Canadian Technical Report of

Fisheries and Aquatic Sciences 1551

August 1987

AN IRRIGATION SYSTEM AND HYDROLOGICAL NETWORK FOR A WETLAND ACIDIFICATION PROJECT

by

K.G. Beaty

Central and Arctic Region

Department of Fisheries and Oceans

Winnipeg, Manitoba R3T 2N6

This is the 10th Technical Report

from the Central and Arctic Region, Winnipeg

Cat no. Fs 97-6/1551E ISSN 0706-6457

Correct citation for this publication is:

Beaty, K.G. 1987. An irrigation system and hydrological network for a wetland acidification project. Can. Tech. Rep. Fish. Aquat. Sci. 1551: iv + 32 p.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF PHOTOGRAPHS

ABSTRACT

Beaty, K.G. 1987. An irrigation system and hydrological network for a wetland acidification project. Can. Tech. Rep. Fish. Aquat. Sci. 1551: iv + 32 p.

In 1983, a wetland acidification study began at the Experimental Lakes Area in northwestern Ontario. The purpose of the project was to study the effects of sulphuric and nitric acids on a wetland and the receiving waters below. Acid rainfall events were created using an irrigation system to distribute lake water evenly over a 3.7 ha wetland. The desired pH was achieved by using a metering pump to inject acid into the irrigation water. This report describes the irrigation system, acidification methods and hydrological network used to create and monitor controlled experimental rain and acid rain events.

Key words: wetlands; acidification; acid rain; hydrology; evapotranspiration; irrigation; groundwater; water budget.

RÉSUMÉ

Beaty, K.G. 1987. An irrigation system and hydrological network for a wetland acidification project. Can. Tech. Rep. Fish. Aquat. Sci. 1551: iv + 32 p.

Une étude sur l'acidification des terres humides a été entreprise en 1983 dans la région des lacs expérimentaux, dans le nord-ouest ontarien. Le projet avait pour but d'étudier les effets des acides sulfurique et nitrique sur un milieu humide ainsi que sur les eaux réceptrices en aval. On a produit des pluies acides à l'aide d'un réseau d'irrigation afin de distribuer l'eau du lac également sur un milieu humide de 3,7 hectares. Le pH souhaité a été obtenu grâce à l'utilisation d'une pompe de dosage, ce qui a permis d'injecter l'acide dans l'eau d'irrigation. Dans ce rapport, on décrit le réseau d'irrigation, les méthodes d'acidification et le réseau hydrologique servant à produire et à contrôler les chutes de pluie et de pluie acide expérimentales créées.

Mots-clés: acidification; bilan d'eau; eau souterraine; évapotranspiration; hydrologie; irrigation; pluie acide; terres humides.

INTRODUCTION

In 1983, a wetland acidification study was started in the Experimental Lakes Area of the Freshwater Institute (Canada Department of Fisheries and Oceans, Western Region). Lake water was pumped from a nearby lake to the study area, acidified and applied evenly to the wetland surface. The purpose of this report is to describe the irrigation system, the acid injection method and the hydrologic network used to create, control and monitor experimental rain and acid rain events. Basic data and maps relevant to this and other related studies in the watershed are given.

While acid precipitation is widely known to cause acidification in lakes and forest soils, the effects on wetlands are less known (Bayley et al. 1987). Gorham et al. (1984) discussed the ecological effects of acid deposition on peatlands and emphasized the need for experimental acidification studies. In this study, the effects of known amounts of sulphuric and nitric acids on a wetland are being determined.

As all natural wetland functions are a result of, or are closely related to, wetland hydrology (Carter et al. 1978), it was therefore important to identify and quantify the hydrologic processes in order to understand the biological and chemical processes that occur as a result of experiment manipulations. For water and chemical balance purposes, it was necessary to consider all sources of input and output within a water budget framework. Parameters that were monitored included precipitation, streamflow, irrigated inflow, and water table fluctuation. Those that were not monitored, but were identified, included ungauged terrestrial inflow, groundwater inflow and outflow and evapotranspiration.

Abundant background data existed prior to the start of this study. Hydrology and weekly stream chemistry sampling began in 1971, providing data that were useful in designing this project. Hydrology, basin history, chemistry and vegetation have been previously described (Bayley and Schindler 1987; Bayley et al. 1987; Bayley et al. 1986; Beaty 1981; Beaty 1984; Behr 1985; Newbury and Beaty 1977; Schindler et al. 1976; Urban and Bayley 1986; and Vitt and Bayley 1984). Parts of the basin were burned by the forest fires in both 1974 and 1980. The effects of the fires were discussed by Schindler et al. (1980).

SITE DESCRIPTION

The experimental wetland is located in the Experimental Lakes Area (ELA) of northwestern Ontario (Lat. 49° 40' N, Long. 90° 43' W). The site is the 3.67 ha wetland portion of the Northeast Subbasin (12.43 ha) in the Rawson Lake (239) watershed (393.34 ha). Figure 1 shows the Northeast Subbasin relative to the Lake 239 watershed and the research field camp, and Fig. 2 shows the experimental wetland relative to the Northeast Subbasin. Photographs 1 and 2 provide aerial views of the NE Subbasin and wetland area. The site lies 1 km NE of the field camp and is accessible by either boat or road.

The wetland surface represents 30% of the subbasin. The remaining 8.76 ha or 70% is terrestrial runoff (non-wetland) area which drains directly into the wetland. Because suitable small catchments or streams could not be found within this area, runoff rates to the wetland could not be monitored. This ungauged inflow had to be estimated from adjacent gauged basins on a proportional unit area basis.

Because the NE Subbasin is a headwater area having no areas adjacent to it of a higher elevation and because of the exposed bedrock drainage divide surrounding the basin, groundwater inflow and outflow for the watershed were considered negligible.

EXPERIMENTAL DESIGN

OBJECTIVE

The objective of the experimental design was to provide a system that would allow a wetland study area to be spray irrigated with acidified water to the equivalent of the pH of precipitation in the most acid areas of the eastern U.S. and Canada. To accomplish this goal, a system for simulating acid rainfall events using an irrigation system was designed, installed and operated. The rationale for the target pH of applied water, application frequency, ratio of nitric and sulphuric acids, and amount of acid is described by Bayley et al. (1986).

DESIGN FACTORS

Major criteria are listed below:

Requirements

- a) maximum acidity of irrigation water = pH 3.0
- b) irrigation events must be within the range of natural rainfall events for the area (rate ≈2 $mm \cdot h^{-1}$ and depth ≈10-15 mm)
- c) spray must have a relatively even application
- d) all pipe, fittings and sprinklers in the wetland to be acid resistant plastic of low trace metal content
- e) system must allow observation and monitoring of flow rates of pumped water, outflow and water table fluctuations
- f) experimental design should include an acidified area and a non-acidified control area

Basic data

- g) site - Northeast Subbasin (12.43 ha)
  - wetland portion (3.67 ha)
- h) source water - Roddy Lake (pH 6.5-7.0)
- i) acidity of long term natural precipitation at ELA ~4.9

j) pumping distance from source to upper end of wetland = 150 m
k) pumping distance from source to lower end of wetland = 450 m
l) maximum lift from Roddy Lake to the basin = 6.7 m
m) net head difference from Roddy Lake to wetland surface = 3.1 m

Agricultural supply companies specializing in irrigation systems were helpful in designing the system. Because the experimental design called for a control area, acid had to be added midway down the irrigation system, rather than at the Roddy Lake source. A variable rate metering pump capable of overcoming the inline pressures of the system was selected to add concentrated acids to the irrigation system at a point just above the experimentally acidified area.

SURVEYS AND MAPPING

Three separate versions of topographic contour mapping exist for the Northeast Subbasin. They were prepared by Northwest Photogrammetry in 1970 (scale = 1:4800, contour interval = 3 m), Lockwood Surveys in 1972 (scale = 1:7920, contour interval = 3 m), and Airquest Resource Surveys in 1987 (scale = 1:1000, contour interval = 1 m). The area values cited in this report were based on the most recent mapping (Airquest in 1987) and should be considered more correct than previously reported values.

Figure 1 shows the Rawson Lake watershed with the Northeast Subbasin and Fig. 2 shows the Northeast Subbasin with the wetlands area.

In the Fall of 1982, surveys were carried out within the 3.67 ha wetland area to establish horizontal and vertical control for the preparation of more detailed maps. Figure 3 shows only the wetland portion of the Northeast Subbasin and serves as a base map. A useful feature of this map is the survey grid which can be used to locate field plot, sample well or other site locations on the map. This grid is a key to most of the figures that follow in this report.

Figure 4 provides a contour plan of the bottom bedrock below the peat surface in the experimental wetland. Depths were measured by probing with extendable steel rods at many points referenced to the survey grid lines.

Figure 5 shows a three dimensional view of the bottom of the wetland using the same information as used in Fig. 4.

Figure 6 provides a similar three dimensional view of the wetland portion of the Northeast Subbasin showing the surface topography of the peat.

Fluctuation in the peat surface was investigated by engineering leveling techniques during the 1984 season. To accomplish this, two healthy mid-size (10 cm diameter) spruce trees were selected near the wetland centre and 30 m away from the central pool. A spike was embedded near the base of each tree to serve as a reference for vertical movement. On seven occasions, the elevations of the reference spikes were determined relative to a stable benchmark on bedrock about 75 m away. Survey errors ranged from 0 to 9 mm and averaged 4 mm. The following table summarizes observed movement in the two reference trees in comparison to the corresponding water level change for six time periods.

	Movement (mm)		
Period in 1984	Tree 1	Tree 2	Water Table
May 16-Jun 12	-2	+5	+21
Jun 12-Jun 25	0	0	-30
Jun 25-Jun 28	+1	+2	+93
Jun 28-Aug 10	+2	0	-180
Aug 10-Aug 17	+9	+7	+7
Aug 17-Sep 18	-12	-12	-10
Net movement	-2	+2	-99

Given the precision of the surveys, the data presented suggests that there was not a great deal of movement in the peat surface. From June 28 to August 10, 1984, the net water table movement was -180 mm while tree movements were 0 and +2 mm.

IRRIGATION SYSTEM

A plan view of the overall irrigation system is shown in Fig. 7. The system consisted of an irrigation pump, a supply line up to the edge of the wetland, and within the wetland, a mainline and lateral pipe distribution network with sprinkler heads, control valves and pressure gauges. Other features included a control hydrant and an inline flow meter.

The irrigation pump was located on the shore of nearby Roddy Lake. Two types of pumps were used. In 1983, the power take-off pump (Monarch, modelNPTO 3M9-540) shown in Photo 3 was used and was powered by a Versatile 150 tractor. This pump easily supplied the required 1211 $L{\cdot}min^{-1}$ (320 GPM US) at 462 kPa (67 psi) but proved to be inconvenient in that it required the use of the camp maintenance tractor for each application. Set up was time consuming, and required an extra person for pump and tractor standby. In 1984, this pump was replaced with a gasoline powered pump (Monarch, Model NG4L 13S). This pump, shown in Photo 4, was powered by a four cylinder Wisconsin gas engine (model VG4D) capable of 37 HP at 2400 RPM. It supplied 1287 $L{\cdot}min^{-1}$ (340 GPM US) at 462 kPa (67 psi) and proved to be both reliable and require less set up time than the first system.

Water was pumped from a depth of 1 m (7 m offshore) through a 12.7 cm (5 in.) diameter supply line of aluminum pipe in 9.1 m (30 ft) lengths with Oliver slip joint rubber gasketted fittings. The joints were flexible to a 5°angle in any direction allowing easy layout with a minimum number of elbows. Aluminum pipe was used only for the first 150 m, to the edge of the wetland. Water was pumped up 6.7 m to cross the drainage divide and down 3.6 m to the wetland surface.

Within the wetland area, only plastic parts were used. Water was distributed to 160 sprinklers through a network of 12.7 cm (5 in.) and 5 cm (2 in.) diameter polyvinyl chloride (PVC) pipes. The network consisted of a 300 m mainline of 12.7 cm diameter pipe along the central axis and 21 lateral lines of 5 cm diameter pipe at right angles to the mainline at 14 m spacing (Fig. 7 and 8). The length of lateral lines on each side of the mainline varied from 22 m to 82 m and averaged 52 m. In all, 2200 m of 5 cm and 300 m of 12.7 cm PVC pipe were used in the wetland. The total volume of water contained by the system when full was 8.3 m^3. This resulted in a flushing time of 6.4 min when the pumping rate was 1.29 $m^3 \cdot min^{-1}$.

All PVC pipe used, was a potable water grade (Series 160, schedule 40). The fittings, the 12.7 cm diameter pipe, and some of the 5 cm diameter pipe were joined by solvent welding. Most of the 5 cm pipes were connected with slip joint rubber gasket fittings but this proved to be inferior to solvent weld connections because it required the pinning of all gasket connections to prevent pipe separation.

Along each lateral, sprinklers were placed at 16 m intervals on 0.6 m risers. To achieve a more even spray, sprinklers on adjacent laterals were offset by 8 m creating a triangular configuration as shown in Fig. 9. The sprinklers used were Rainbird plastic irrigation sprinklers (no. P3PJ) with 2.78 mm (7/64 in.) diameter adjustable spray nozzles (Photo 5). The range of spray varied with sprinkler adjustment, wind, operating line pressure, and nozzle cleanliness. The range of a clean, properly adjusted sprinkler operated at 274 kPa (40 psi) was a radius of 8-9 m. However, when improperly set or partially obstructed, this range could vary from 7 to 13 m.

Even distribution of water was accomplished by means of 42 control valves, one on each side of the mainline on each of the 21 laterals. A pressure gauge was mounted on each lateral line below each control valve. The pressure in all lateral lines could then be equalized by observing the pressure gauges and adjusting the control valves accordingly. Photograph 6 shows the branching of a lateral from the mainline and a control valve with pressure gauge. Trees and wind also affected spray coverage. "Even spray" should be interpreted as meaning that each of the 160 sprinklers were capable of discharging water at the same rate but, for reasons stated, application within each circle of theoretical coverage may not have been uniform. Therefore, the site selection for samples, plots, traps etc. was important. The irrigation system delivered water to approximately 3.5 ha or 95% of the 3.67 ha area. The small area (0.16 ha) between lateral 21 and the outflow weir was not irrigated.

Pressure gauges also offered a convenient means by which to quickly check the system during operation. Normal operating pressures were 462 kPa (67 psi) near the pump, 345 kPa (50 psi) in the mainline at the acid mixing area (laterial 6), and 274 kPa (40 psi) in each lateral. With gauges installed at these key locations, problems such as pipe breaks could be detected and isolated quickly by watching for pressure drops in the gauges (Photos 6, 7 and 8).

A hydrant (Photo 9) was installed in the mainline near the pump. It served as a bypass to divert water back to the lake during the pump warm up and cool down phases. It also allowed the system to be brought up to pressure slowly, thereby preventing possible damage caused by rapid changes in line pressure, as air was driven from the pipes and the system was charged with water.

A record of volumes and rates of water pumped was provided by an inline flow meter (Photo 10) located near the pump (McCrometer bolt on saddle meter, Model No. M0300).

Draining of the system after each application of water presented a problem due to the hummock and hollow nature of the wetland surface. Most of the residual water volume could be drained by removing drain plugs that were installed at low points. However, draining the system at the end of the season, for winter, was considerably more difficult. In addition to removing up to 27 drain plugs, some pipes had to be cut and laterals had to be manually lifted to drain low areas.

Photograph 11 shows some of the pipe which had to be hand carried into the site. To minimize damage to the vegetation during construction, a main boardwalk (Photos 12, 13 and 14) was built of planks and logs. Secondary boardwalks were later added to provide for access to scientific sites and to allow for precise level surveys on the spongy peat to be carried out (Photo 13). The locations of all boardwalks are shown in Fig. 10.

ACID ADDITION SYSTEM

For experimental purposes, the wetland was divided into two areas, one a control portion and the other an acidified portion. The control area (0.85 ha) extended up to the mid-point between laterals 6 and 7 and the acidified area (2.66 ha) extended from there to lateral 21. The laterals and acid addition area are shown in Fig. 8 and the acid addition area is further detailed in Fig. 11.

Because operating pressures were normally 345 kPa (50 psi) in the mainline at the addition area, it was necessary to pump the acid into the irrigation system.

Two alternatives for acid addition were considered, a large volume of diluted acid mixture and a smaller volume of concentrated acid mixture. The second option, involving the handling and pumping of concentrated acid solutions, was chosen to minimize pumping time and cost of the pump. The shorter pumping time also meant that a reduced volume of lake water would be applied to the wetland. The only advantage of the first alternative, using diluted acid, would have been safety. However, this benefit may have been offset by problems introduced by longer pumping times.

The acid mixture was the same for all additions and was determined on an equivalent basis of 50% sulphuric and 50% nitric acids (Bayley et al. 1987). This resulted in a 14.2 L concentrated solution of H_2SO_4 (4.8 L) and HNO_3 (9.4 L) being applied on three occasions in 1983 and on six occasions in each of 1984, 1985 and 1986. The pH of each application was maintained very close to pH 3.0. A spray rinse of water lasting approximately 20 minutes preceded and followed each acidification event.

The acids were mixed in the field camp, then transported to the site by vehicle. Photograph 15 shows how the acids were mixed outdoors while wearing an acid resistant suit, gloves and face shield, and while using an electric fan to direct toxic fumes away from the individual.

The pump used to introduce the acid into the mainline was a variable rate, diaphragm, chemical metering pump (Blue White Industries, Chem-Feed, model C-1530LP) as shown in Photo 8. It had a maximum feed rate of 80 $mL \cdot min^{-1}$ against 0 kPa and was capable of pumping against a maximum of 689 kPa (100 psi).

Acid was pumped from a 20 L Nalgene® container through a strainer, 9.5 mm diameter Teflon® lines, and three anti-backflow check valves. Two of the check valves were mounted on the pump head and one was fixed to the mainline. The check valve on the mainline permitted operation of the irrigation system with or without the acid pump in place.

Mixing of the acid into the irrigation water was achieved by means of a mixing loop built into the mainline (Photo 16). The four elbows thoroughly mixed the acid before reaching lateral 7. Sampling taps located on either side of the loop permitted samples to be taken to verify irrigation chemistry. The mixing loop design also allowed for thermal expansion to take place without overstressing glued fittings. The thermal expansion of the mainline was calculated to be 76 cm over 300 metres between 0°C and +30°C.

Photographs 8, 16 and 17 show the setup for acid addition. In the event of an acid related accident, 2-200 L tanks were accessible, one containing a saturated sodium bicarbonate solution and the other containing water only. A 1.5 kW Honda gas powered generator was used to provide power for the acid pump, a night work light and small power tools.

HYDROLOGICAL MONITORING

Although irrigation began in 1983, streamflow from the wetland and precipitation monitoring began in 1971. A meteorological station located 1.2 km away, across the lake to the WSW and 20 m higher than the wetland (Fig. 1), has provided continuous records of rainfall, snowfall, wind, air temperature and relative humidity since 1969. These background data, as well as station descriptions, are provided in Beaty (1981, 1984, unpublished data).

During the period of this experiment, the hydrologic parameters that were monitored included streamflow, precipitation, and water table elevation at several points.

Stream outflow from the Northeast Subbasin was measured and recorded continuously from April to mid November of each year. Flow was normally zero from mid November to early April. Initially a small concrete flume (Photo 18) was used to measure the flow. In July 1985, this was replaced with a 120° v-notch concrete weir (Photo 19). Stage discharge curves for each station were developed using volumetric discharge measurements for low flows and current meter discharge measurements for mid to high flows. A Leupold Stevens type A-71 water level recorder provided continuous records of stage from which discharges were calculated.

Precipitation was measured weekly from a standard rain gauge at station 4 located near the weir. Daily total and recorded hourly rainfall were observed at the nearby meteorological station.

Fluctuations in water table were measured with a network of 24 non-recording and five recording water table wells (Fig. 12). The non-recording wells were simply lengths of 1.9 cm diameter PVC pipe inserted to a depth of about 1 m below the water table. The lower ends were covered to prevent filling with peat during insertion and slots in the sides allowed for free water level response. Platforms were constructed at each well so that the observers body weight would not influence the water level in the wells. Routine measurements of depth to water below the well top were made with a dipstick. Well top elevations were determined by level survey (Photo 13) so that relative water table elevations could be calculated. Water table elevation data could then be used to prepare water table contour plans (Fig. 13) and water table profile diagrams (Fig. 14) for various conditions of wetness.

The five recording wells provided a more continuous record of water table fluctuation along the wetland central axis than the 24 manual observation wells. Photographs 14 and 20 show a recorder and shelter. Leupold Stevens, type F, 8 day float recorders were used. Figure 15 shows a typical water table recession in the wetland central area during an 8 day rainless period with a diurnal fluctuation due to midday evapotranspiration and a slight evening water table recharge. Figure 16 shows the water table response to 14.9 mm of irrigation water. Figure 17 shows the typical water table in the wetland central area on a seasonal scale, which, when combined with peat surface elevation, indicates the variable zone of unsaturated peat thickness.

The volume of irrigation water applied to the wetland was measured by the inline flow meter shown in Photo 10 and described in the previous section.

ACKNOWLEDGMENTS

Many individuals have assisted in the installation and operation of the system described in this report. Dr. D.W. Schindler provided the incentive for the project while Dr. S.E. Bayley and Dr. R.W. Newbury provided the scientific direction. Installation and operation in 1983 was carried out or assisted by Jim Millman, Craig Allan, Hank Vandenhort, Wally Lesawich and Bob Newbury. In 1984, the system was operated and maintained by Jim Millman, Steven Holloway, Jeff Neufeld and Louise MacDonald, in 1985, by Mark Lyng, Dave Holla and Geoff Tomlinson, and, in 1986, by Mark Lyng, Gordon Taylor and Neil McCutcheon. Valuable design assistance was provided by Mr. Jim Shields of Even Spray Chemical Ltd., Winnipeg and Mr. Chuck Waters of Scepter Manufacturing Ltd., Winnipeg.

REFERENCES

BAYLEY, S.E., and D.W. SCHINDLER. 1987. Sources of alkalinity in Precambrian Shield watershed streams under natural conditions and after stress (fire or acidification). In T.C. Hutchinson and K. Meema (ed.) Effects of acidic deposition on forests, wetlands and agricultural ecosystems, May 12-17, 1985, Toronto, Ontario. Proceedings of the workshop. Springer-Verlag, New York.

BAYLEY, S.E., D.H. VITT, R.W. NEWBURY, K.G. BEATY, R. BEHR, and C. MILLER. 1987. Experimental acidification of a Sphagnum dominated peatland: first year results. Can. J. Fish. Aquat. Sci. 44: 194-205.

BAYLEY, S.E., R.S. BEHR, and C.A. KELLY. 1986. Retention and release of sulphur from a freshwater wetland. Water Air Soil Pollut. 31(1-2): 101-114.

BEATY, K.G. 1981. Hydrometeorological data of the Experimental Lakes Area, northwestern Ontario, 1969 through 1978 (in three parts). Can. Data Rep. Fish. Aquat. Sci. 285: vi + 1-97 (Part I); v + 98-316 (Part II); iv + 317-367 (Part III).

BEATY, K.G. 1984. Hydrometerological data for the Experimental Lakes Area, northwestern Ontario, 1979-1981. Can. Data Rep. Fish. Aquat. Sci. 480: v + 146 p.

BEHR, R.S. 1985. Sulphur dynamics in an experimentally acidified mire in northwestern Ontario. M.Sc. Thesis, University of Manitoba, Winnipeg, MB. 105 p.

CARTER, V., M.S. BEDINGER, R.P. NOVITSKI, and W.O. WILEN. 1978. Water resources and wetlands, p. 344-376. In P.E. Greeson, J.R. Clark and J.E. Clark (eds.) Wetland functions and values: the state of our understanding. American Water Resources Association, Minneapolis, MN.

GORHAM, E., S.E. BAYLEY, and D.W. SCHINDLER. 1984. Ecological effects of acid deposition upon peatlands: a neglected field in "acid-rain" research. Can. J. Fish. Aquat. Sci. 41: 1256-1268.

NEWBURY, R.W., and K.G. BEATY. 1977. Water budgets in small Precambrian lake basins in northwestern Ontario, Canada, p. 132-139. In Preprint Volume, 2nd Conference on Hydrometeorology, October 25-27, 1977, Toronto. American Meteorological Society, Boston, MA.

SCHINDLER, D.W., R.W. NEWBURY, K.G. BEATY, and P. CAMPBELL. 1976. Natural water and chemical budgets for a small Precambrian lake basin in central Canada. J. Fish. Res. Board Can. 33: 2526-2543.

SCHINDLER, D.W., R.W. NEWBURY, K.G. BEATY, J. PROKOPOWICH, T. RUSZCZYNSKI, and J.A. DALTON. 1980. Effects of a windstorm and forest fire on chemical losses from forested watersheds and on the quality of receiving streams. Can. J. Fish. Aquat. Sci. 37: 328-334.

URBAN, N.R., and S.E. BAYLEY. 1986. The acid-base balance of peatlands: a short-term perspective. Water Air Soil Pollut. 30(3-4): 791-800.

VITT, D.H., and S.E. BAYLEY. 1984. The vegetation and water chemistry of oligotrophic basin mires of northwestern Ontario. Can. J. Bot. 62: 1485-1500.

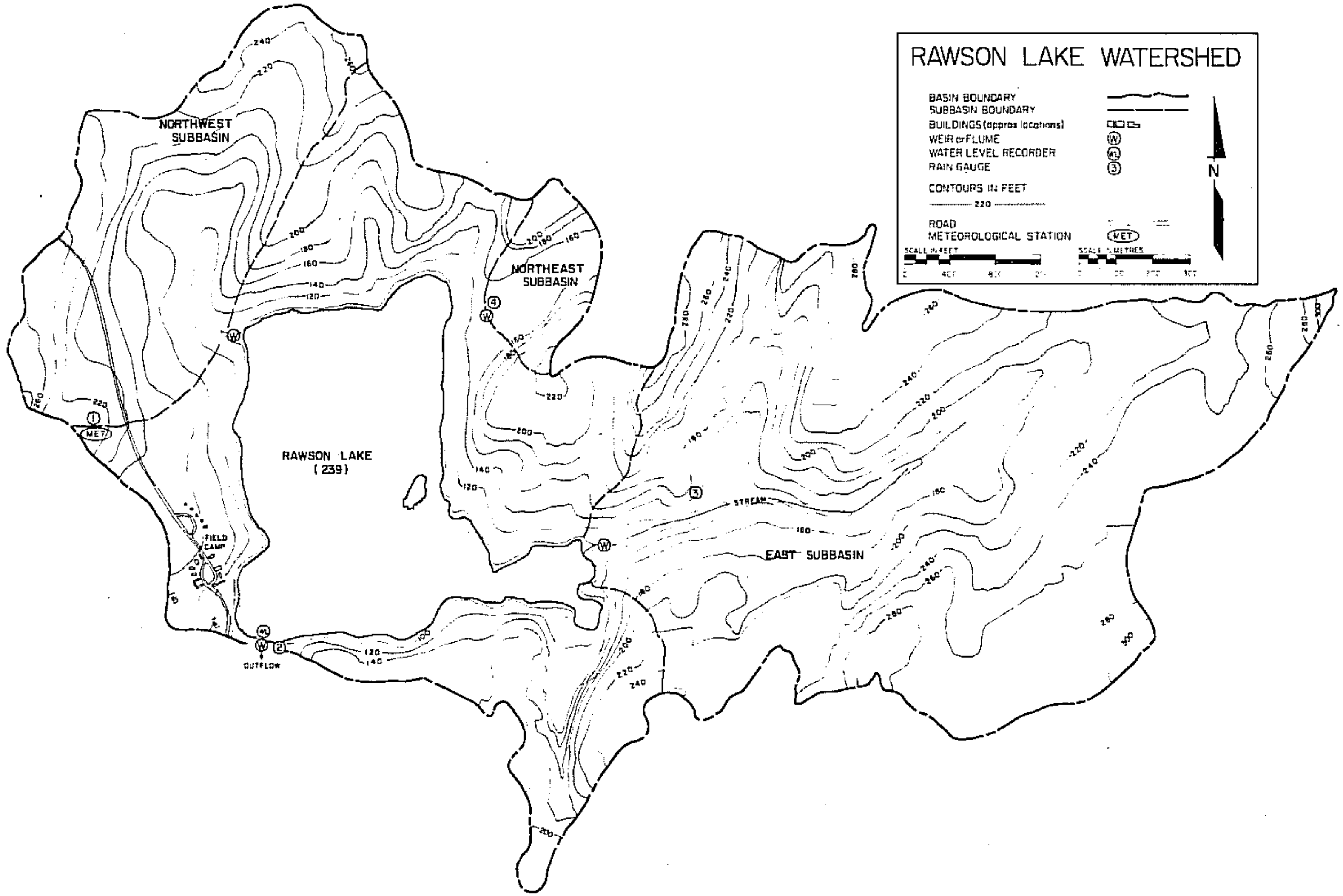

Fig. 1. Topographic map of the Rawson Lake Watershed. Contours are in feet above an assumed datum.

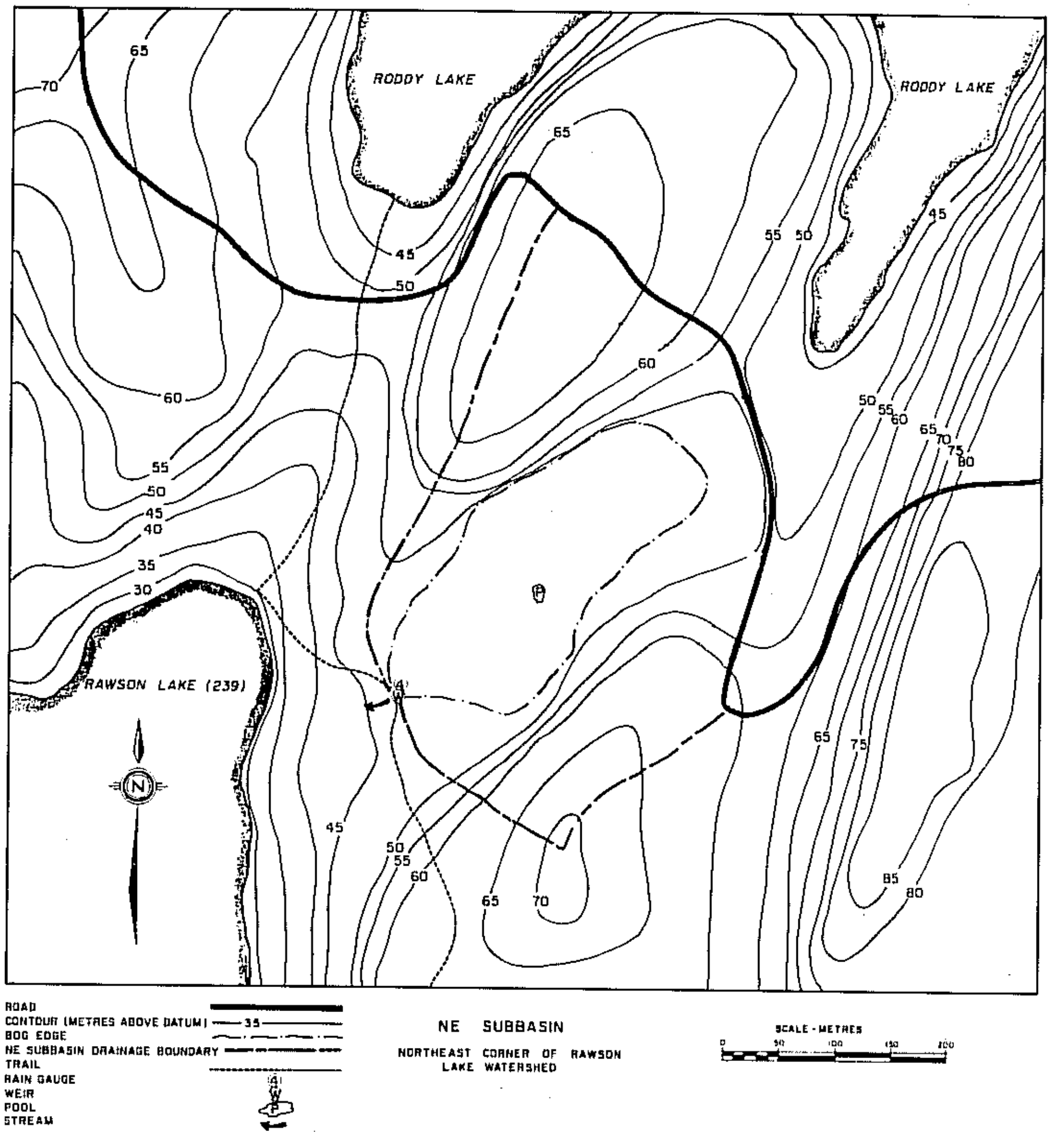

Fig. 2. Topographic map of the NE Subbasin.

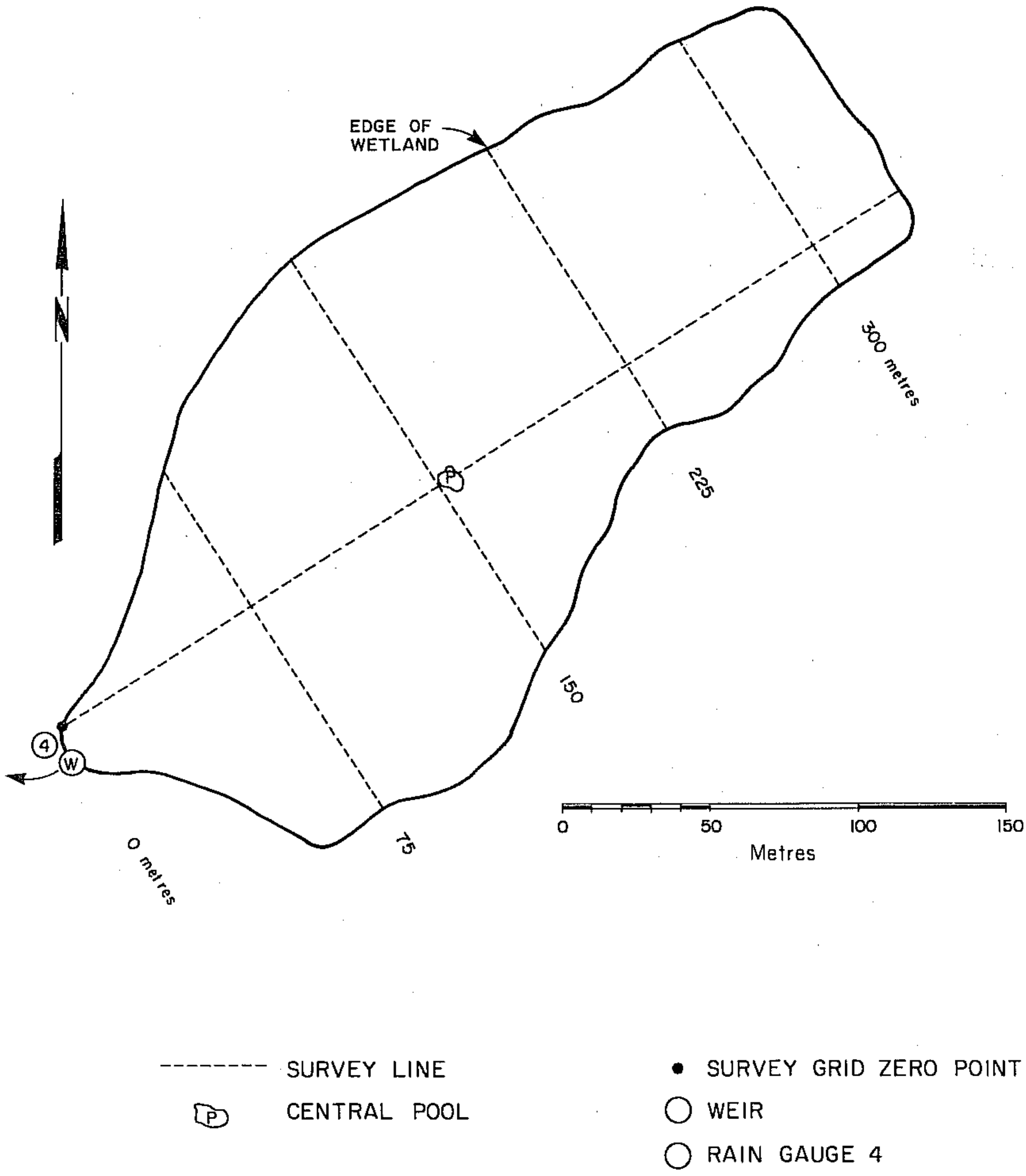

Fig. 3. Base map of the NE wetland showing the survey grid for horizontal control.

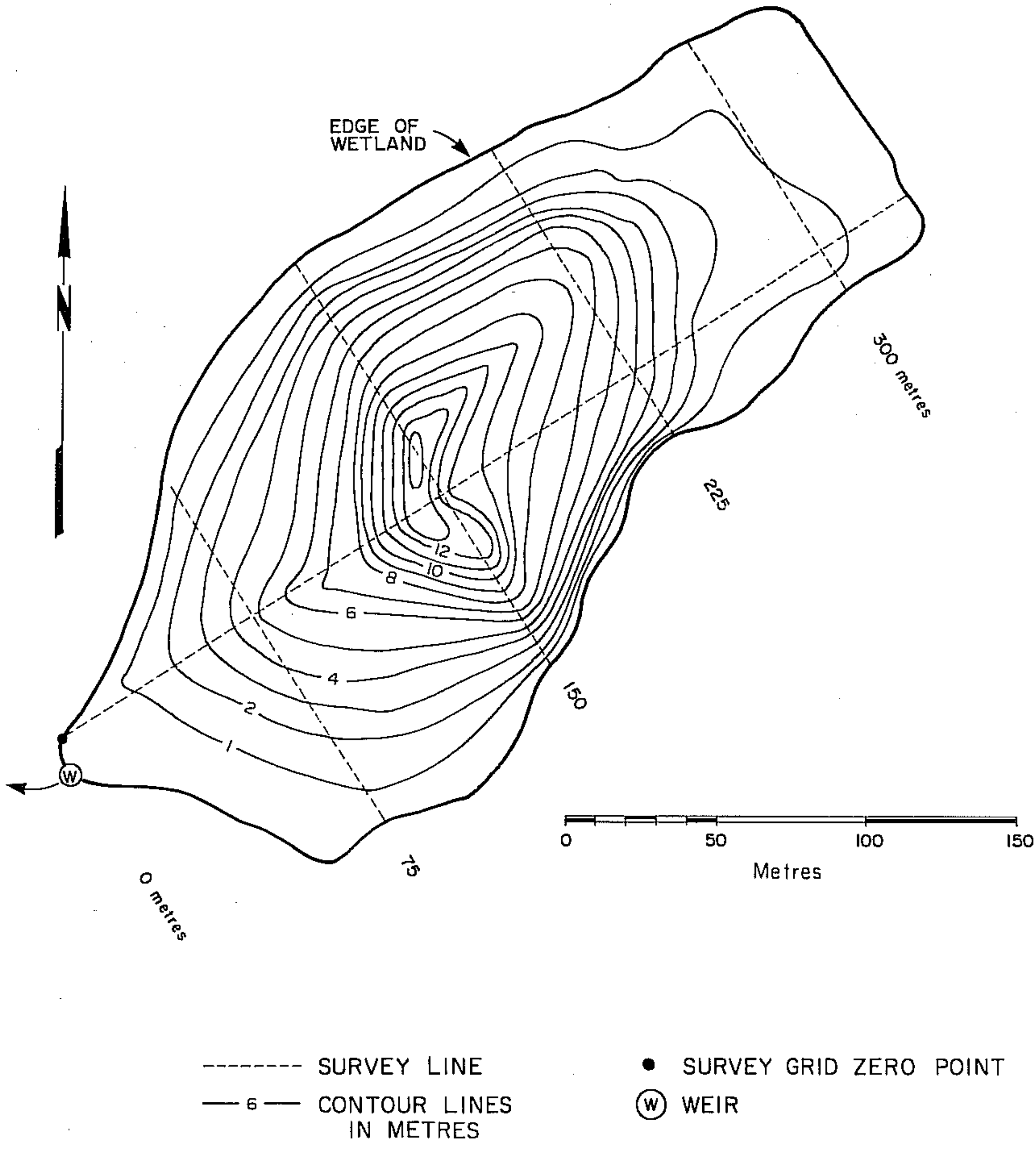

Fig. 4. Contour plan of the wetland bottom. Contours are depths (m) below peat surface.

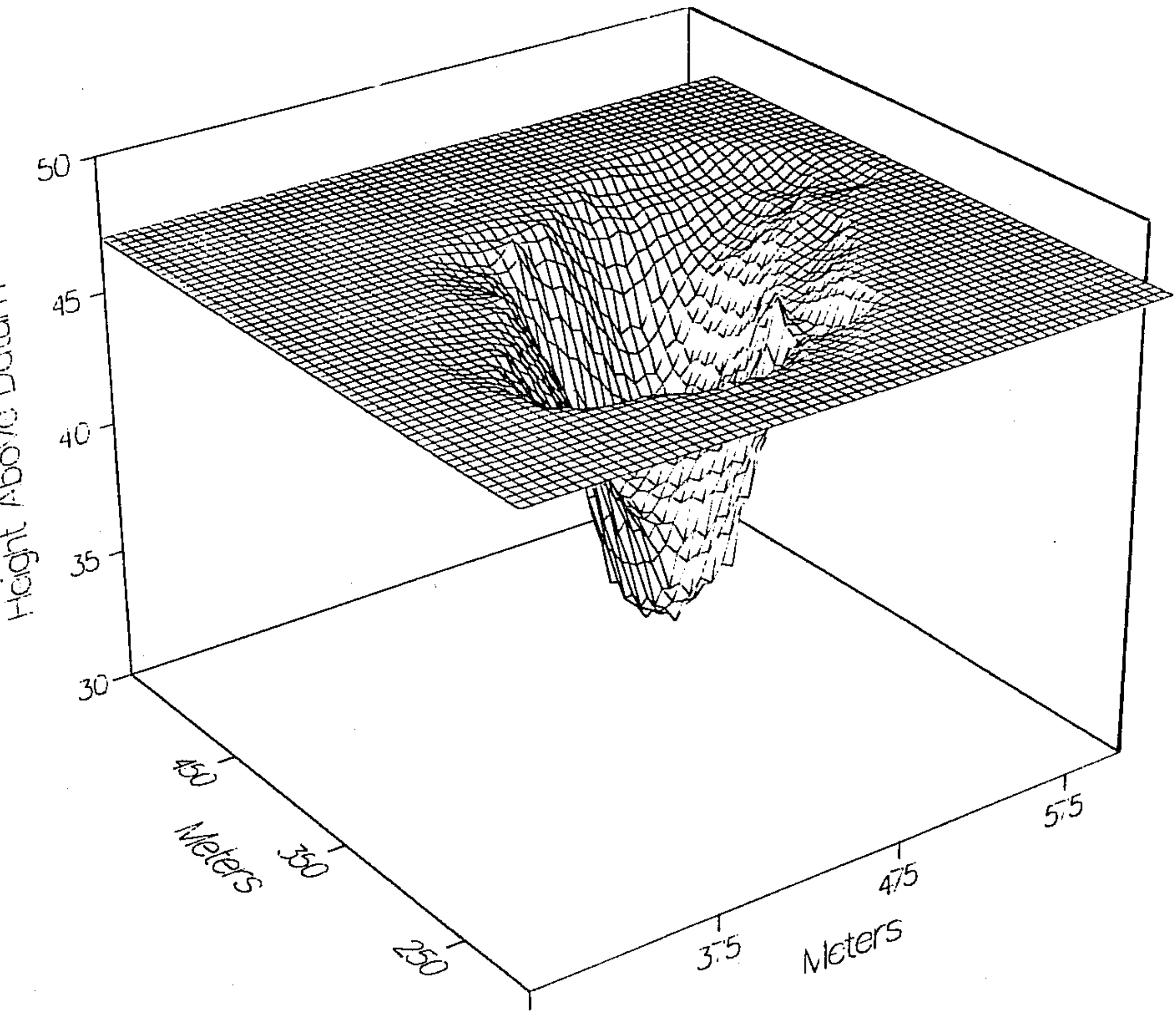

Fig. 5. A three dimensional view of the wetland bottom. Peat thickness is 14 m near the centre.

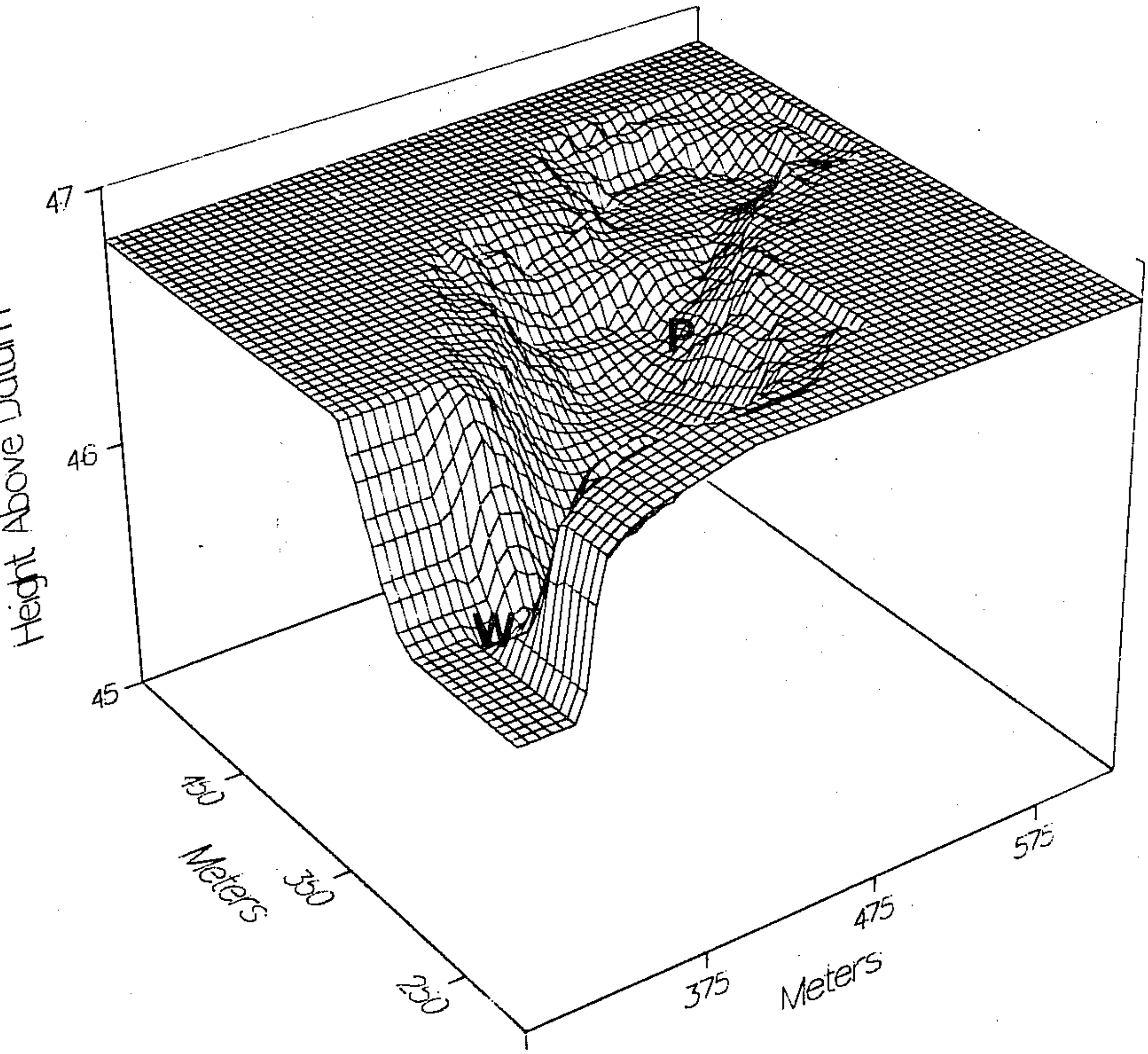

Fig. 6. A three dimensional view of the wetland surface in the NE Subbasin. W and P show approximate locations of the outflow weir and central pool.

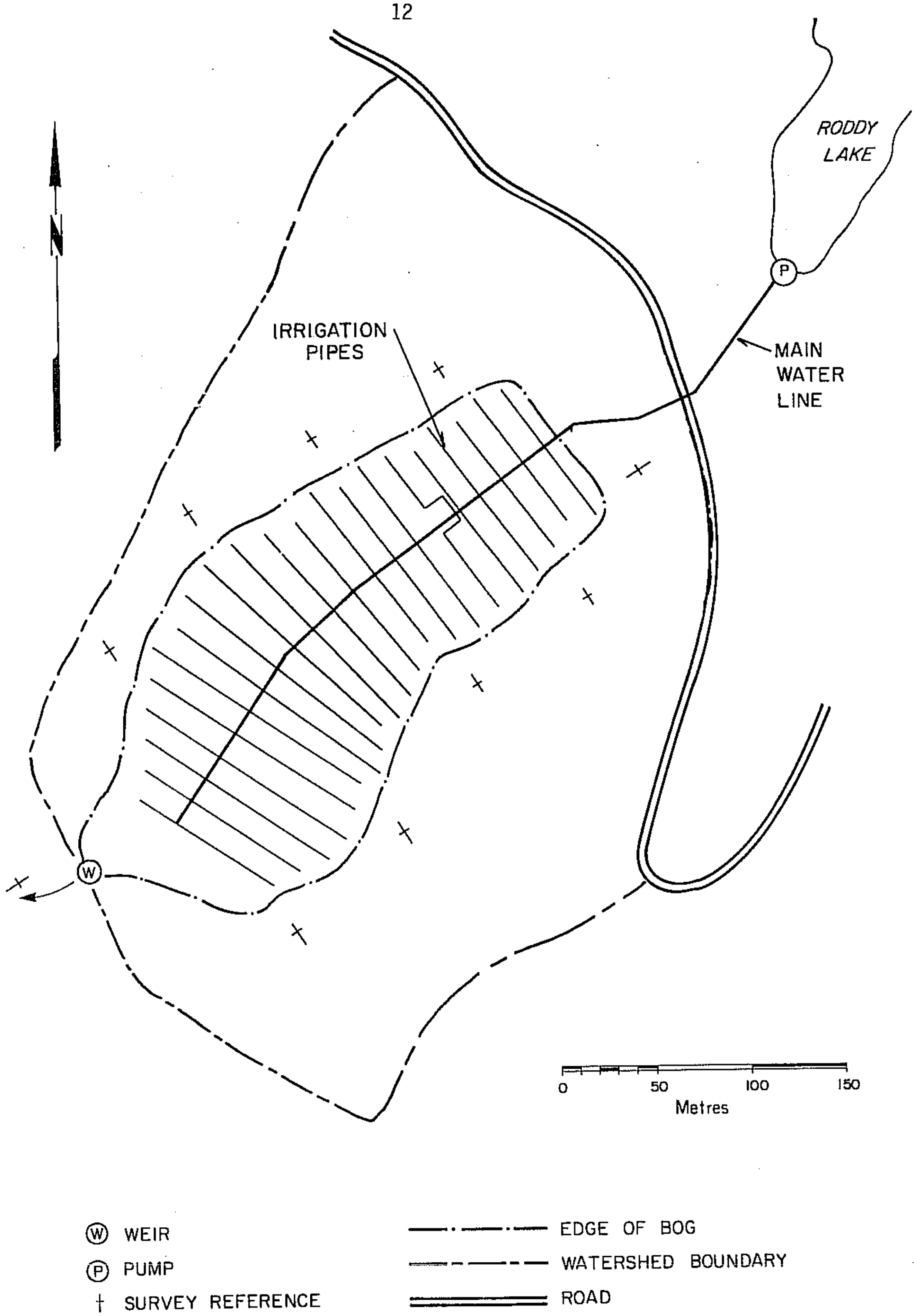

Fig. 7. Plan of irrigation system in the NE Subbasin showing general layout of the pump, main water line and irrigation lateral pipes.

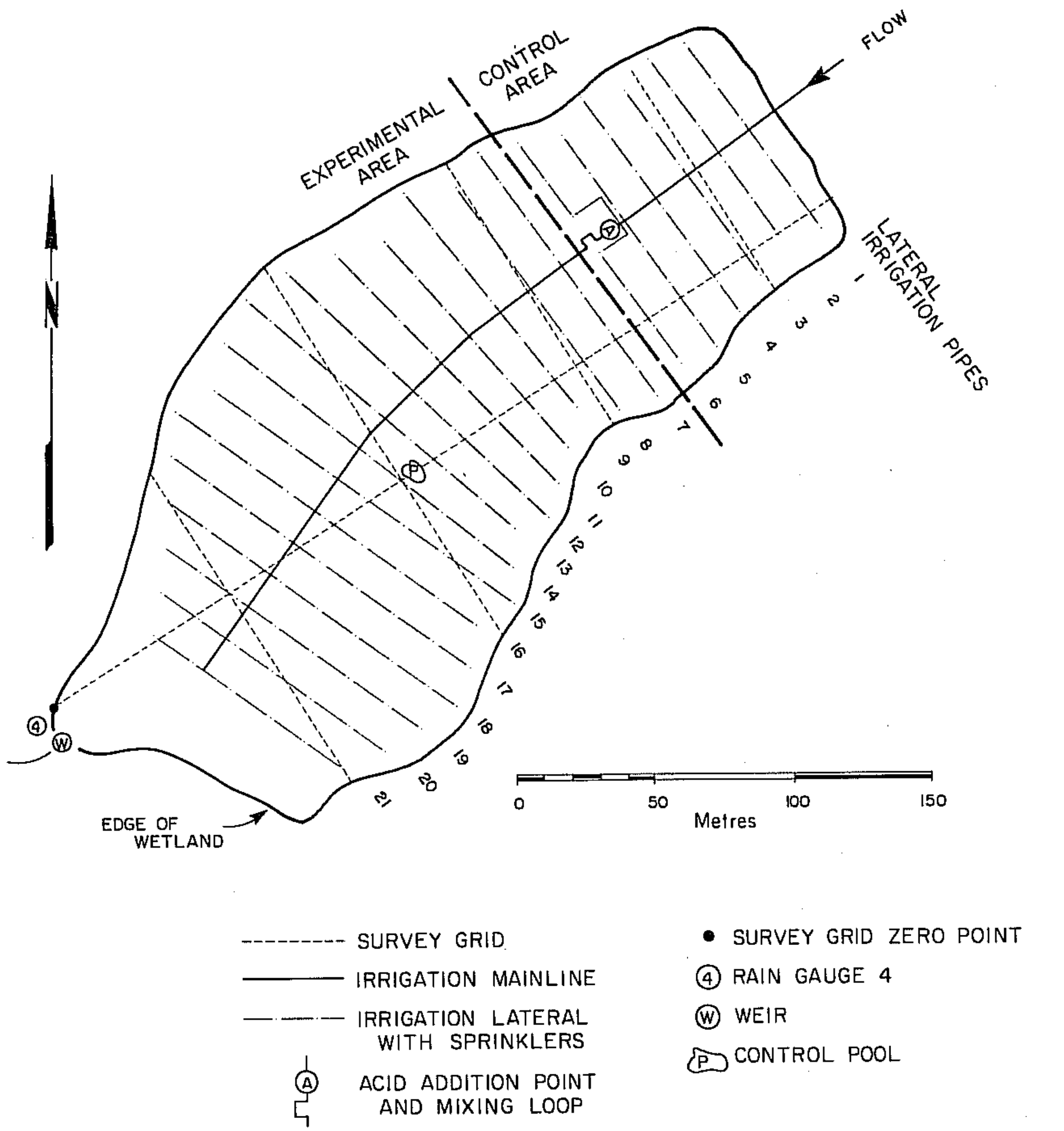

Fig. 8. Plan view of the irrigation system in the NE wetland showing line, sprinkler and acid injection locations as well as the experimental and control areas.

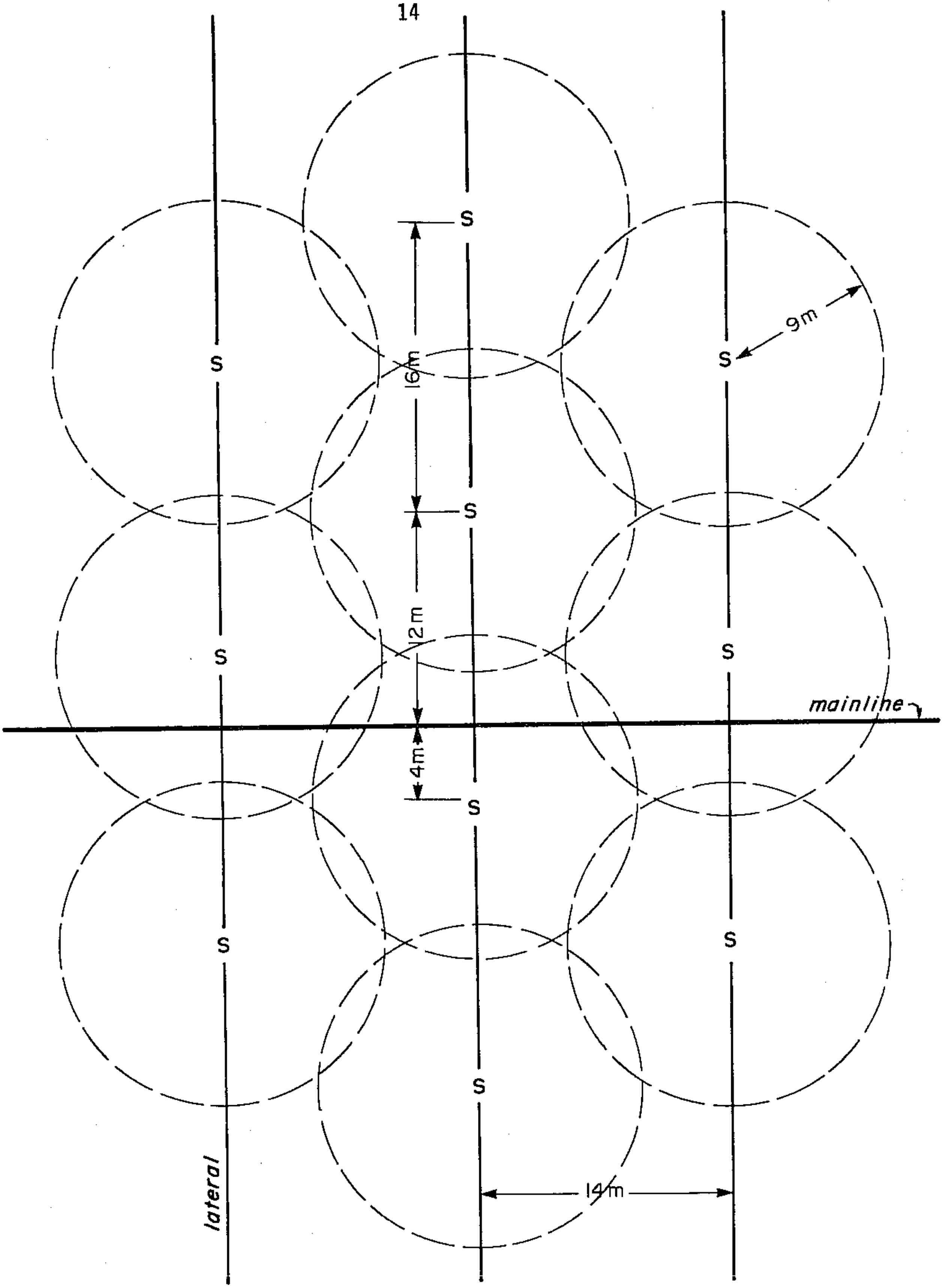

Fig. 9. Sprinkler (s) layout plan and spray coverage with a 9 m radius.

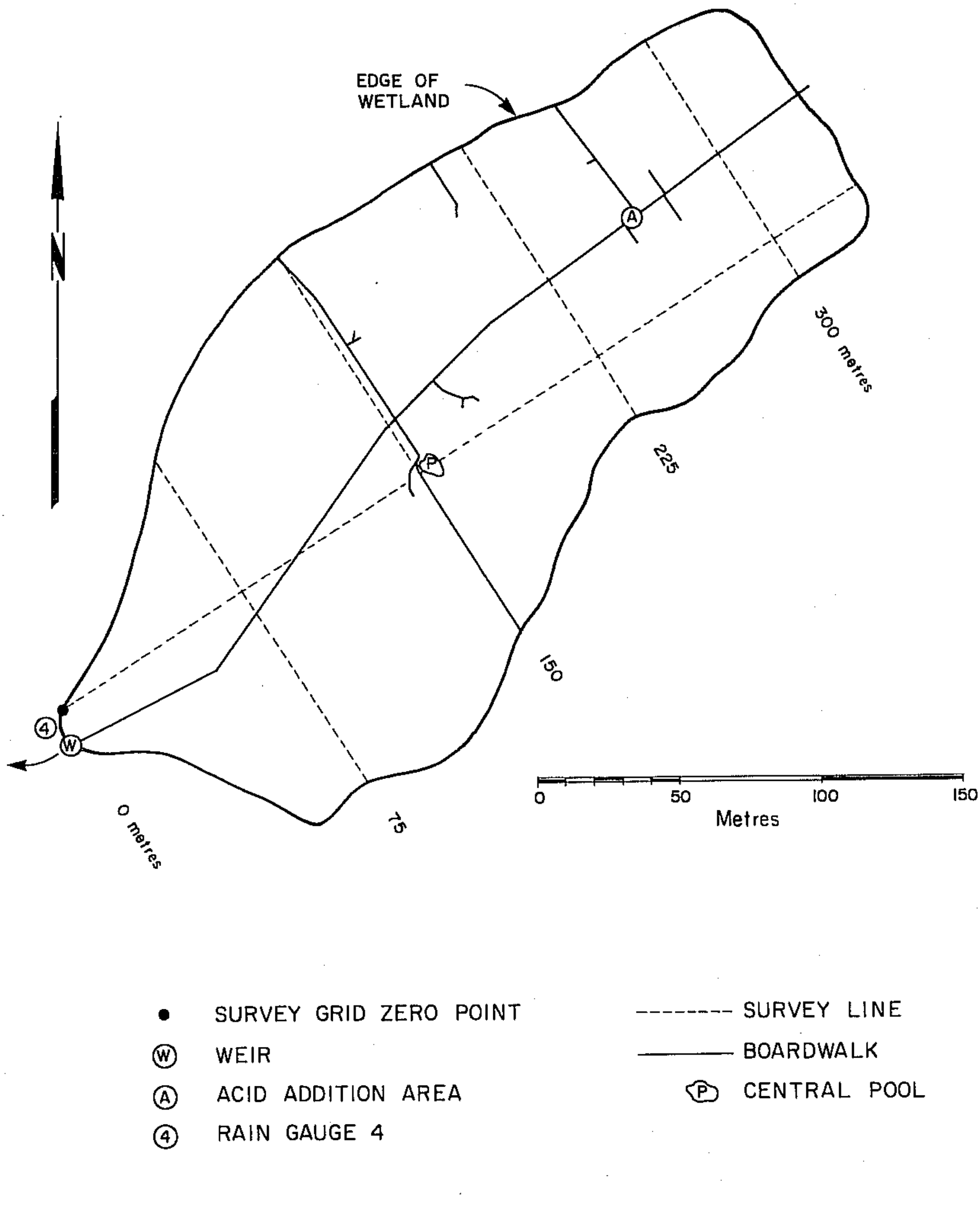

Fig. 10. Location plan of boardwalks in the NE wetland.

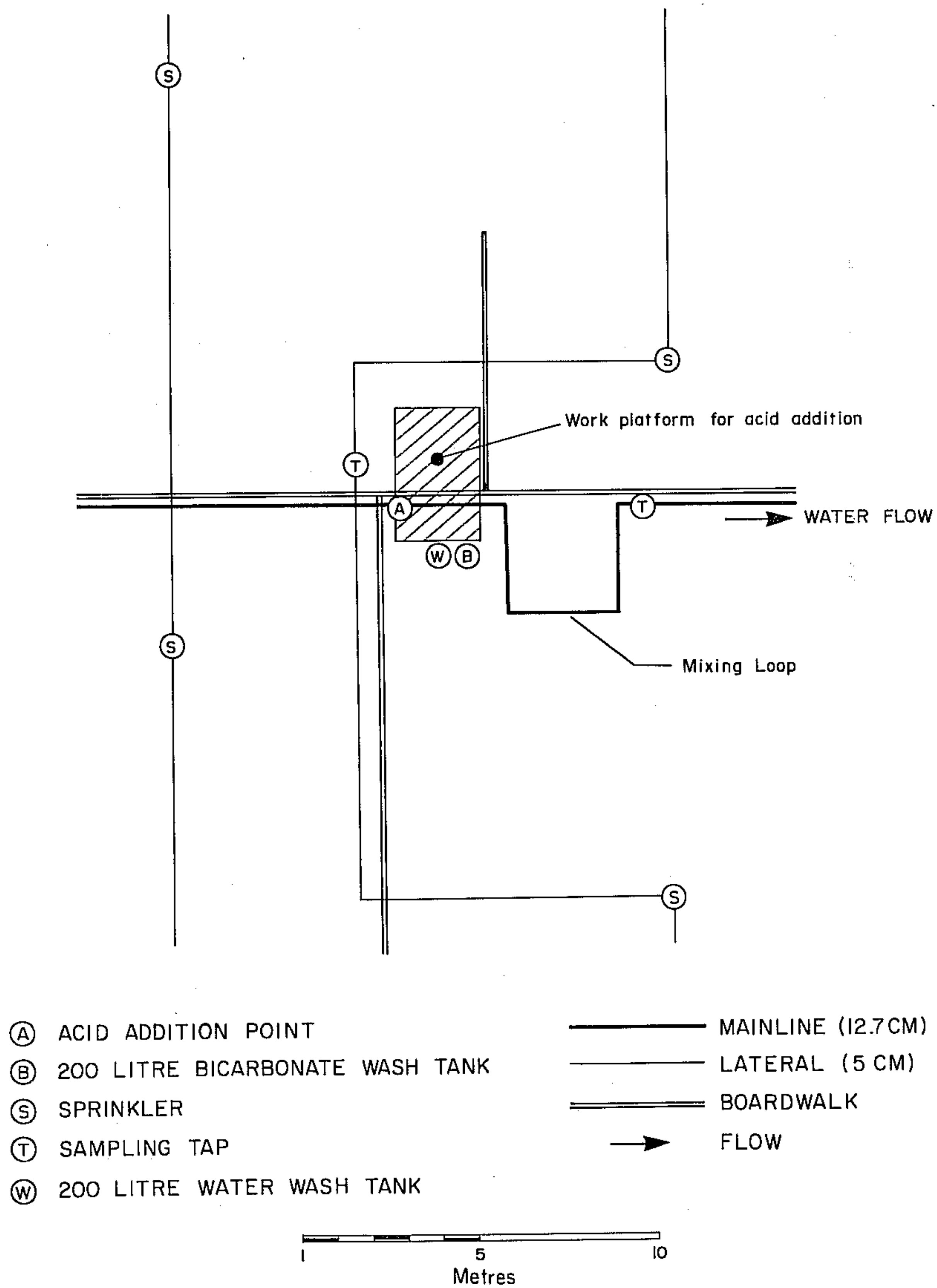

Fig. 11. Detail of acid addition area.

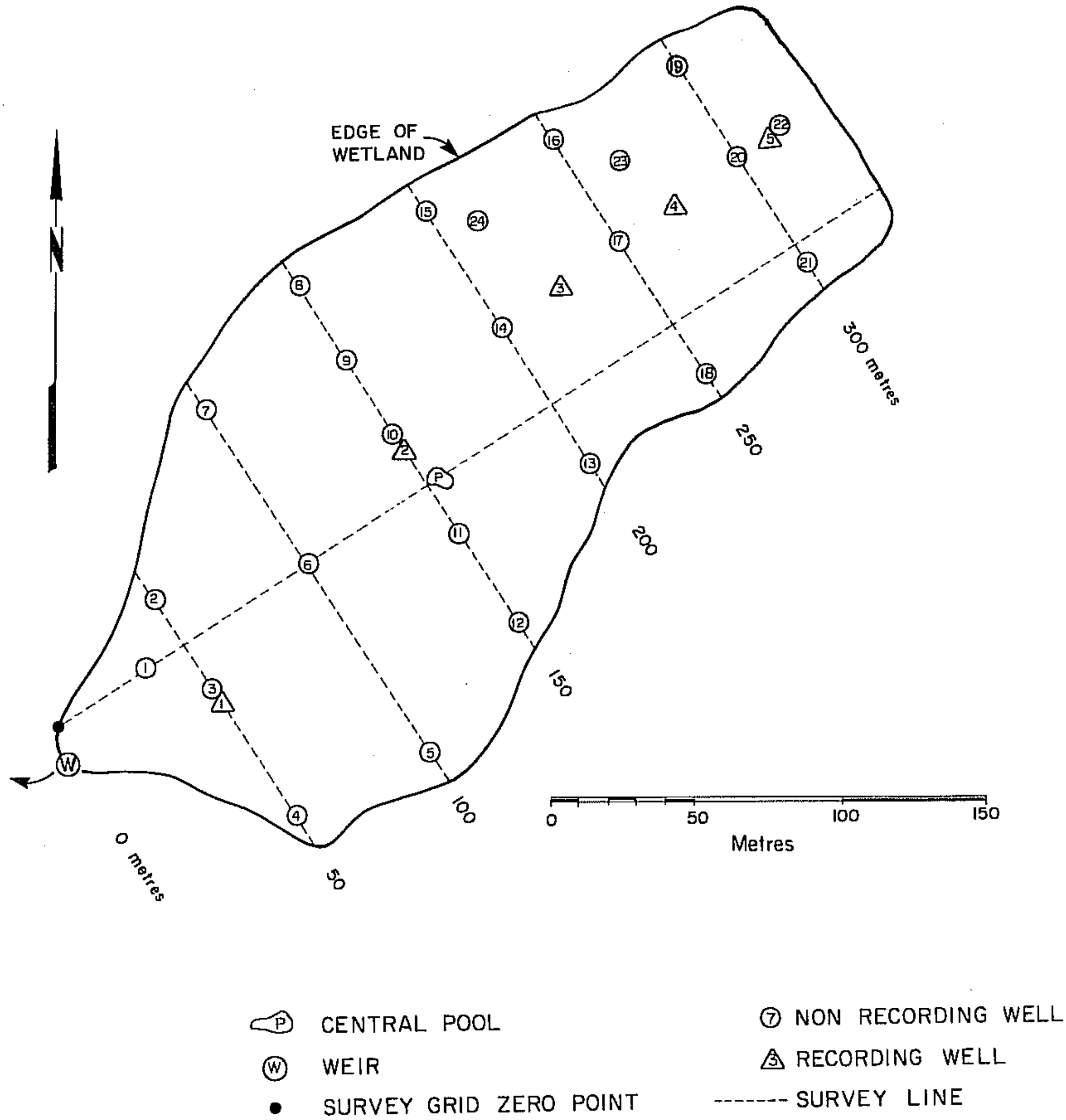

Fig. 12. Location plan of water table wells in the NE wetland.

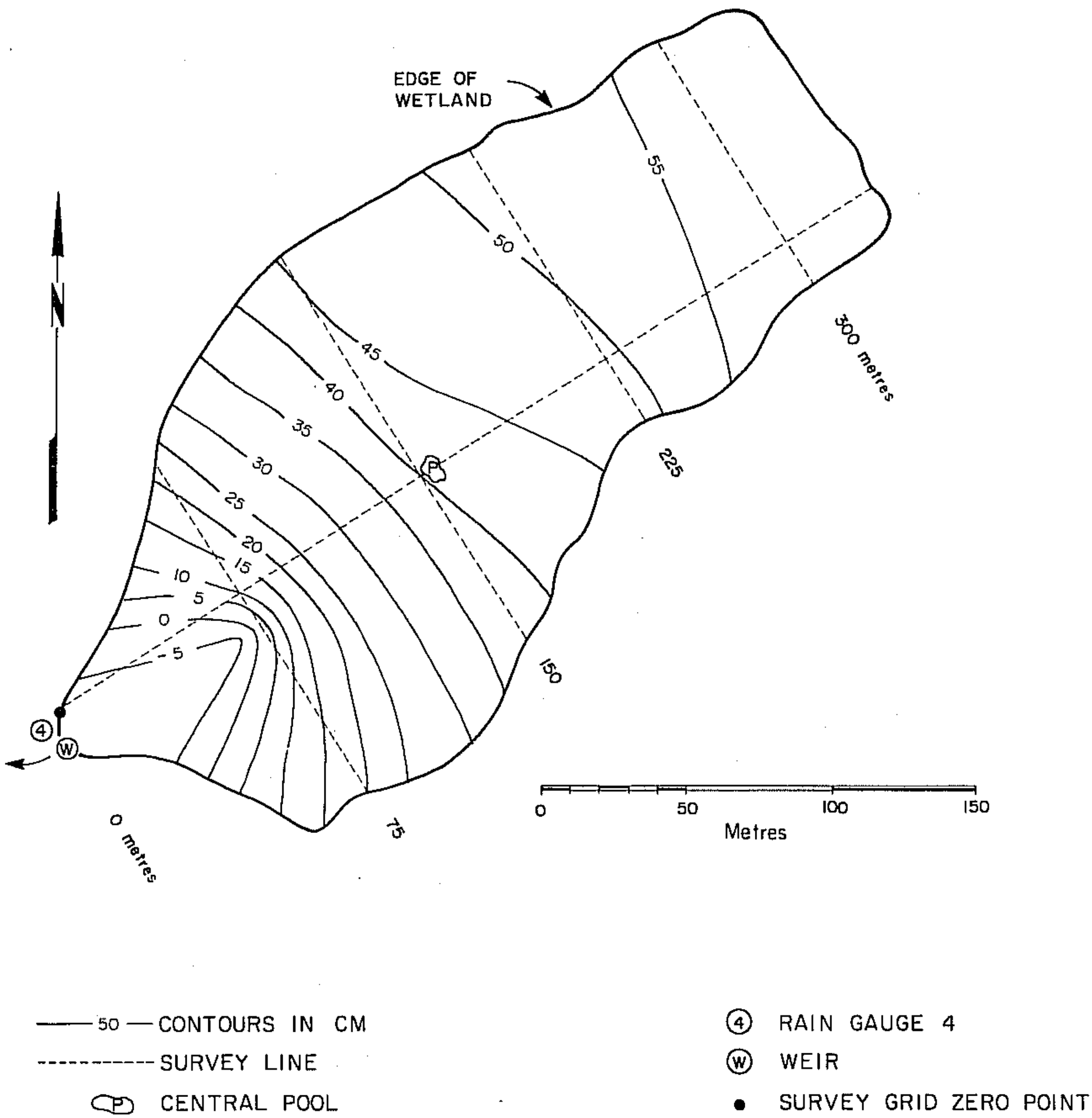

Fig. 13. Typical water table contour plan. Contours were determined from water table records collected on June 5, 1984 at 13:00 cst. The reference datum is +46.0 m.

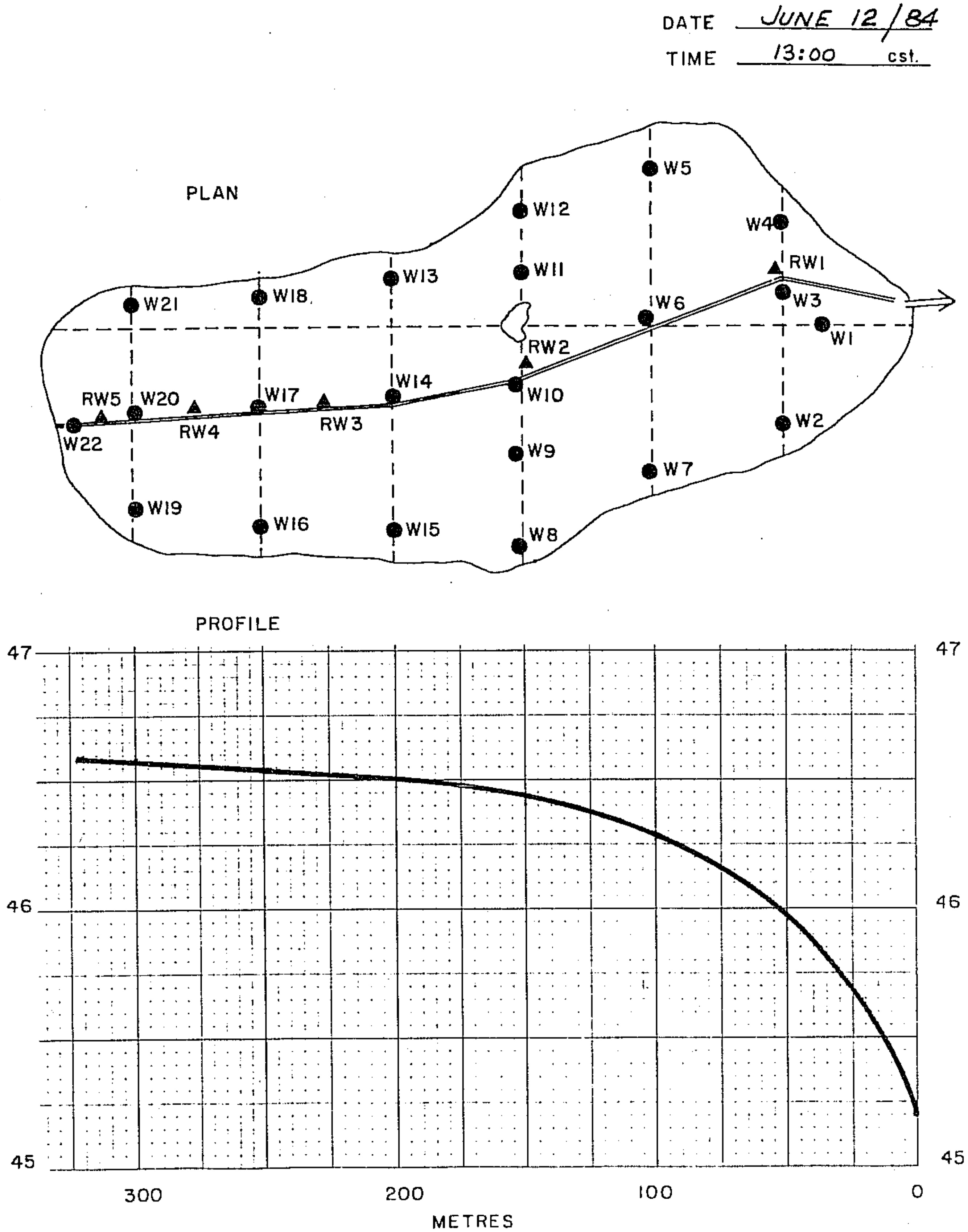

Fig. 14. Plan-profile diagram of the NE wetland showing water table well locations (plan view) and water table (profile view) on June 12, 1984 for the central wells W3, W6, W10, W14, W17, W20, W22 and the outflow weir.

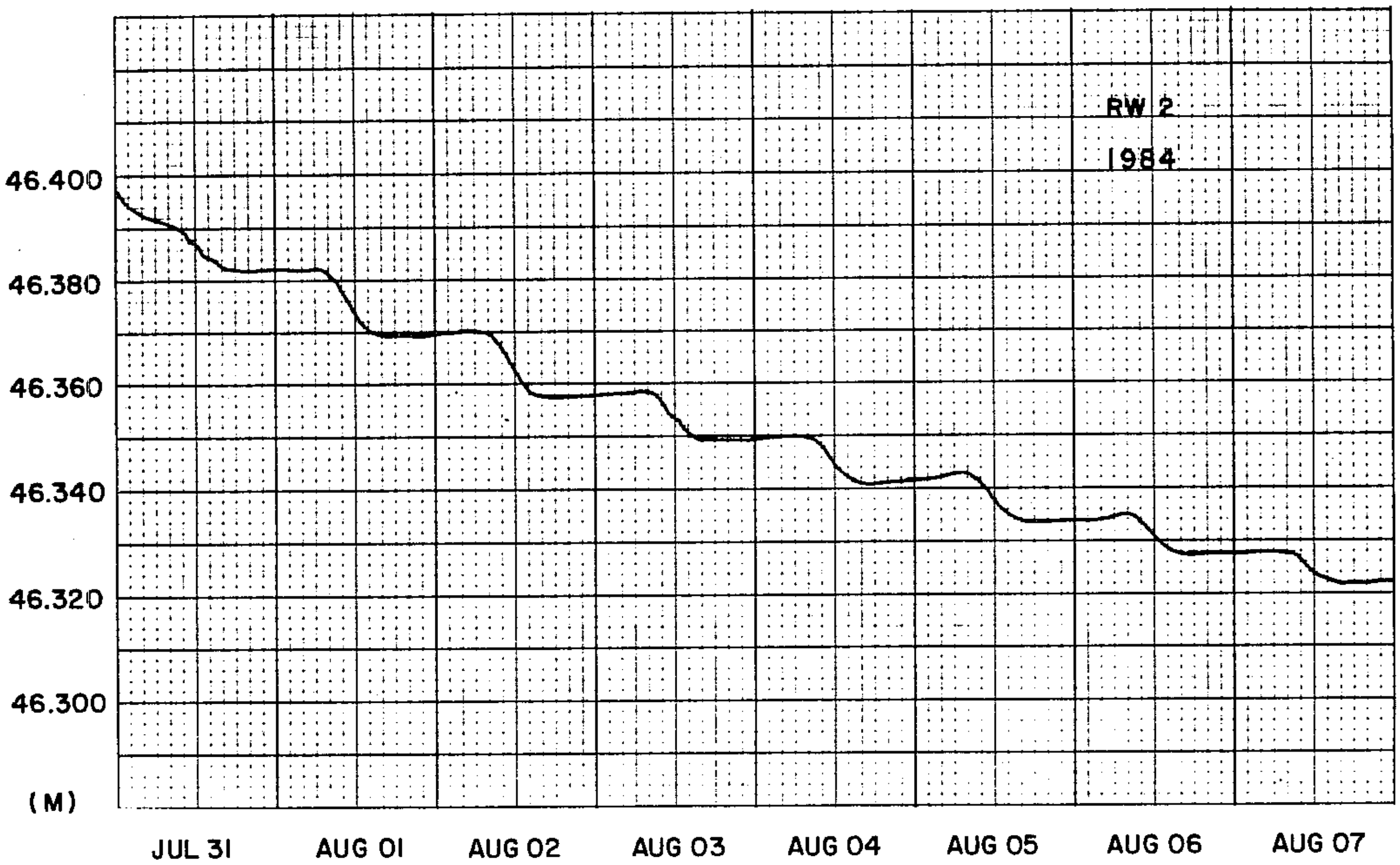

Fig. 15. Water table recession at RW2, near the wetland centre, during an eight day period with no rainfall. Diurnal response is prominent with records showing a slight evening recharge and midday loss due to evapotranspiration. Water levels are in metres.

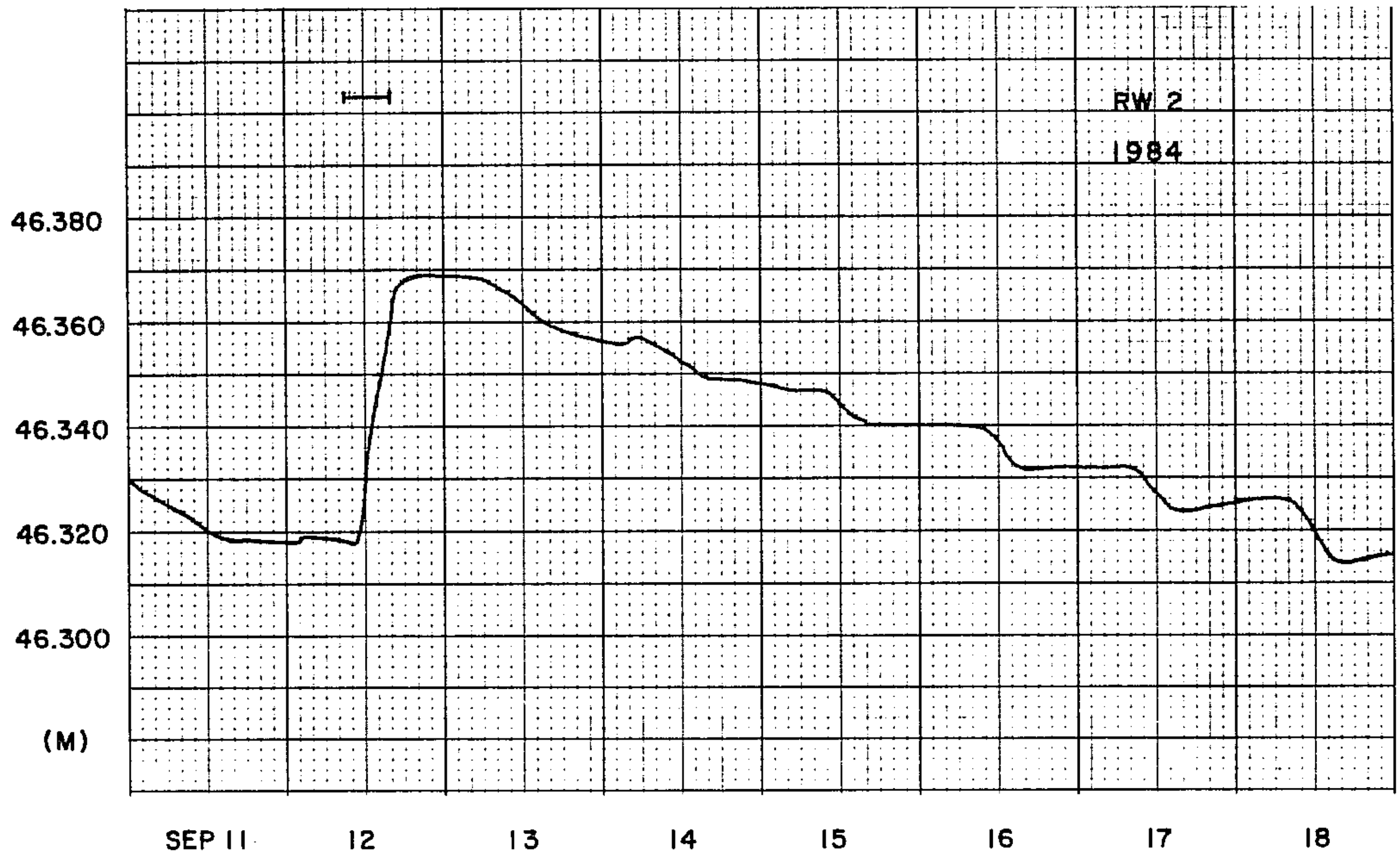

Fig. 16. Water table response, at RW2, from 14.9 mm of irrigated water and 4.0 mm of natural rainfall on September 12, 1984. Water levels are in metres. ├──┤ period of irrigation.

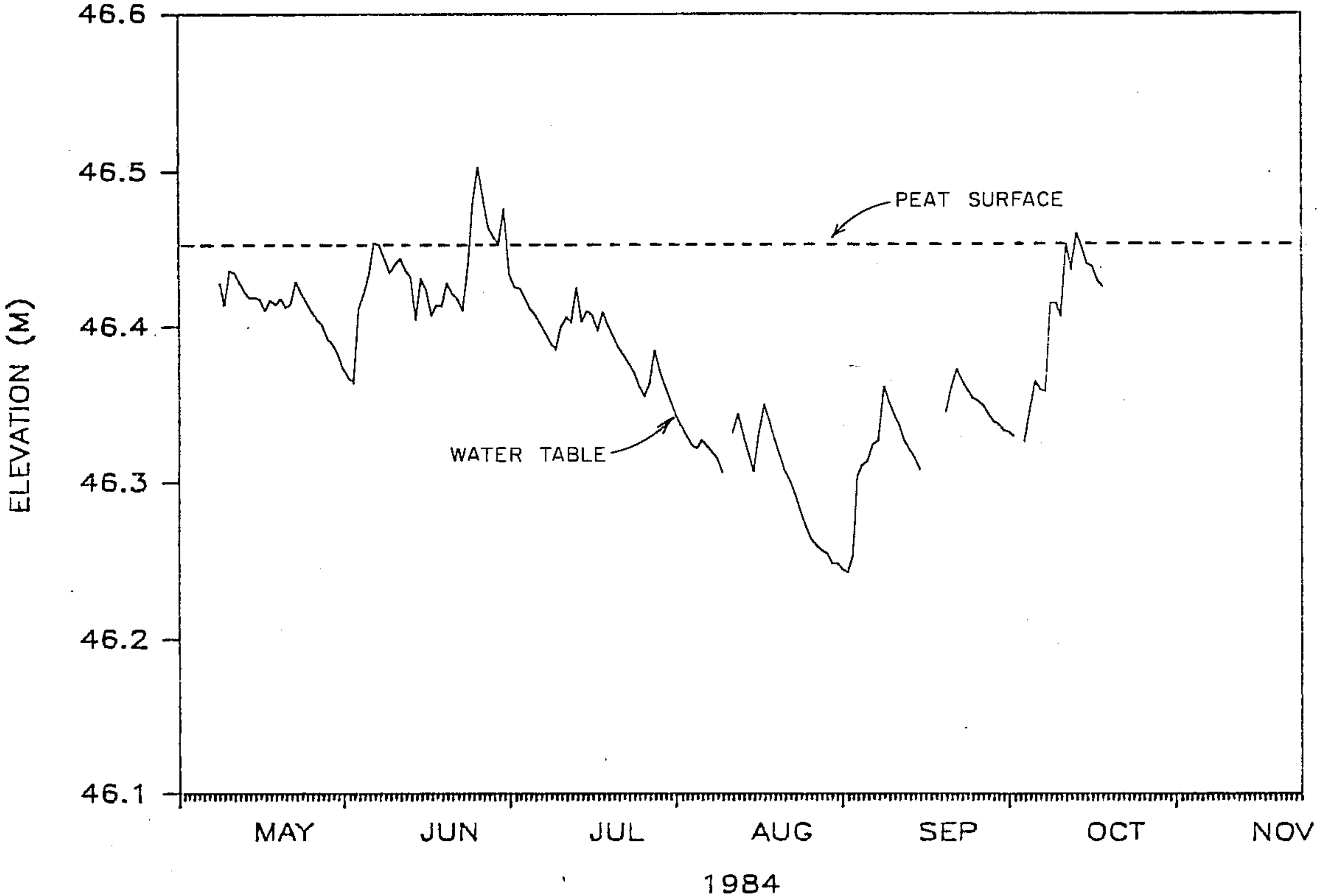

Fig. 17. Hydrograph of water table response at recording well 2 for the 1984 season.

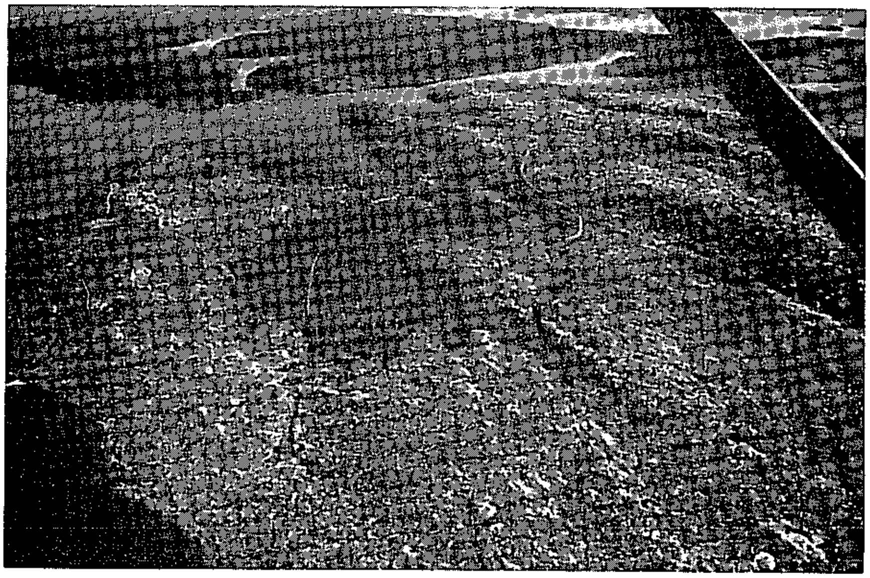

Photo 1. Oblique aerial view of the NE Subbasin with Rawson Lake in the bottom left.

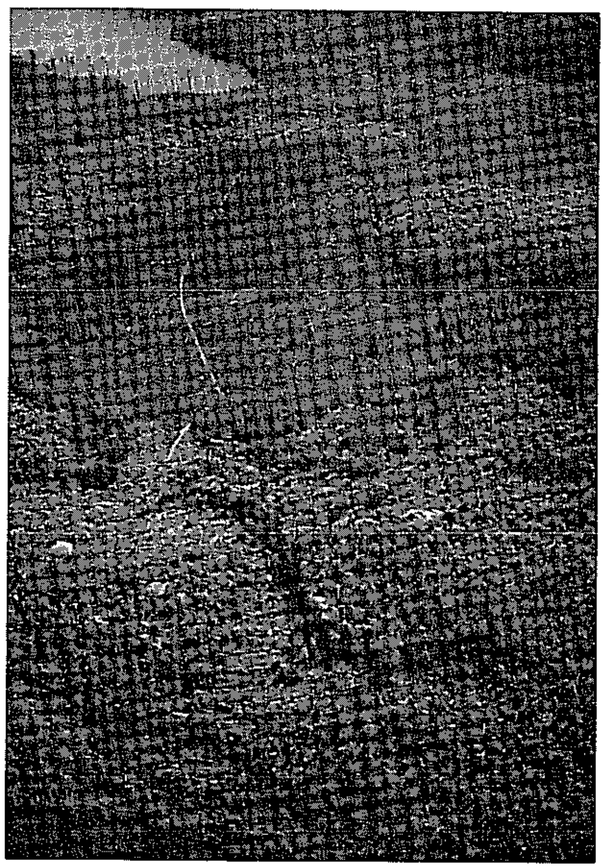

Photo 2. Aerial view of the wetland with Roddy Lake in the top left. The main boardwalk is visible.

Photo 3. Power take-off (PTO) pump used in 1983 to irrigate the NE wetland. Power was supplied by a large diesel tractor.

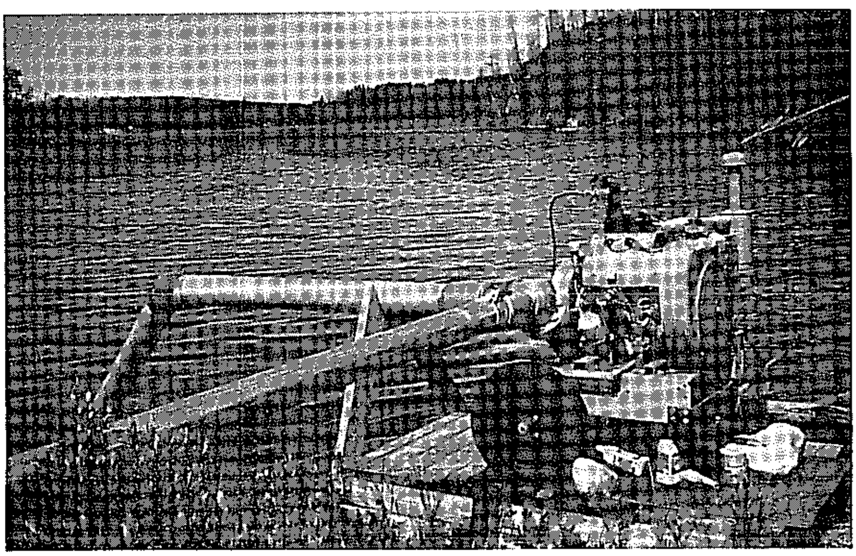

Photo 4. Gasoline engine powered pump used in 1984 and 1985 to irrigate the NE wetland. This pump replaced the PTO pump shown above.

Photo 5. One of the 160 plastic sprinklers used to irrigate the NE wetland.

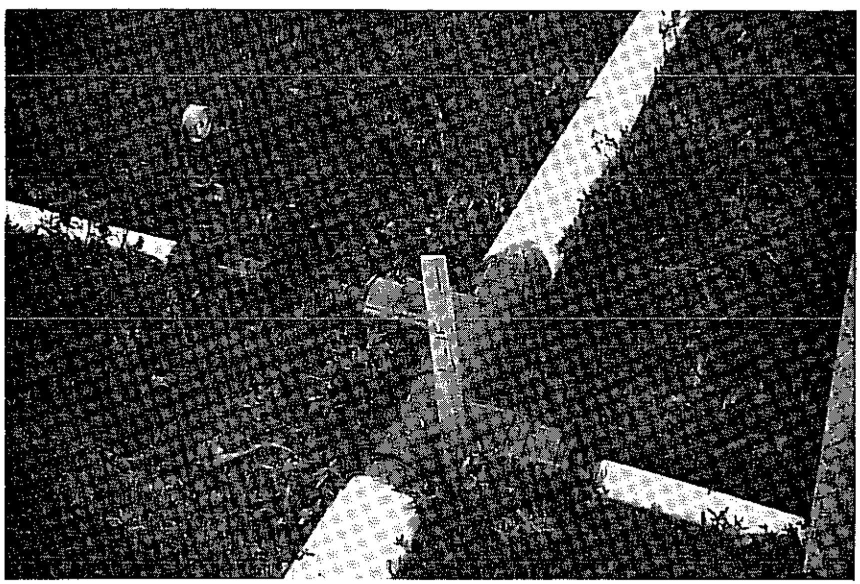

Photo 6. Close up of the intersection of one of 21, 5 cm diameter lateral lines and the 12.7 cm diameter mainline. On each lateral side (42), flows were controlled with a valve and line pressures were observed on a pressure gauge.

Photo 7. Pressure gauge located near the pump, on the discharge side, used to verify that inline pressures were normal.

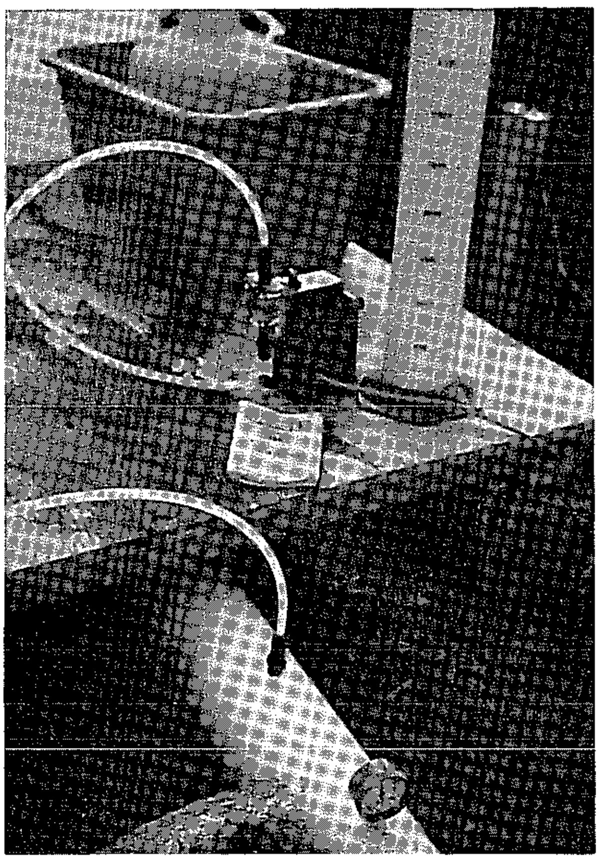

Photo 8. Acid was pumped with a variable rate chemical metering pump through a one way check valve. A pressure gauge on the mainline verified that pressures in the system were normal.

Photo 9. The hydrant used to control the rate of water delivery and pressure to the sprinkler system.

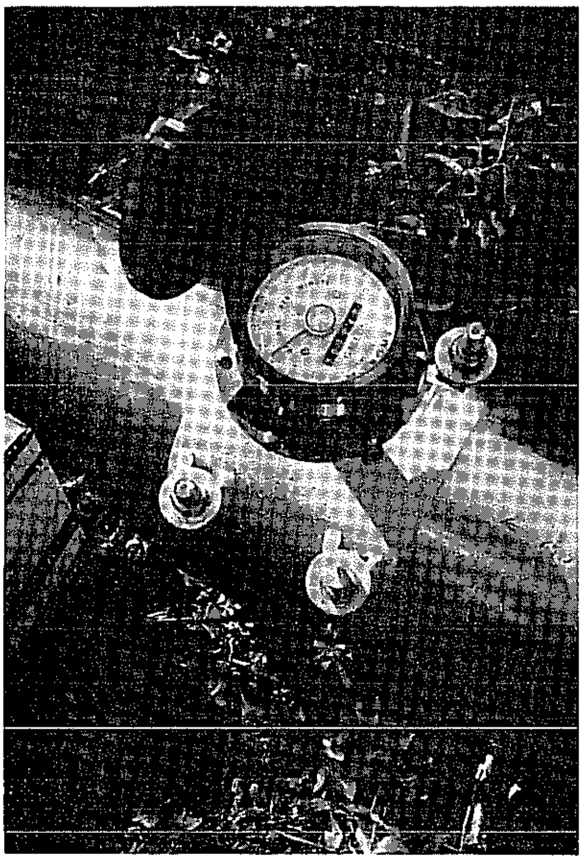

Photo 10. Inline flow meter located near the pump, on the discharge side, used to meter total volume of water pumped and display actual pumping rate.

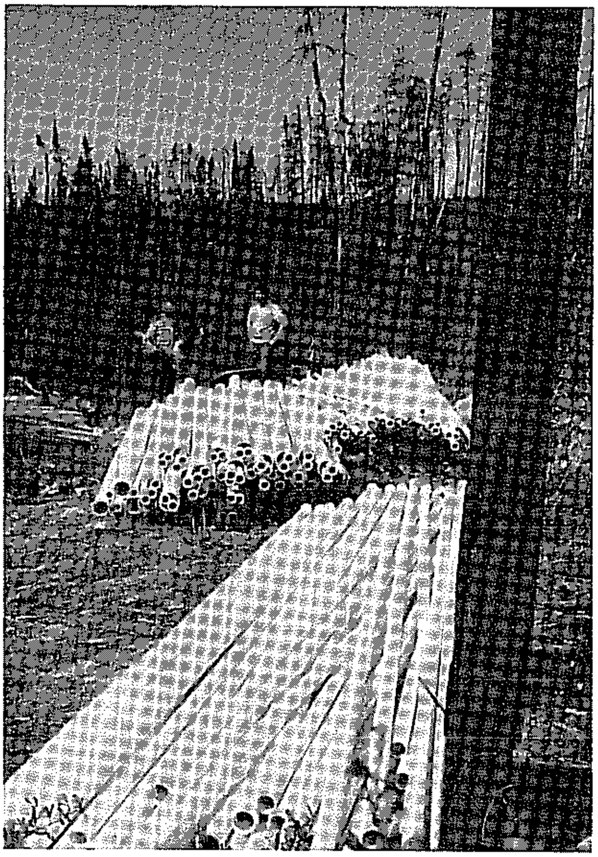

Photo 11. Plastic water pipe before installation. All materials had to be carefully carried into the wetland using a network of boardwalks.

Photo 12. Central area of the wetland showing the boardwalk, a recording groundwater well (RW2) and the area around the central pool.

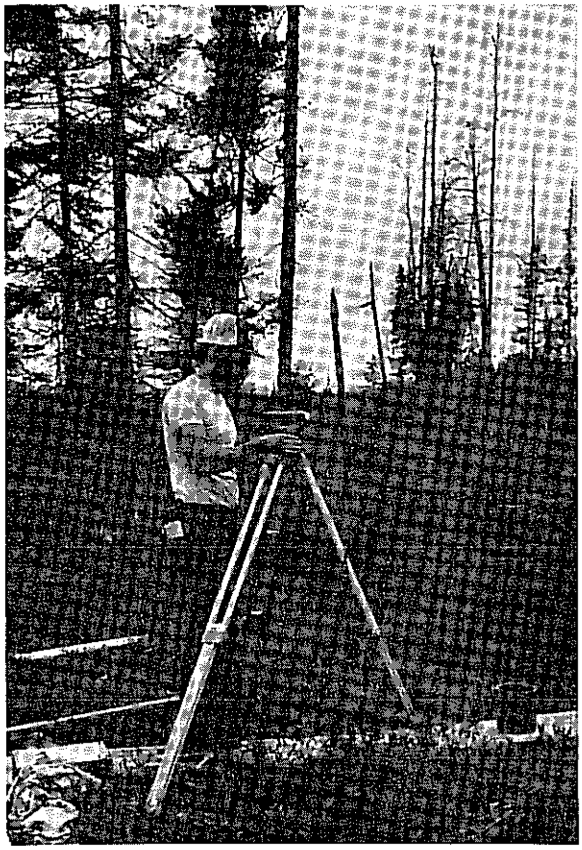

Photo 13. Wooden boardwalks throughout the wetland allowed for level surveys, using an engineers level.

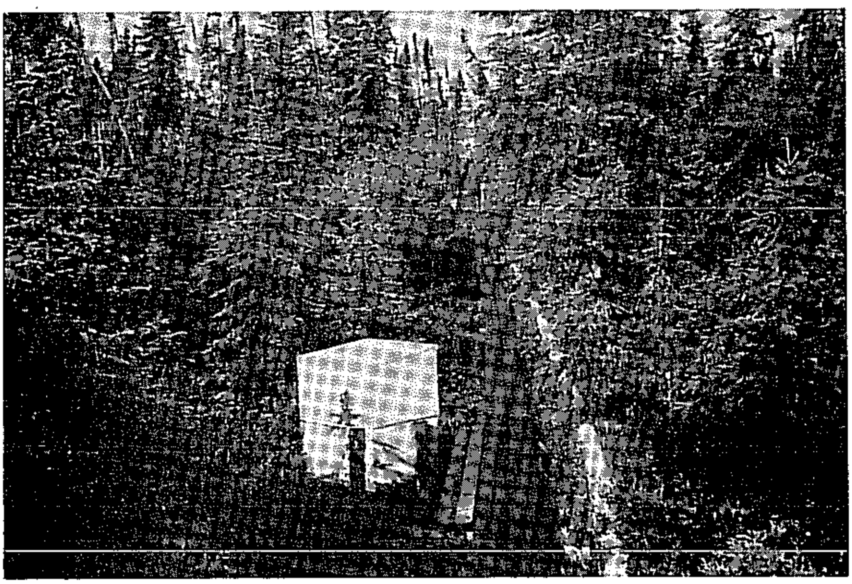

Photo 14. Main boardwalk, irrigation mainline and recording groundwater well shelter in the upper control portion of the wetland.

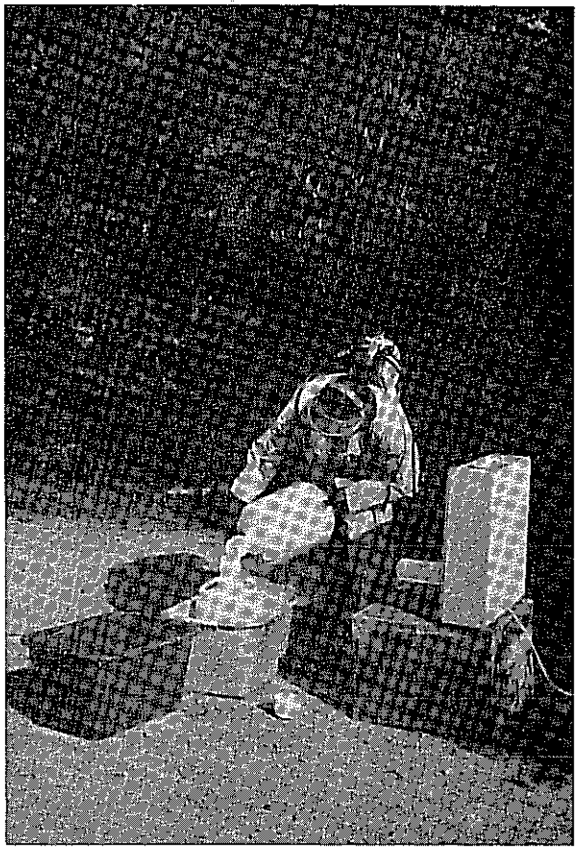

Photo 15. Sulphuric and nitric acids were mixed outdoors while wearing an acid resistant suit, gloves and face shield. An electric fan directed toxic fumes away from the individual pouring the acid.

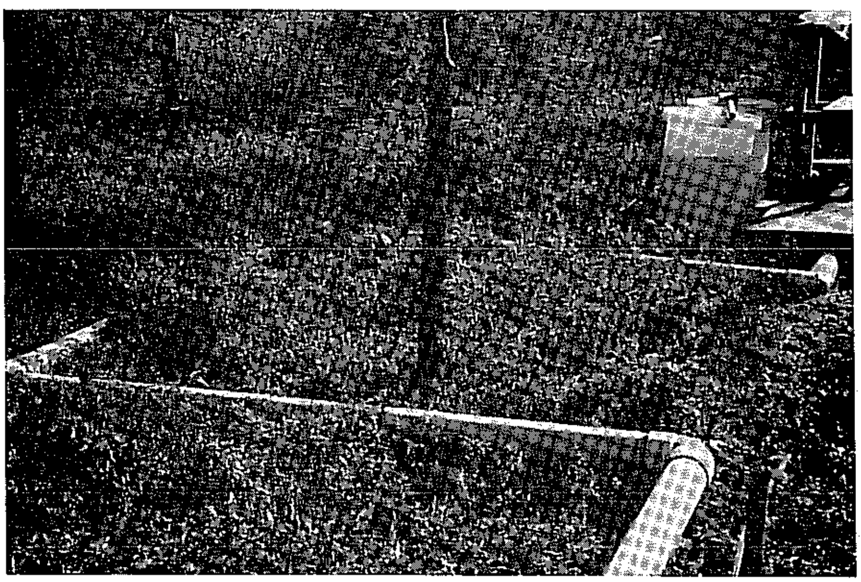

Photo 16. A mixing loop was located after the injection point. The design of this loop was also intended as an expansion joint. A sampling tap in the foreground allowed for pH samples to be taken after mixing.

Photo 17. Acid was added at the mixing platform located between laterals 5 and 6. The two large tanks contained water and bicarbonate solution for washing and neutralizing as well as safety in the event of an accident.

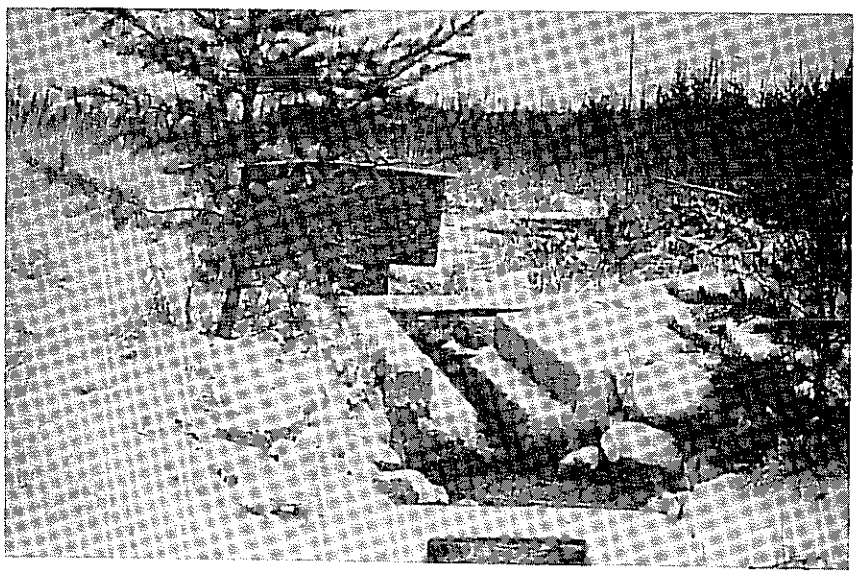

Photo 18. Outflow from the NE Subbasin was monitored through a small concrete flume from July, 1979 to July 1985.

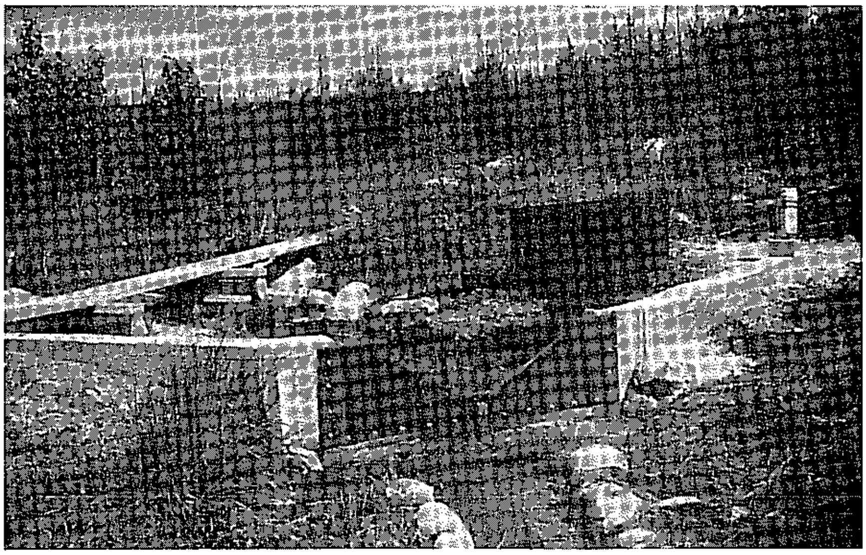

Photo 19. A 120° V-notch concrete weir was constructed in July 1985 to replace the flume in photograph 20.

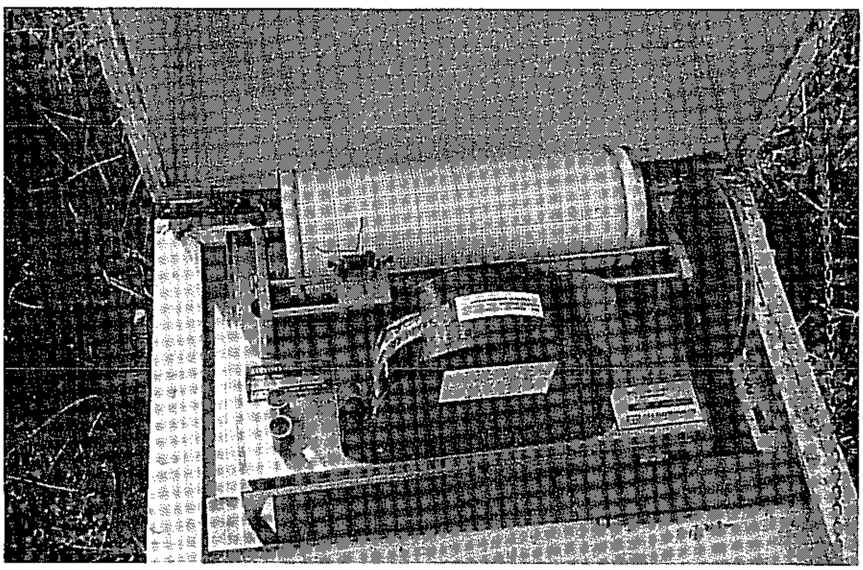

Photo 20. Groundwater recorder showing water table rise during an irrigation event.