:30	03/06/01	3:15	46.75	8.50	2.48E-06	7.0E-03
	6.03	03/06/01	3:15	03/07/01	8:15	29.00	6.25	3.59E-06	1.0E-02
P90 Wetland	28.89	03/29/01	5:30	04/02/01	10:30	28.00	4.13	1.51E-05	4.3E-02
	28.89	04/02/01	10:30	04/04/01	7:00	32.50	2.22	9.61E-06	2.7E-02

Fetter (1995)

$k = (d_{t2}L/d_{c2}t)\ln(h_o/h)$

k = hydraulic conductivity

L = sample length

h = final head in falling tube

t = time elapsed from ho to h

d_t = inside diameter of falling head tube

d_c = inside diameter of sample chamber

Grain-Size Analyses			**P20**		**P45**		**P76**		**P90**	
	sieve no.	size (mm)	mass (g)	% by wt	mass (g)	% by wt	mass (g)	% by wt	mass (g)	% by wt
gravel	10	2	76.34	45.78	141.71	41.27	142.71	47.48	141.74	43.87
coarse sand	70	0.2	60.65	36.37	157.39	45.83	86.48	28.77	128.99	39.92
fine sand	100	0.006	6.09	3.65	16.75	4.88	7.49	2.49	1.32	0.41
silt	Mastersizer 2000	<0.006	23.35	14.00	27.22	7.93	63.04	20.98	50.61	15.66
clay	Mastersizer 2000	<2.0x10-3	0.31	0.19	0.32	0.09	0.84	0.28	0.43	0.13

Mastersizer 2000 Analyses

		P20	**P45**	**P76**	**P90**
	size (mm)	%	%	%	%
silt	0.006-2.0*10-3	98.69	98.85	98.69	99.16
clay	<2.0x10-3	1.31	1.15	1.31	0.84
$d_{10\,(mm)}$		4.40E-03	4.93E-03	4.20E-03	4.55E-03
$d_{50\,(mm)}$		1.99E-02	3.31E-02	2.10E-02	1.91E-02

Falling-Head Tests-P20

W20-1D

Date	Time	Water Level (ft.)	k_v (ft/d)
9/30/00	13:08	0	
	13:45	7.02	1.32E-04
	1:46	7.1	5.56E-05
	1:48	7.2	3.47E-05
		avg. k_v =	**7.4E-05**

W20-3D

Date	Time	Water Level (ft.)	k_v (ft/d)
9/30/00	13:14	0	
	13:14 15	3.25	9.03E-03
	13:14 35	4.56	1.56E-03
	13:15 05	4.88	2.05E-04
	13:18	5.1	5.24E-05
	14:17	5.23	1.53E-06
		avg. k_v =	**2.2E-03**

MW20-3

Date	Time	Water Level (ft.)	k_v (ft/d)
9/30/00	13:37	0	
	13:37 10	1.96	8.17E-03
	13:37 20	2.33	1.54E-03
	13:40	2.45	3.13E-05
	15:40	3.4	5.50E-06
		avg. k_v =	**2.4E-03**

Falling-Head Tests-P45

1440 min = 1 day

W45-2D

Date	Time	Water Level (ft.)	k_v (ft/d)	
9/30/00	9:46	0		
	9:47	0.72	5.00E-04	
	9:48	1.02	2.08E-04	
	9:50	1.55	1.84E-04	
	9:55	2.02	6.53E-05	
	10:10	2.77	3.47E-05	
	10:44	3.1	6.74E-06	
	16:27	4.02	3.92E-06	
		avg. kv =	**1.4E-04**	**ft/d**

MW45-6

Date	Time	Water Level (ft.)	k_v (ft/d)	
9/30/00	9:41	0		
	10:12	0.104166667	2.33E-06	
	10:46	0.15625	1.06E-06	
	16:00	0.42	5.83E-07	
		avg. kv =	**1.3E-06**	**ft/d**

MW45-4

Date	Time	Water Level (ft.)	k_v (ft/d)	
9/30/00	9:13	0		
	9:14	0.44	3.06E-04	
	9:15	1.29	5.90E-04	
	9:16	2.3	7.01E-04	
	9:17	2.74	3.06E-04	
	9:19	3.84	3.82E-04	
	9:21	4.81	3.37E-04	
	9:23	5.54	2.53E-04	
	9:25	5.94	1.39E-04	
	9:28	6.37	9.95E-05	
	9:30	6.6	7.99E-05	
	10:51	8.35	1.50E-05	
	15:54	9.59	2.84E-06	
		avg. kv =	**2.7E-04**	**ft/d**

Falling-Head Tests-P76 1440 min = 1 day

W76-1D

Date	Time	Water Level (ft.)	k_v (ft/d)
9/29/00	17:00	0	
	17:12	0.166666667	9.65E-06
9/30/00	15:05	0.42	1.34E-07
		avg. k_v =	**4.9E-06**

MW76-1 1st time

Date	Time	Water Level (ft.)	k_v (ft/d)
9/29/00	16:23	0	
	16:23 30	1.8	2.50E-03
	16:24	2.29	6.81E-04
	16:25	3.09	5.56E-04
	16:28	4.21	2.59E-04
	16:29	4.39	1.25E-04
	16:42	4.86	2.51E-05
		avg. k_v =	**6.9E-04**

MW76-1 2nd Time

Date	Time	Water Level (ft.)	k_v (ft/d)
9/29/00	16:56	0	
	16:57	1.02	7.08E-04
	17:02	3.09	2.88E-04

W76-2D

Date	Time (sec.)	Water Level (ft.)	k_v (ft/d)
	0	0	
	10	4.02	2.41E+01
	15	4.55	6.36E+00
	20	4.8	3.00E+00
	25	4.9	1.20E+00
	30	6.1	1.44E+01
	60	6.15	1.00E-01
	75	6.2	2.00E-01
		avg. k_v =	**7.1E+00**

may intersect fracture
not able to pump dry during water sampling

MW76-2

Date	Time	Water Level (ft.)	k_v (ft/d)
9/29/00	16:16	0	
	16:17	0.125	8.68E-05
	16:21	0.59	8.07E-05
	16:26	1.16	7.92E-05
	16:27	1.29	9.03E-05
	16:31	1.6	5.38E-05
	16:41	2.33	5.07E-05
	16:44	2.5	3.94E-05
	16:49	2.52	2.78E-05

W76-3D

Date	Time	Water Level (ft.)	k_v (ft/d)
9/29/00	17:16	0	
	17:41	0.104166667	2.89E-06
9/30/00	15:08	0.229166667	6.74E-08
		avg. k_v =	**1.5E-06**

MW76-3

Date	TIme	Water Level (ft.)	k_v (ft/d)
9/29/00	16:46	0	
	17:07	0.260416667	8.61E-06
	17:28	0.265625	1.72E-07
	17:49	0.302083333	1.21E-06
9/30/00	15:24	0.48	9.54E-08
		avg. k_v =	**2.5E-06**

	17:24	3.95	4.78E-05
	30		
	17:44	3.98	1.07E-06
9/30/00	15:19	4.75	**4.2E-07**
		avg. k_v =	**2.1E-04**

	30		
	17:03	3.4	4.53E-05
	17:11	3.66	2.26E-05
	17:26	4.11	2.08E-05
	17:46	4.5	1.35E-05
9/30/00	15:21	5.65	6.27E-07
		avg. k_v =	**4.7E-05**

Falling-Head Tests-P90

W90-1SS	DRY		
Date	**Time**	**Water Level (ft.)**	**k_v (ft/d)**
9/29/00	11:52 30	0	
	11:53	0.166666667	2.31E-04
	11:54	0.79	4.33E-04
	11:55	0.99	1.39E-04
	11:56	1.51	3.61E-04
	11:58	1.94	1.49E-04
	12:00	2.32	1.32E-04
	12:03	2.52	4.63E-05
	12:05	3.32	2.78E-04
	12:07	3.49	5.90E-05
	12:10	3.92	9.95E-05
	12:12	3.95	1.04E-05
	12:14	4.08	4.51E-05
	12:16	4.1	6.94E-06
	12:18 30	4.32	6.11E-05
	12:19 30	4.35	2.08E-05
	12:31	4.52	1.03E-05
		avg. k_v =	**1.30E-04**

not able to fill to top due to disturbed structure towards surface

Sandpoint-k_H		DRY	
Date	**Time**	**Water Level (ft.)**	**k_H (ft/d)**

W90-1S	1st Time	DRY	
Date	**Time**	**Water Level (ft.)**	**k_v (ft/d)**
9/29/00	11:57	0	
	11:57 30	0.87	1.21E-03
	11:58	3.97	4.31E-03
	11:59	4.62	4.51E-04
	12:00	5.15	2.10E-04
	12:00 45	5.47	2.96E-04
	12:06	5.51	4.63E-06
		avg. k_v =	**1.1E-03**

W90-1S	2nd Time		
Date	**Time**	**Water Level (ft.)**	**k_v (ft/d)**
9/29/00	12:07 45	0	
	12:08	1.05	2.92E-03
	12:09	2.49	1.00E-03
	12:10	4.16	1.16E-03
	12:11	4.38	1.53E-04
	12:12	4.56	1.25E-04
	12:13	4.85	2.01E-04
	12:14	4.95	6.94E-05
	12;15	5.02	4.86E-05
		avg. k_v =	**7.1E-04**

9/29/00	12:54 45	4.5	
	12:55 15	4.52	2.78E-05
	12:56	4.65	1.20E-04
	12:57	4.69	2.78E-05
	12:58	4.73	2.78E-05
	12:59	4.75	1.39E-05
	3:00	5.72	5.66E-06
		avg. k_H =	**3.7E-05**

W90-1S 3rd Time

Date	**Time**	**Water Level** (ft.)	**k_v** (ft/d)
9/29/00	12:17 15	0	
	12:18	1.49	1.38E-03
	12:19	2.8	9.10E-04
	12:20	3.54	5.14E-04
	12:22	4.47	3.23E-04
		avg. k_v =	**7.8E-04**

W90-1D 1st Time DRY

Date	**Time**	**Water Level** (ft.)	**k_v** (ft/d)
9/29/00	12:23 15	0	
	12:24	0.98	9.07E-04
	12:25	2.53	1.08E-03
	12:25 30	2.88	4.86E-04
	12:26	3.41	7.36E-04
	12:27	3.7	2.01E-04
	12:28 30	4.28	2.69E-04
	12:29	4.33	6.94E-05
	12:30 30	4.58	1.16E-04
	12:32	4.9	1.48E-04

MW90-1 DRY

Date	**Time**	**Water Level** (ft.)	**kv** (ft/d)
9/29/00	11:21	0	
	11:21 20	0.72	1.50E-03
	11:21 45	1.23	8.50E-04
	11:22 20	1.74	6.07E-04
	11:22:0 0 45	2.12	6.33E-04
	11:23 30	2.55	3.98E-04
	11:24	2.83	3.89E-04
	11:24 30	3.05	3.06E-04
	11:25	3.29	3.33E-04
	11:25	3.5	2.92E-04

	13:34	5.18	9.72E-05
		avg. k_v =	**4.1E-04**
W90-1D	2nd Time	DRY	
Date	**Time**	**Water Level (ft.)**	**k_v (ft/d)**
9/29/00	12:35	0	
	12:35 30	0.8	1.11E-03
	12:37	2.25	6.71E-04
	12:38	2.68	2.99E-04
	12:39	3.28	4.17E-04
	12:40	3.58	2.08E-04
	12:42	4.15	1.98E-04
	12:43	4.45	2.08E-04
	12:44	4.61	1.11E-04
	12:45	4.79	1.25E-04
	12:47	4.96	5.90E-05
		avg. k_v =	**3.4E-04**

	30		
	11:26	3.72	3.06E-04
	11:27	4.01	2.01E-04
	11:28	4.27	1.81E-04
	11:30	4.69	1.46E-04
	11:33	5.1	9.49E-05
	11:35	5.29	6.60E-05
	11:40	5.56	3.75E-05
	11:45	5.63	9.72E-06
	15:08	7.55	1.03E-06
9/30/00	12:12	11.68	2.21E-06
		avg. k_v =	**3.3E-04**

APPENDIX G

SEEPAGE METER FLUX AND MINI-PIEZOMETER GRADIENTS

P20 1999 Field Season
Mini-Piezometer Gradient Data

7/6/99

Piezometer No.	Length Above Sediment (in.)	Water Level (outside) (in.)	Water Level (inside) (in.)	Vertical Gradient (+/-)
MP-20-1A	39.375	20.9375	20.4	**-0.03**
MP-20-B	41	15.125	23.4	0.44
MP-20-C	37	17.875	17.4	**-0.02**
MP-20-D	35.125	9.375	9	**-0.02**
MP-20-E	39.6875	23.125	22.8	-0.02

7/15/99

Piezometer No.	Length Above Sediment (in.)	Water Level (outside) (in.)	Water Level (inside) (in.)	Vertical Gradient (+/-)
MP-20-1A	39.375	24.1875	23.52	-0.03
MP-20-B	41	18.25	17.04	-0.06
MP-20-C	37	26.4375	25.8	-0.03
MP-20-D	35.125	12.375	12	-0.02
MO-20-E	39.6875	20.375	20.28	0.00

7/27/99

Piezometer No.	Length Above Sediment (in.)	Water Level (outside) (in.)	Water Level (inside) (in.)	Vertical Gradient (+/-)
MP-20-1A	39.375	28.4375	15.96	-0.60
MP-20-Bs	41	22.6875	21.96	-0.04
MP-20-Bd	42.875	19.5	DRY	no data
MP-20-Cs	37	25.25	25.08	-0.01
MP-20-Cd	29.75	11.1875	20.52	0.31
MP-20-D	35.125	16.875	16.32	-0.02
MP-20-E	39.6875	30.24	30.24	0.00

P45 1999 Field Season

Mini-Piezometer Gradient Data

7/17/99

Piezometer No.	Length Above Sediment (in.)	Water Level (outside) (in.)	Water Level (inside) (in.)	Vertical Gradient (+/-)
3/4 " P in lake	37.875	31.875	31.2	-0.02
MP-45-1	49.5	37.625	37.44	**-0.02**
MP-45-1A	38.25	23.875	23.64	-0.01
MP-45-B	38.125	18.75	18	-0.03
MP-45-C	44.875	21.125	21.48	**0.02**
MP-45-D	44.375	35.625	36	0.02
MP-45-E	38.75	19.75	19.32	**-0.02**

7/15/99

Piezometer No.	Length Above Sediment (in.)	Water Level (outside) (in.)	Water Level (inside) (in.)	Vertical Gradient (+/-)
3/4 " P in lake	37.875	34.625	33.12	-0.07
MP-45-1	49.5	26.75	26.4	-0.03
MP-45-1A	38.25	39.75	40.56	0.04
MP-45-B	38.125	21.625	21	-0.03
MP-45-C	44.875	24.5	24.6	0.01
MP-45-D	44.375	39.125	39.12	0.00
MP-45-E	38.75	22.875	22.68	-0.01

7/27/99

Piezometer No.	Length Above Sediment (in.)	Water Level (outside) (in.)	Water Level (inside) (in.)	Vertical Gradient (+/-)
3/4 " P in lake	37.875	37.5	37.2	-0.01
MP-45-1	49.5	29.9375	29.76	-0.02
MP-45-1A	38.25	43.625	43.2	-0.02
MP-45-B	38.125	24.625	23.4	-0.06
MP-45-C	44.875	27.5625	27.36	-0.01
MP-45-D	44.375	41.875	41.88	0.00
MP-45-E	38.75	25.875	25.32	-0.03

P76 1999 Field Season
Mini-Piezometer Gradient Data

7/6/99

Piezometer No.	Length Above Sediment (in.)	Water Level (outside) (in.)	Water Level (inside) (in.)	Vertical Gradient (+/-)
MP-45-1A	20.375	21.125	21.125	**0**
MP-45-B	21.375	18.875	18.24	-0.02
MP-45-C	31	13.5	22.8	0.32
MP-45-D	34	22.125	21.72	-0.02
MP-45-E	31	20.125	19.32	**-0.03**
MP-45-F	28.5	19	18.6	-0.01

7/15/99

Piezometer No.	Length Above Sediment (in.)	Water Level (outside) (in.)	Water Level (inside) (in.)	Vertical Gradient (+/-)
MP-45-1A	20.375	23.25	22.68	-0.01
MP-45-B	21.375	21.75	20.28	-0.04
MP-45-C	31	25.6875	24.72	-0.03
MP-45-D	34	24.5	23.76	-0.03
MP-45-E	31	22.0625	21.36	-0.02
MP-45-F	28.5	21.125	20.52	-0.02

7/27/99

Piezometer No.	Length Above Sediment (in.)	Water Level (outside) (in.)	Water Level (inside) (in.)	Vertical Gradient (+/-)
MP-76-1As	20.375	26.125	25.68	-0.01
MP-76-1Ad	22.25	10.5	10.68	0.00
MP-76-B	21.375	DRY	DRY	no data
MP-76-C	31	28.875	27.96	-0.03
MP-76-D	34	27.4375	26.64	-0.03
MP-76-Es	31	24.125	24	0.00
MP-76-Ed	15.5	6.4375	5.88	-0.01
MP-76-F	28.5	24.125	23.52	-0.02

P90 1999 Field Season

Mini-Piezometer Gradient Data

7/6/99

Piezometer No.	**Length Above Sediment (in.)**	**Water Level (outside) (in.)**	**Water Level (inside) (in.)**	**Vertical Gradient (+/-)**
MP-90-1A	37.875	16.0625	15.1875	**-0.04**
MP-90-B	37.375	25.125	37.44	0.56
MP-90-C	31.4375	8.3125	8.0625	-0.01
MP-90-D	35	15.9375	15	**-0.04**
MP-90-E	39	23.125	22.2	**-0.04**
MP-90-F	37.25	15.75	14.76	-0.04

7/15/99

Piezometer No.	**Length Above Sediment (in.)**	**Water Level (outside) (in.)**	**Water Level (inside) (in.)**	**Vertical Gradient (+/-)**
MP-90-1A	37.875	21	16.8	0.19
MP-90-B	37.375	30.1875	32.16	-0.09
MP-90-C	31.4375	13.375	13.32	0.00
MP-90-D	35	21.125	17.76	0.13
MP-90-E	39	28.0625	27.84	0.01
MP-90-F	37.25	20.75	17.04	0.16

7/27/99

Piezometer No.	**Length Above Sediment (in.)**	**Water Level (outside) (in.)**	**Water Level (inside) (in.)**	**Vertical Gradient (+/-)**
MP-90-1As	37.875	26.75	21.36	-0.24
MP-20-1Ad		15.9375	15.6	-0.01
MP-90-B	37.375	36	32.28	-0.16
MP-90-C	31.4375	19.25	18.72	-0.02
MP-90-Ds	35			no data
MP-20-Dd	33.5	22.5	23.16	0.02
MP-90-Es	39	33.875	32.52	-0.06
MP-90-Ed	25.5	19.9375	19.2	-0.02
MP-90-F	37.25	26.75	21.24	-0.24

Seepage meter data **1999 Field Season**

Diameter (seepage meter) = 19.1875 in.

Area (seepage meter) = 289 in^{2}* 2.01 ft$_2$

hydraulic flux q' = Q/A

P20	Start Date	Initial Time (min.)	Initial Volume (ml)	End Date	End Time (min.)	End Volume (ml)	Change in Volume (ml)	Change in Volume (ft^3)	Elapsed Time (hr.)	Discharge (Q) (ft^3/d)	Hydraulic Flux (ft^3/day/ft^2)	Gradient of Corresponding MP	Hydraulic Conductivity kv (ft/d)
SM20-1	6/28/99	9:25	0	7/6/99	14:38	15	15	5.30E-04	197.22	6.45E-05	3.21E-05		
	7/6/99	14:49	400	7/7/99	10:59	470	70	2.47E-03	20.17	2.94E-03	1.47E-03	0.03	4.8E-02
	7/7/99	11:01	0	7/15/99	13:40	180	180	6.36E-03	194.65	7.84E-04	3.90E-04	0.03	1.0E-02
	7/15/99	13:49	500	7/16/99	13:06	395	-105	-3.71E-03	23.28	-3.82E-03	-1.90E-03	-0.60	3.2E-03
	7/16/99	13:11	500		no additional seepage meter data								
SM20-2	6/28/99	9:35	0	7/6/99	14:52	40	40	1.41E-03	197.28	1.72E-04	8.56E-05		
	7/6/99	14:56	400	7/7/99	11:07	390	-10	-3.53E-04	20.18	-4.20E-04	-2.09E-04	-0.02	1.1E-02
	7/7/99	11:10	0	7/15/99	14:07	1010	1010	3.57E-02	194.95	4.39E-03	2.19E-03	0.03	7.3E-02
	7/15/99	14:19	100	7/16/99	13:12	105	5	1.77E-04	22.88	1.85E-04	9.22E-05	0.01	9.2E-03
	7/16/99	13:16	100		no additional seepage meter data								
SM20-3	6/28/99	9:45	0	7/6/99	14:58	0	0	0.00E+00	197.22	0.00E+00	0		
	7/6/99	15:51	400	7/7/99	11:16	395	-5	-1.77E-04	19.42	-2.18E-04	-1.09E-04	-0.02	5.4E-03
	7/7/99	11:20	400	7/15/99	13:58	782	382	1.35E-02	194.63	1.66E-03	8.28E-04	0.02	4.1E-02
	7/15/99	14:02	100	7/16/99	13:18	313	213	7.52E-03	23.27	7.76E-03	3.86E-03	0.02	1.9E-01
	7/16/99	13:23	100		no additional seepage meter data								

Seepage meter data **1999 Field Season**

Diameter (seepage meter) = 19.1875 in.

Area (seepage meter) = 289 in^{2}*

hydraulic flux q' = Q/A

P45	Start Date	Initial Time (min.)	Initial Volume (ml)	End Date	End Time (min.)	End Volume (ml)	Change in Volume (ml)	Change in Volume (ft3)	Elapsed Time (hr.)	Discharge (Q) (ft3/d)	Hydraulic Flux (ft3/day/ft2)	Gradient of Corresponding MP	Hydraulic Conductivity kv (ft/d)
SM45-1	6/28/99	11:14	0	7/7/99	15:15	10	10	3.53E-04	220.02	3.85E-05	1.92E-05	0.02	9.6E-04
	7/7/99	15:18	0	7/15/99	10:15	24	24	8.48E-04	188.95	1.08E-04	5.36E-05	0.03	1.8E-03
	7/15/99	10:21	500	7/16/99	15:20	415	-85	-3.00E-03	28.98	-2.49E-03	-1.24E-03	-0.02	6.2E-02
	7/16/99	15:25	500	no additional seepage meter data									
SM45-2	6/28/99	12:30	0	7/7/99	15:28	155	155	5.47E-03	218.97	6.00E-04	2.99E-04	0.02	1.5E-02
	7/7/99	15:30	0	7/15/99	10:30	250	250	8.83E-03	187.00	1.13E-03	5.64E-04	0.01	5.6E-02
	7/15/99	10:33	250	7/16/99	15:31	160	-90	-3.18E-03	28.97	-2.63E-03	-1.31E-03	-0.03	4.4E-02
	7/16/99	15:36	500	no additional seepage meter data									
SM45-3	6/28/99	12:15	0	7/7/99	15:31	250	250	8.83E-03	219.27	9.66E-04	4.81E-04	0.02	2.4E-02
	7/7/99	15:54	0	7/15/99	10:23	152	152	5.37E-03	186.48	6.91E-04	3.44E-04	0.01	3.4E-02
	7/15/99	10:27	250	7/16/99	15:46	160	-90	-3.18E-03	29.32	-2.60E-03	-1.30E-03	-0.03	4.3E-02
	7/16/99	15:49	500	no additional seepage meter data									

Seepage meter data **1999 Field Season**

Diameter (seepage meter) = 19.1875 in.

Area (seepage meter) = 289 in^2*

hydraulic flux q' = Q/A

P76	Start Date	Initial Time (min.)	Initial Volume (ml)	End Date	End Time (min.)	End Volume (ml)	Change in Volume (ml)	Change in Volume (ft3)	Elapsed Time (hr.)	Discharge (Q) (ft3/d)	Hydraulic Flux (ft3/day/ft2)	Gradient of Corresponding MP	Hydraulic Conductivity kv (ft/d)
SM76-1	6/28/99	14:50	0	7/6/99	18:50	150	150	5.30E-03	196.00	6.49E-04	3.23E-04	0.01	3.2E-02
	7/6/99	18:53	0	7/7/99	13:12	65	65	2.30E-03	18.32	3.01E-03	1.50E-03	0.01	1.5E-01
	7/7/99	13:15	0	7/15/99	15:33	90	90	3.18E-03	194.22	3.93E-04	1.96E-04	0.01	1.9E-02
	7/15/99	15:37	100	7/16/99	floated to surface-no data								
SM76-2	6/28/99	14:30	0	7/6/99	19:03	240	240	8.48E-03	196.55	1.03E-03	5.15E-04	0.03	1.7E-02
	7/6/99	19:06	0	7/7/99	13:32	213	213	7.52E-03	17.43	1.04E-02	5.16E-03	0.02	2.6E-01
	7/7/99	13:35	0	7/15/99	15:52	245	245	8.65E-03	194.28	1.07E-03	5.32E-04	0.01	5.3E-02

P90	Start Date	Initial Time	Initial Volume	End	End Time	End Volume	Change In Volume	Change in Volume	Elapsed Time	Discharge (Q)	Hydraulic Flux	Gradient of Corresponding MP	Hydraulic Conductivity kv
		(min.)	(ml)	Date	(min.)	(ml)	(ml)	(ft3)	(hr.)	(ft3/d)	(ft3/day/ft2)		(ft/d)
SM90-1	06/28/99	16:30	0	07/06/99	12:20	80	80	2.83E-03	187.83	3.61E-04	1.80E-04		
	07/06/99	12:23	0	07/07/99	9:28	120	120	4.24E-03	21.08	4.82E-03	2.40E-03	0.04	6.0E-02
	07/07/99	9:31	0	07/15/99	11:21	150	150	5.30E-03	193.83	6.56E-04	3.27E-04	0.19	1.7E-03
	07/15/99	11:24	250	07/16/99	9:50	315	65	2.30E-03	12.43	4.43E-03	2.21E-03	0.24	9.2E-03
	07/16/99	9:53	100	no additional seepage meter data									
SM90-2	06/28/99	17:00	0	07/06/99	12:28	550	550	1.94E-02	187.47	2.49E-03	1.24E-03		
	07/06/99	12:31	0	07/07/99	9:32	170	170	6.00E-03	21.02	6.86E-03	3.41E-03	0.04	8.5E-02
	07/07/99	9:34	0	07/15/99	11:35	315	315	1.11E-02	194.02	1.38E-03	6.85E-04	0.13	5.3E-03
	07/15/99	11:39	100	07/16/99	10:17	420	320	1.13E-02	12.63	2.15E-02	1.07E-02	0.06	1.8E-01
	07/16/99	10:28	100	no additional seepage meter data									
SM90-3	06/28/99	16:55	0	07/06/99	12:33	70	70	2.47E-03	187.63	3.16E-04	1.57E-04		
	07/06/99	12:36	0	07/07/99	9:35	147	147	5.19E-03	20.10	6.20E-03	3.09E-03	0.04	7.7E-02
	07/07/99	9:39	0	07/15/99	11:26	345	345	1.22E-02	193.78	1.51E-03	7.51E-04	0.01	7.5E-02
	07/15/99	11:33	100	07/16/99	10:31	200	100	3.53E-03	12.97	6.54E-03	3.26E-03	0.06	5.4E-02
	07/16/99	10:35		no additional seepage meter data									

Seepage Meter Data **2000 Field Season**

Diameter (seepage meter) = 11.25 in in2 = 0.69 ft2 **Q = Akv(h/l)**

hydraulic flux q' = Q/A Area (seepage meter) = 99 in2

Seepage Meter	**Start** Date	**Initial Time**	**Initial Volume** (ml)	**End** Date	**End Time**	**End Volume** (ml)	**Change in Volume** (ml)	**Change in Volume** (ft3)	**Elapsed Time** (hr.)	**Discharge** (Q) (ft3/d)	**Hydraulic Flux** (ft3/day/ft2)	**Gradient of Corresponding MP**	**Hydraulic Conductivity kv** (ft/d)
SM-1	10-Jul	12:40	100	17-Jul	12:33	265	165	5.83E-03	191.88	3.64E-04	5.30E-04	0.01	4.9E-02
SM-2	10-Jul	12:38	100	17-Jul	13:34	204	104	3.67E-03	192.93	2.28E-04	3.32E-04	0.01	3.1E-02
SM-3	10-Jul	12:36	100	17-Jul	13:28	294	194	6.85E-03	192.87	4.26E-04	6.20E-04	0.01	5.8E-02
SM-4	10-Jul	12:30	100	17-Jul	13:20	220	120	4.24E-03	192.83	2.64E-04	3.84E-04	0.20	1.9E-03
SM-5	10-Jul	12:14	100	17-Jul	13:15	206	106	3.74E-03	193.02	2.33E-04	3.39E-04	0.20	1.7E-03
SM-6	10-Jul	12:34	100	17-Jul	13:12	277	177	6.25E-03	192.63	3.89E-04	5.66E-04	0.20	2.8E-03
SM-7	10-Jul	12:00	100	17-Jul	12:55	155	55	1.94E-03	192.92	1.21E-04	1.76E-04	0.23	7.7E-04
SM-8	10-Jul	12:05	100	17-Jul	13:06	191	91	3.21E-03	193.02	2.00E-04	2.91E-04	w.l. still recovering	no gradient
SM-9	10-Jul	12:50	100	17-Jul	14:12	89	-11	-3.88E-04	193.37	-2.41E-05	-3.51E-05	0.02	-2.1E-03
SM-10	10-Jul	13:05	100	17-Jul	12:03	100	0		193.03			0.01	
SM-11	10-Jul	13:10	100	17-Jul	13:59	514	414	1.46E-02	192.82	9.10E-04	1.32E-03	0.01	1.3E-01
SM-12	10-Jul	13:28	100	17-Jul	13:40	238	138	4.87E-03	192.20	3.04E-04	4.43E-04	0.24	1.8E-03
SM-13	10-Jul	13:30	100	17-Jul	13:45	582	482	1.70E-02	192.25	1.06E-03	1.55E-03	0.24	6.4E-03
SM-14	10-Jul	13:32	100	17-Jul	13:51	180	80	2.83E-03	192.32	1.76E-04	2.56E-04	0.09	2.8E-03
										avg. flux	**5.21E-04**		

SM9&10 had bags that did not allow water to exchange

Seepage Meter	**Start** Date	**Initial Time**	**Initial Volume** (ml)	**End** Date	**End Time**	**End Volume** (ml)	**Change in Volume** (ml)	**Change in Volume** (ft3)	**Elapsed Time** (hr.)	**Discharge** (Q) (ft3/d)	**Hydraulic Flux** (ft3/day/ft2)	**Gradient of Corresponding MP**	**Hydraulic Conductivity kv** (ft/d)
SM-1	17-Jul	13:36	100	1-Aug	10:35	119	19	1.16	332.98	8.36E-02	1.22E-01	0.01	1.1E+01
SM-2	17-Jul	13:26	100	1-Aug	10:34	123	23	1.40	333.13	1.01E-01	1.47E-01	0.01	1.4E+01
SM-3	17-Jul	13:32	100	1-Aug	10:33	100	0		333.02			0.01	
SM-4	17-Jul	13:22	100	1-Aug	10:32	240	140	8.54	333.17	6.15E-01	8.95E-01	0.29	3.1E+00
SM-5	17-Jul	13:18	100	1-Aug	10:30	196	96	5.86	333.20	4.22E-01	6.14E-01	0.29	2.1E+00
SM-6	17-Jul	13:14	100	1-Aug	10:28	224	124	7.57	333.23	5.45E-01	7.93E-01	0.29	2.8E+00
SM-7	17-Jul	13:05	100	1-Aug	no data	no data	no data	no data	no data	no data	no data	no data	no data
SM-8	17-Jul	13:08	100	1-Aug	no data	no data	no data	no data	no data	no data	no data	no data	no data
SM-9	17-Jul	14:19	100	1-Aug	10:54	206	106	6.47	332.58	4.67E-01	6.79E-01	0.26	2.6E+00
SM-10	17-Jul	14:10	100	1-Aug	10:57	139	39	2.38	332.78	1.72E-01	2.50E-01	0.10	2.5E+00
SM-11	17-Jul	14:02	100	1-Aug	10:58	260	160	9.76	332.93	7.04E-01	1.02E+00	0.26	3.9E+00
SM-12	17-Jul	13:44	100	1-Aug	11:10	160	60	3.66	333.43	2.64E-01	3.83E-01	0.42	9.1E-01

SM-13	17-Jul	13:49	100	1-Aug	11:11	90	-10	-0.61	333.37	-4.39E-02	-6.39E-02	0.42	-1.5E-01
SM-14	17-Jul	13:55	100	1-Aug	11:07	156	56	3.42	333.20	2.46E-01	3.58E-01	0.23	1.6E+00
										average flux	**4.32E-01**		

APPENDIX H

WRNSHYD MODEL OUTPUT PARAMETERS AND RESULTS

WRNSHYD Model Input Parameters and Results for P20 Wetland

```
Watershed Name: P20
Units of measurement: English
Hydrologic Region: Continental/Maritime (6)

Area (ac    ):      1   Aspect: East/West

Precip (in    )...
  Jan:     3.3  Feb:   2.3  Mar:    2.1  Apr:     1.8
  May:     2.3  Jun:    2.4  Jul:    1.3  Aug:     1.4
  Sep:     1.7  Oct:   2.0  Nov:    3.1  Dec:     3.1


     Lapse Rate:      1.0
     Snow Catch:     None
  Gauge Exposure:       0.0

   WindSpeed(mi/h  ):    0.0     DaysNoSnow:   0
   Tree Type:  Spruce-Fir         Height(ft    ):       0.0
   Snow Scouring:     N

                                 Unimpacted  Impacted
     Max Basal Area(ft²/ac):        200        200
         Basal Area(ft²/ac):        150        150
 Total Area Clearcut(ac    ):         0          1
  Basal Area in Cuts(ft²/ac):       150          0
    Roughness of Cut(ft    ):         0.3        0.3
  Width of Cut Block(ft    ):       0.0      208.7
   Area of Cut Block(ac    ):         0          1

Annual Watershed Results

                             Unimpacted  Impacted
Watershed Totals (Area =       1.0):
    Precipitation     (in    ):    26.8       26.8
    Evapotranspiration(in    ):  14.6       12.6
    Water Yield       (in    ):    12.2       14.2
```

WRNSHYD Model Input Parameters and Results P45 Wetland

Watershed Name: P45
Units of measurement: English
Hydrologic Region: Continental/Maritime (6)

Area (ac): 6 Aspect: East/West

Precip (in)...
Jan: 3.3 Feb: 2.3 Mar: 2.1 Apr: 1.8
May: 2.3 Jun: 2.4 Jul: 1.3 Aug: 1.4
Sep: 1.7 Oct: 2.0 Nov: 3.1 Dec: 3.1

Lapse Rate: 1.0
Snow Catch: None
Gauge Exposure: 0.0

WindSpeed(mi/h): 0.0 DaysNoSnow: 0
Tree Type: Spruce-Fir Height(ft): 0.0
Snow Scouring: N

	Unimpacted	Impacted
Max Basal Area(ft²/ac):	200	200
Basal Area(ft²/ac):	150	150
Total Area Clearcut(ac):	0	6
Basal Area in Cuts(ft²/ac):	150	0
Roughness of Cut(ft):	0.3	0.3
Width of Cut Block(ft):	0.0	08.7
Area of Cut Block(ac):	0	6

Annual Watershed Results

	Unimpacted	Impacted
Watershed Totals (Area = 5.8):		
Precipitation (in):	26.8	26.8
Evapotranspiration(in):	14.6	12.6
Water Yield (in):	12.2	14.2