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Report T-615

Specific Conductance and Ionic Characteristics of the Shark River Slough, Everglades National Park, Florida

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SPECIFIC CONDUCTANCE AND IONIC CHARACTERISTICS OF THE SHARK RIVER SLOUGH, EVERGLADES NATIONAL PARK, FLORIDA

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INTRODUCTION

The Shark Slough region of Everglades National Park is the largest freshwater flow system in south Florida. It serves as an area of water storage and recharge for the Biscayne Aquifer, provides critical habitat for a diverse assemblage of marsh dwelling fauna and flora and acts as a major source of fresh water to the estuarine areas of Everglades National Park. Water management requires a documentation of historical and present water quality and an understanding of the factors which influence changes in water quality.

The purpose of this study is to analyze the relationship between specific conductance and ionic composition for long-term water quality monitoring stations in Shark Slough (Figure 1) and to evaluate the usage of specific conductance as a tool to document water quality changes in Everglades National Park.

This report contains the following four sections:

I. Specific conductance/total major cation relationships.

II. Ionic character of Shark Slough source water.

III. Specific conductance and ionic character of waters in Shark Slough and Northeast Shark Slough including Tamiami Canal at S-12 structures, Bridge 53, Northeast Shark Slough, central Shark Slough and the edges of Shark Slough.

IV. Shark Slough biweekly specific conductance monitoring program.

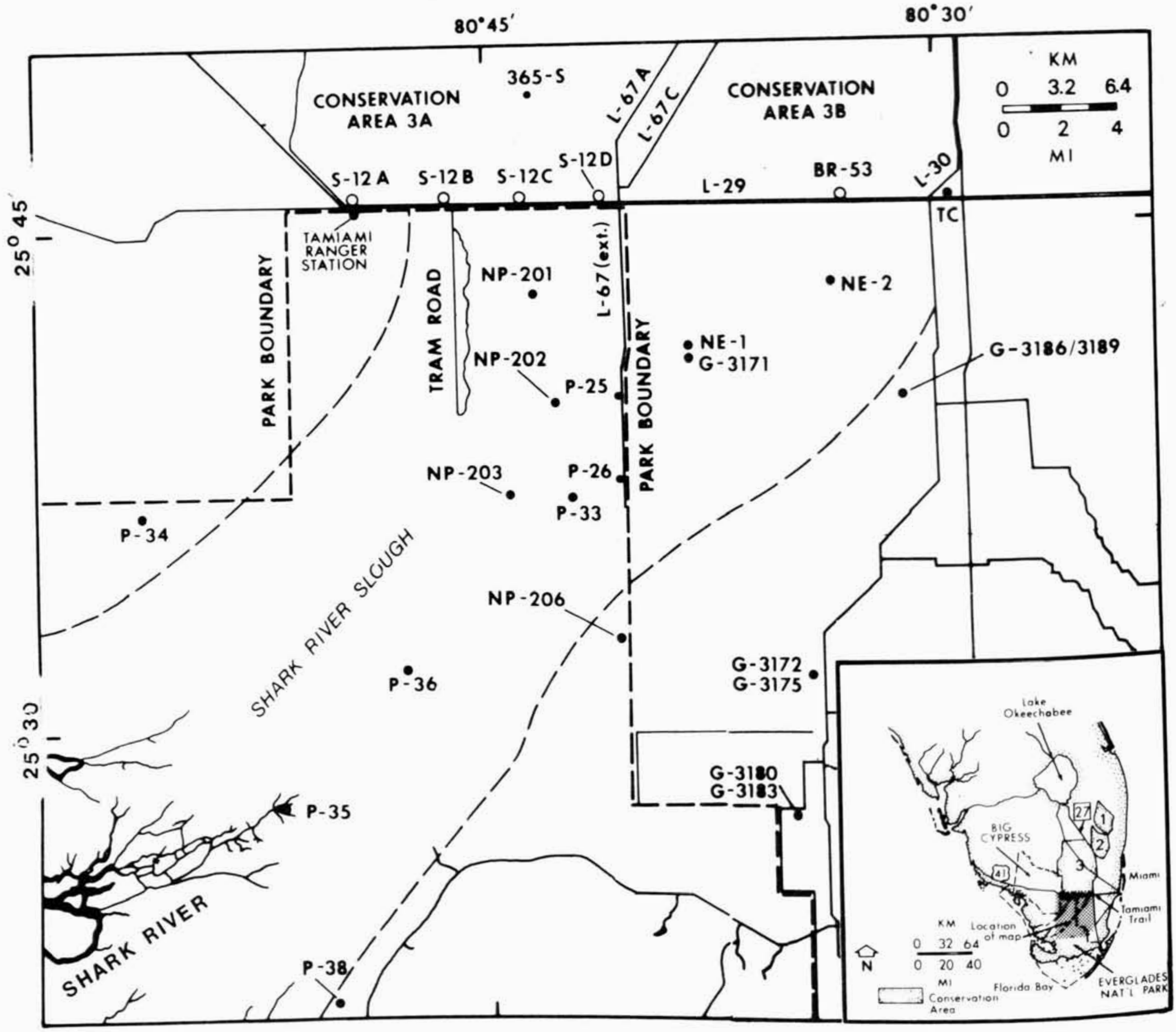

Figure 1. Map of the Shark River Slough, Everglades National Park

I. Specific Conductance/Total Major Cation Relationships

The monitoring of specific conductance within Everglades National Park's surface waters has been conducted at permanent water quality stations since the 1950's as part of the National Park Service/USGS cooperative hydrology program (Figure 2). From December 1977 through September 1979 the National Park Service has also monitored specific conductance biweekly over an extensive network of 97 locations in Shark Slough allowing for documentation of seasonal and temporal changes in specific conductance. The effects of short-term water delivery patterns and management practices on the overall control of specific conductance patterns within Shark Slough were also analyzed.

Specific conductance is a measurement of the ability of a substance to conduct an electrical current. In aqueous solution, specific conductance has been defined as "the reciprocal of the resistance in ohms, measured between the opposite faces of a centimeter cube at a specified temperature" (ASTM, 1964). In water, it is the presence of charged ionic species in solution that makes the solution conductive, providing a relationship between ionic concentration and specific conductance (Hem, 1970). Open natural systems such as Shark Slough, however, contain a variety of ionic and undissociated species, whose concentrations and proportions may vary widely. In order to utilize specific conductance as an indicator of possible changes in the physical and chemical character of water in Shark Slough, its relationship to total ionic concentration was first determined utilizing linear regression analysis, by relating specific conductance measurements to periodic chemical analyses of water.

Linear regression analyses were completed at ten of the water quality stations where the period of record was the longest. At these stations, ionic concentrations were converted from mass units (milligrams/liter) so that the correlation between specific conductance and dissolved ionic concentration could be established on the basis of consistent charge equivalent units (Hem, 1970).

The conversion from mass units to charge equivalence units was made for each cation as follows:

Cation Concentration (mg/l) x F, = charge equivalence (micro-equivalents/l)

where F, equalled 1000 times the reciprocal of the combining weights of the appropriate ions:

$$F_{calcium} = 49.9$$

$$F_{sodium} = 43.5$$

$$F_{magnesium} = 82.3$$

$$F_{potassium} = 25.6$$

For this analysis, only major cations (Ca^{++}, Na^{+}, Mg^{++}, K^{+}) and major anions ($HCO_3^{=}$, Cl^{-}, $SO_4^{=}$, F^{-}) were used, as they accounted for approximately 98 percent of the total ionic concentration in the Shark Slough water. Additionally, since the

Station	USGS Identifier	Sample Size (n)
365-S	02289043	7
S-12A	254542080493000	8
S-12B	02289018	18
S-12C	02289040	14
S-12D	254620080395000	10
P-25	02290827	3
P-26	253735080402100	5
BR-53	02289060	126
NE-1	254130080380500	5
NE-2	254315080331500	4
NP-201	02290861	4
NP-202	02290862	2
NP-203	02290832	2
NP-206	02290811	4
P-33	02290815	53
P-34	02290870	48
P-35	02290830	37
P-36	02290828	23
P-38	02290820	46
T.C. (L30)	02289250	9

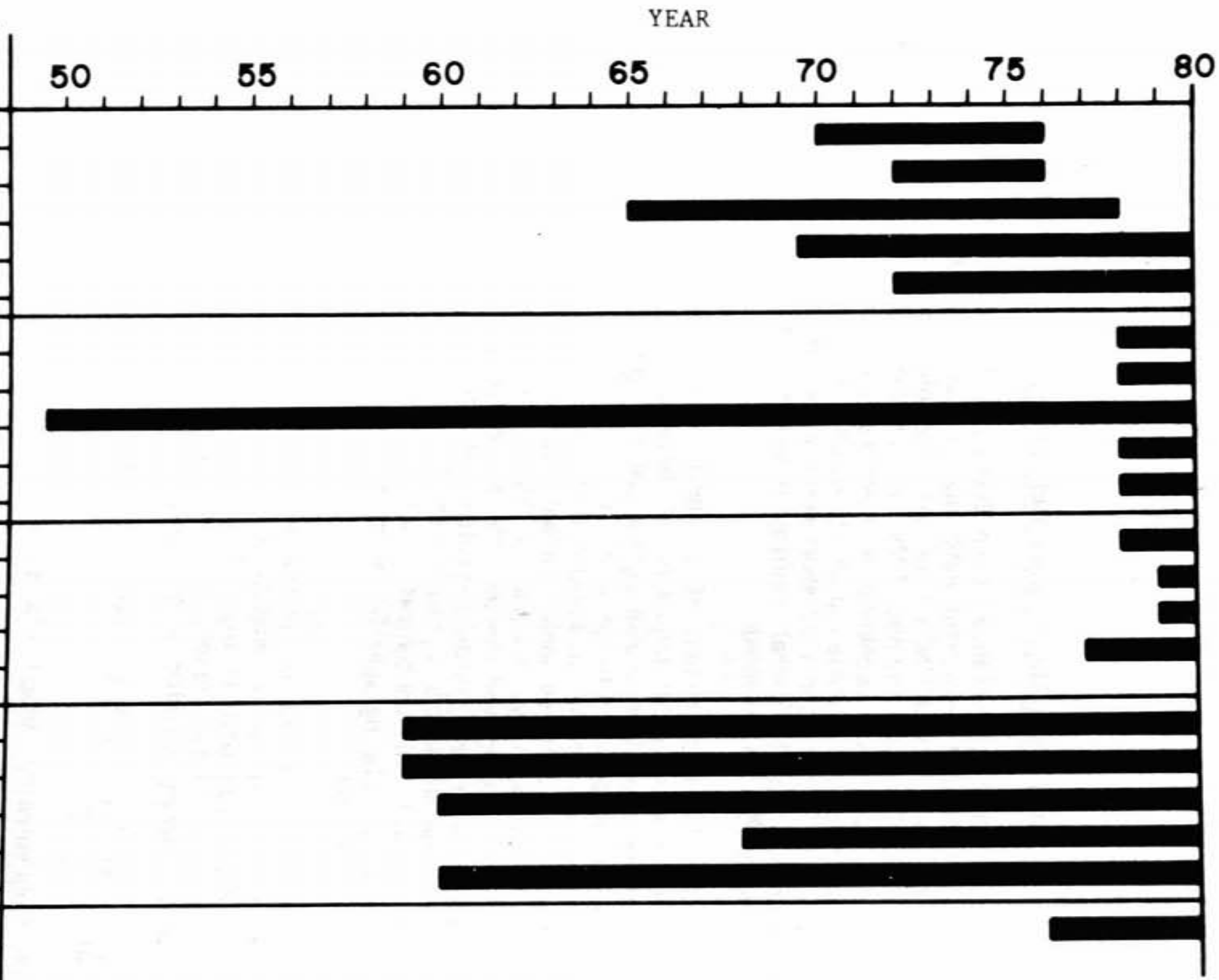

Figure 2: Water quality analysis period of record and sample size for Shark Slough stations.

sum of the major cations (equivalents/l) almost always equalled the sum of the major anions (± 5%), only the sums of the major cations (equivalents/l) were analyzed for correlation with specific conductance (micromhos/cm). Correlation coefficients were established as a measure of the strength of the correlations.

The established linear relationship is shown for four of the ten stations analyzed (Figure 3). These four stations are representative of marsh conditions (365-S), slough conditions (P-33 and P-35) and canal delivery water (S-12D). Data available from these and other stations in Shark Slough indicate that specific conductance is strongly correlated to total ionic concentration at each station (Table 1).

Because of this strong correlation, the specific conductance data base may be used as a tool in monitoring potential physical and chemical changes in water quality that are associated with man induced changes in the hydrologic system, such as the construction of levees and canals.

II. Ionic Character of Shark Slough Source Waters

Precipitation and surface water discharge, which is delivered from the canals and conservation areas north of the slough through the S-12 control structures, are the primary sources of water entering Shark Slough. The relative importance of each of these sources varies both seasonally and annually. Generally, rainfall is the predominant input during the late spring and early summer when intense rainfall events occur, and S-12 deliveries are low. Controlled water deliveries gradually increase throughout the summer so that rainfall and S-12 contributions are approximately equal during the late summer-early fall period. It is during this time of the year that Shark Slough receives its maximum amount of water. Rainfall rapidly decreases with the onset of the dry season in October so that in late fall-early winter S-12 deliveries are the predominant water inputs. The S-12 deliveries generally decrease throughout the winter with both rainfall and S-12 delivery reaching their annual minimums in spring.

The sources of controlled water delivered to Shark Slough vary, depending both upon the hydrological regime in the water system north of Everglades National Park and the operation of the individual S-12 structures. Controlled delivery water at the S-12 structures is a combination of marsh waters flowing from Conservation Area 3A and water originating south of Lake Okeechobee which are transported southward by canals.

The intricacy of this complex hydraulic delivery system and its variable mode of operation becomes an important factor in analyzing the downstream ionic concentrations. Specific conductance confidence intervals and ionic character for the source waters of Shark Slough were determined by utilizing data from the USGS WATSTORE water quality data bank, including 19 surface water stations adjacent to or within Shark Slough. In addition, published water quality data for bulk precipitation in Everglades National Park (Irwin and Kirkland, 1980) and provisional USGS data for shallow ground water wells east of Shark Slough (Waller, 1979) were used to characterize precipitation and ground water quality. Specific conductance and the ionic character vary significantly among the various source water types

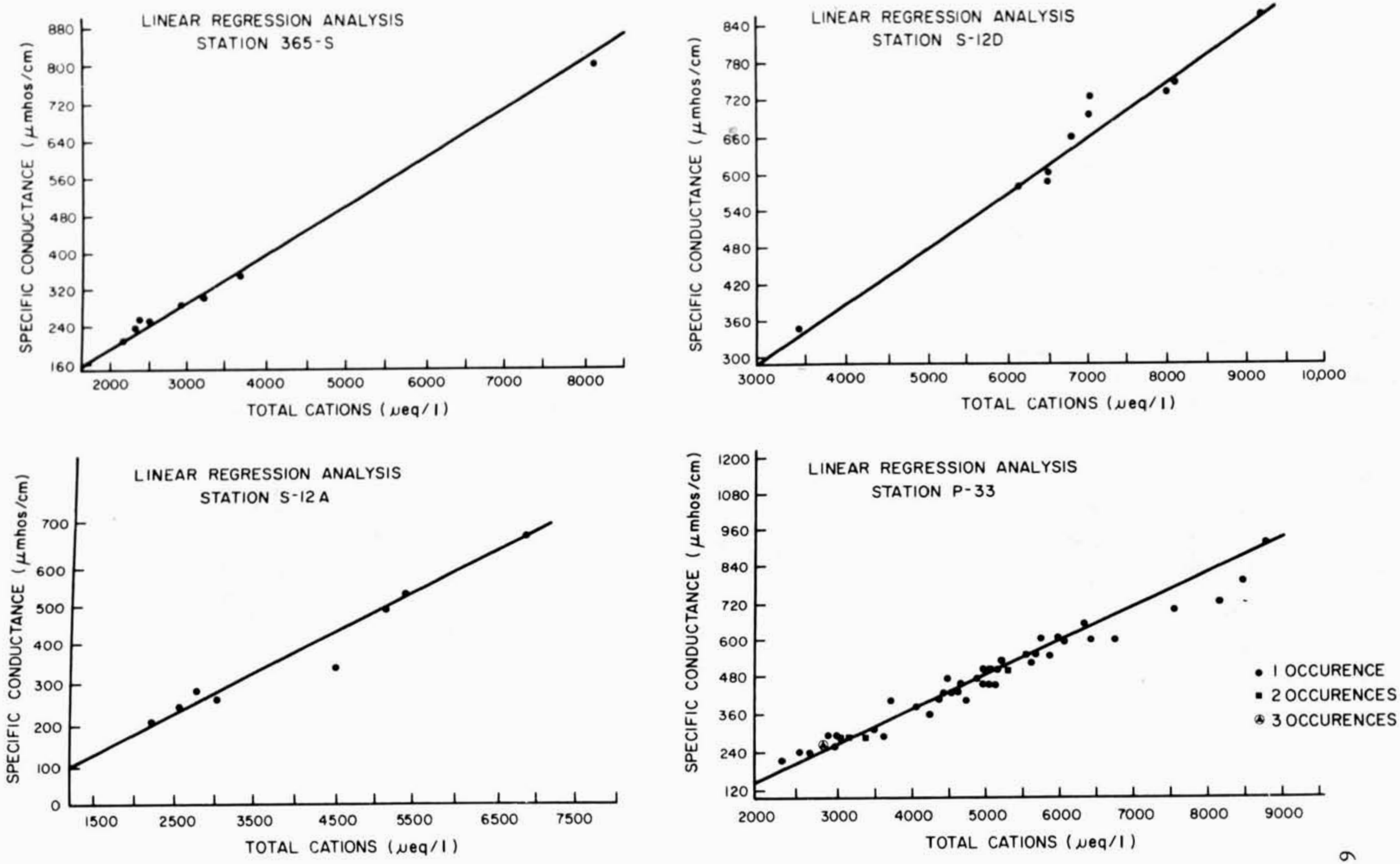

Figure 3. Linear regression analysis TOTAL CATIONS vs. SPECIFIC CONDUCTANCE for stations in Shark Slough.

Table 1. Correlation Coefficients for the Relationship between Specific Conductance (μmhos/cm) and Total Major Cations (meq/l) for 10 Stations in Shark Slough.

Station Number	Correlation Coefficient (r) Specific Conductance (μmho/cm) with Total Major Cations (μeq/ℓ)
365-S	0.999
S-12A	0.956
S-12B	0.989
S-12C	0.965
S-12D	0.999
P-33	0.952
P-36	0.959
P-35	0.996
P-38	0.989
P-34	0.980

influencing Shark Slough (Table 2). Marsh waters flowing south from Conservation Area 3A (station 365-S) have a mean specific conductance of 272 micromhos/cm and a mean total major cation concentration of 55.2 mg/l. Waters which "short-circuit" the marsh system of the conservation area and flow southward via canals (L-67A near S-12D) have both a higher mean specific conductance ($\bar{x}$ = 653 micromhos/cm) and a higher mean total major cation concentration ($\bar{x}$ = 137.5 mg/l) or an increase of more than 140 percent above those levels found in the naturally occurring marsh waters.

The ionic character of these water types also differ. The marsh water, interacting with the local lithology and ground water, is predominantly a "calcium bicarbonate water" where the calcium accounts for 69.4 percent of the total major cation concentration and sodium comprises only 23.7 percent of the cation composition. In the canal waters (station located in L-67A just above S-12D), calcium comprises only 46.6 percent of the total major cation concentration while sodium supplies 41 percent of the major cations.

These differences in specific conductance, total major cation composition and ionic character indicate that the chemical character of canal water in L-67A is more closely related to the chemical character of water found further north in the south Florida water system than to marsh waters found in Conservation Area 3A. These canal transported waters originate in a region south of Lake Okeechobee having a different lithologhy and are characterized by higher specific conductance and sodium concentration (Waller and Earle, 1975). As these waters flow south they are influenced by agricultural practices and diluted by precipitation and runoff, but do not have as long a contact with the calcium carbonate lithology found in the conservation area as does the marsh water. Additionally, chemical character of the canal waters are not as influenced by the biological and chemical activity taking place in the slower flowing, shallow marsh system.

The other major source of water to Shark Slough, precipitation, varies greatly in character from other water types which are discharged into Everglades National Park. Bulk precipitation samples obtained from late 1973 through 1979 at the Tamiami Ranger Station in Everglades National Park indicate a dilute bulk precipitation (Irwin and Kirkland, 1980). These samples contained a mean specific conductance of 37 micromhos/cm and a total major cation concentration that averaged 4.7 mg/l, which is 8.5 percent of the mean total cation concentration of the "marsh" water and only 3.4 percent of the mean total cation concentration of the canal water.

Rainfall dilutes the ionic concentration of the water in Shark Slough, thereby lowering specific conductance. The ionic concentration of the precipitation is too low, however, to influence the ionic composition (i.e., cation ratios) of the surface water in the slough.

The last probable source of water input into Shark Slough is ground water. The Biscayne Aquifer is a major reservoir for ground water which surfaces in Shark Slough. Because of the nature of the aquifer, with its extremely porous geological formation, there is a large amount of interaction between surface water and ground water. Typically, surface waters from the marsh recharge the ground water. However, during dry periods, it seems probable that the ground water may

Table 2. Ionic Characteristics of Major Water Input Types in Shark Slough, Everglades National Park

Water Type	Station Location	N Sample Size	$\bar{X}$ Specific Conductance (μmhos/cm)	Ca^{++} (mg/l)	Ca^{++} as % of Total Cations	Na^{+} (mg/l)	Na^{+} as % of Total Cations	Total Major Cations (mg/l)
Marsh Water	Station 365-S (Conservation Area 3A)	9	272	38.3	69.4%	13.1	23.7%	55.2
Canal Delivery Water	L-67A near S-12D	10	653	64.1	46.6%	56.4	41.0%	137.5
Bulk Precipitation[1]	Tamiami Ranger Station	26	37	2.3	48.9%	1.8	32.2%	4.7
Ground Water[2] (shallow)	East Everglades G-3186, G-3189 G-3172, G-3175 G-3180, G-3183	46	435	77.4	84.2%	10.3	11.2%	91.9

[1]Data from Irwin, G. A. and R. T. Kirkland. 1980. Chemical and physical characteristics of precipitation at selected sites in Florida, USGS Water Resource Investigations 80-81, Tallahassee, Florida.

[2]Data from Waller, B. G. 1979. Effects of land use on ground water quality in the East Everglades, Dade County, Florida, 1978-1979, (Provisional Open File Report, USGS).

surface in depressed areas, such as alligator holes, and the streams at the southern end of the slough, influencing the chemistry of these surface waters.

The chemistry of the surface waters, discussed later in this paper, is determined largely by the source of the surface water, and is modified due to precipitation input and evapotranspiration, weathering of the geological formation, and chemical changes brought about by biological functioning of organisms in the marsh and chemical equilibria. Conversely, the ground water chemistry is more stable, influenced primarily by the source of recharge water and, overwhelmingly, by dissolution and weathering of the Biscayne Aquifer.

Shallow ground water chemical data were not available at locations in Shark Slough proper but were available for adjacent east Everglades wells penetrating the Biscayne Aquifer (Waller, 1979). Water quality data taken from a composite of shallow wells identify a "typical" ground water that has a mean specific conductance of 435 micromhos/cm and a total major cation concentration of 91.9 mg/l. The ionic character of the shallow ground water is a calcium bicarbonate water, with 84.2 percent of the total major cations being calcium and only 11.2 percent of the total major cations being sodium. This type of ionic composition would be expected in an area whose geological formation is composed of limestone.

While the chemical characteristics of the shallow ground water in the Everglades area are relatively stable and generally free of the large fluctuations seen in surface waters of Shark Slough, localized deviations from the composite ground water characteristics were noted.

Station G-3171, a shallow ground water well (12 feet) located approximately 2 miles east of canal L-67 (extended), has a mean specific conductance ($\bar{x}$ = 752 micromhos/cm), 73 percent higher than that found in the composite ground water and a mean total cation concentration ($\bar{x}$ = 160.4 mg/l) 75 percent higher than that found in the composite east Everglades ground water.

Additionally, while the ionic character of the G-3171 ground water is the same as that found in the east Everglades, the cation composition changes slightly. G-3171 ground water's total cation concentrations are 77.8 percent calcium and 17.2 percent sodium.

The higher than expected sodium and chloride concentrations found in the G-3171 support the theory that a major source of recharge for ground water at this station is L-67 (extended) canal water, which has a higher NaCl concentration than recharge waters originating in the marsh.

It is seen (Figure 4) that the four major types of source waters can be distinguished from one another on the basis of specific conductance alone. Because of this, a spatially comprehensive specific conductance monitoring program in Shark Slough may be a valuable assessment tool in the analysis of factors influencing water quality in the slough under varying hydrological conditions as presented in section IV of this paper.

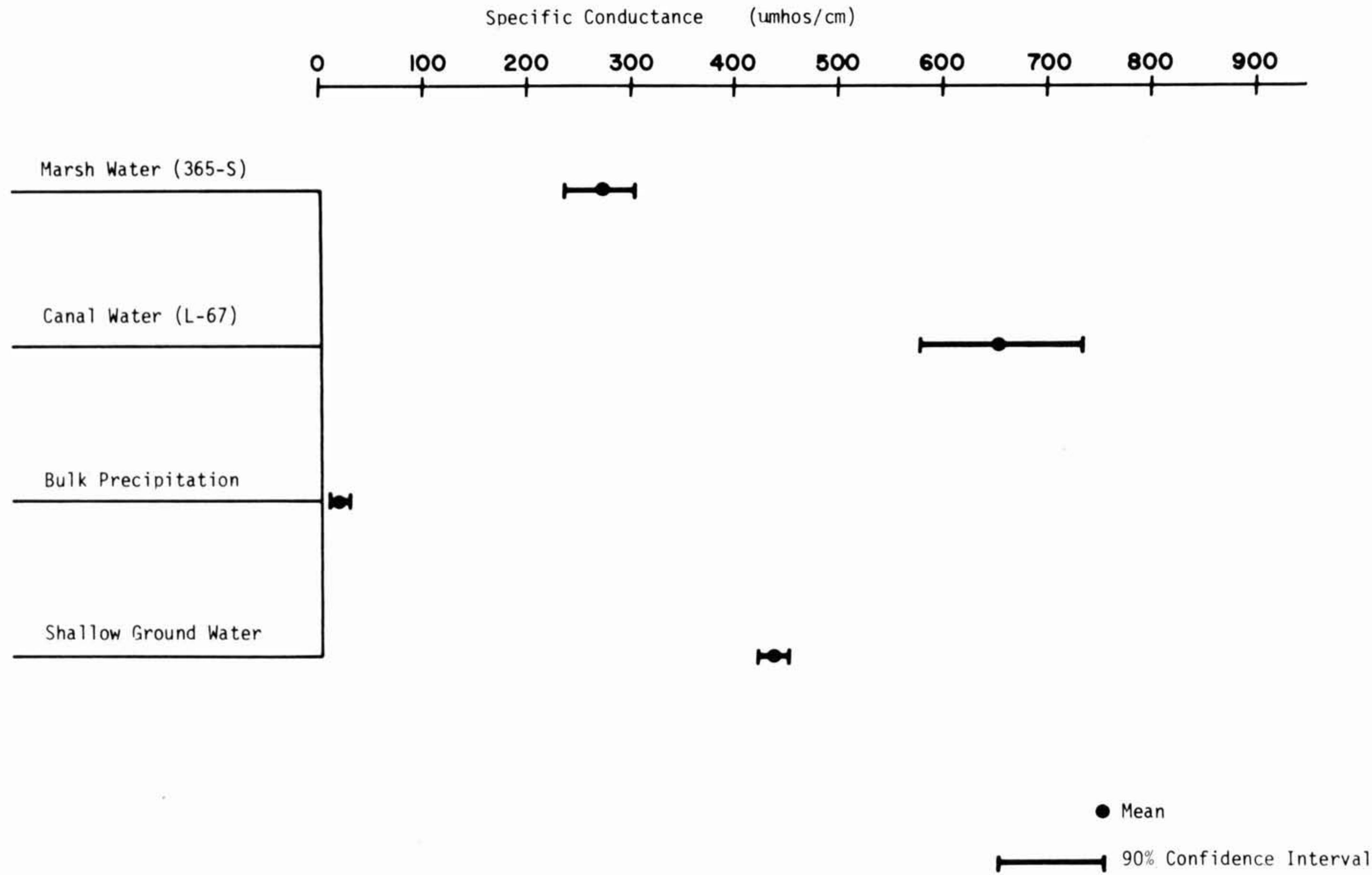

Figure 4. Specific conductance 90% confidence intervals for major source water types in Shark Slough.

III. Specific Conductance and Ionic Character of Waters In Shark Slough and Northeast Shark Slough

Important goals of this research were to determine the extent to which routine specific conductance monitoring might be used as a resource management tool in characterizing water types, signal potential changes in overall water quality and add to our knowledge of hydrological factors influencing the water quality and water movements in Shark Slough.

A complex variety of factors including rainfall, source and amount of water delivery, evapotranspiration, tidal influence, and chemical and biological changes in the slough determine the overall chemical composition of the slough's water. For specific conductance measurements to be a valid and useful management tool, it is necessary to relate these data to both water chemistry analysis at monitoring stations, and the slough's hydrologic regime.

Period of record data were utilized for eighteen stations, three of which (stations S-12A, S-12B, S-12C) are located along the Tamiami Canal at delivery sites into Shark Slough. Two additional stations are also located along the Tamiami Canal, but east of L-67A along the northern periphery of Northeast Shark Slough (Bridge 53 and Tamiami Canal, east of L-30). Nine stations are located in Shark Slough proper, six in the central slough (NP-201, NP-202, NP-203, P-33, P-35, and P-36) and three along the edge of the slough (NP-206, P-34, P-38). Two additional stations (P-25, P-26) are located in canal L-67 (extended), which divides Shark Slough from Northeast Shark Slough along the eastern boundary of Everglades National Park. The final two stations (NE #1 and NE #2) are located in Northeast Shark Slough (Figure 1).

While data at ten of these stations (Bridge 53, S-12A, S-12B, S-12C, P-33, P-34, P-35, P-36 and P-38, Tamiami Canal, east of L-30) have been collected for several years (Figure 2), establishment of water quality sampling at eight other stations (P-25, P-26, NE #1, NE #2, NP-201, NP-202, NP-203, NP-206) has occurred only in the past two years. Because of this, only the ten stations with the longest period of record were used for detailed analysis, while only general reference were made to the eight most recent additions to the network.

For the purpose of convenience, the ten stations receiving in-depth analysis are further subdivided in this report into four sections. The first of these, Section A, is concerned with period of record data for stations S-12A, S-12B and S-12C. In Section B, water quality at Bridge 53 is discussed during three time periods: (1) prior to the construction of L-29 when this station monitored overland sheet flow from Conservation Area 3A into the Northeast Shark Slough (1950-1961), (2) after the construction of L-29 when the station was located in the new Tamiami Canal (1962-1978), and (3) most recently, after the construction of S-333 which, when opened, allows the flow of canal waters from L-67A eastward along the Tamiami Canal and subsequently into Northeast Shark Slough (1978-1979). Also considered in Section B is water quality monitored in the Tamiami Canal east of L-30 (Station 02289250) from 1976-1979.

Section C is concerned with specific conductance and ionic composition in the central Shark Slough long-term stations (P-33, P-35 and P-36), while Section D concerns the long-term stations along the periphery of Shark Slough (P-34 and P-38). Relevant data for all of these stations are summarized in Table 3.

A. Tamiami Canal at the S-12 Delivery Sites

Shark Slough, at its northernmost extent in Everglades National Park is separated from Conservation Area 3A by the L-29 levee and the Tamiami Canal. At 4 locations along the northern park boundary, S-12 structures have been built to facilitate the delivery of water from the Tamiami Canal into Shark Slough.

The primary sources of water in the Tamiami Canal at the S-12 structures include the seepage of groundwater and flow of marsh water from Conservation Area 3A and the canal waters flowing into the Tamiami Canal from the L-67A canal, just above S-12D. The amount and proportion of water from each of these sources that enter Shark Slough vary, being dependent upon water levels in Conservation Area 3A, the amount of water flowing south through the L-67 canals and the number, and gate height of the opened S-12 structures. Specific conductance and ionic composition of the water at the various S-12 structures vary with the source. Most frequently, the water at S-12D, P-25 and P-26, all located in L-67A or L-67 (extended), have high specific conductance and high sodium:calcium ratios typical of canal water (Figures 5 and 6). The water at S-12A, S-12B and S-12C, however, appear to represent more of a mixture of canal water and inputs from the ground water and marsh flow out of Conservation Area 3A.

The frequency histograms in Figure 6 indicate several things about water available for delivery at S-12A, S-12B and S-12C. At times, the primary source of these waters appear to be sheet-flow from Conservation Area 3A, while at other times, the source is inflow westward of canal water from L-67A. An east-west gradient exists so that canal type water appears more frequently at S-12C than it does at S-12A.

The water type at any particular delivery site at any particular time, appears to be largely dependent on the hydraulics of the system. Water from L-67A canal generally is found at S-12D, P-25 and P-26 along L-67 (extended). These waters then may enter Shark Slough either by flow through S-12D, if it is open, and seepage along L-67 (extended) canal. If S-12D is the only structure open, and the gradient toward the east in the Conservation Area 3A is great enough, water found at S-12A, S-12B or S-12C may be primarily seepage from groundwater and marshwater. If, however, these structures are open, the situation exists that the water discharged through the structures is more rapidly replaced by flow westward of canal water from the L-67A canal than by sheet-flow southward from Conservation Area 3A.

A more in-depth analysis of flow regime under varying hydrological conditions and gate opening schemes is necessary before the controlling mechanisms are fully understood or amount of flow of the various types of water are quantified. However, even basic knowledge of the specific conductance/hydraulics relationship may be of help in interpreting spatial changes in conductivity contours for the entire slough (Section IV).

Table 3. Ionic Characteristics of Water at Selected Stations in the Shark Slough area, Everglades National Park

Station Number	Location	$\bar{x}$ Specific Conductance (µmhos/cm)	90% Confidence Interval Specific Conductance	$\bar{x}$ Total Major Cations (mg/l)	$\bar{x}$ Calcium (% Total Cations)	$\bar{x}$ Sodium (% Total Cations)
S-12 A	Tamiami Canal S-12 A	379	265-493	76.9	64.7%	25.6%
S-12 B	Tamiami Canal S-12 B	436	350-523	83.2	62.6%	28.8%
S-12 C	Tamiami Canal S-12 C	415	314-516	96.8	58.7%	32.9%
Tamiami Canal (east of L-30)	Tamiami Canal East of L-30	616	374-850	128.7	57.9%	34.2%
NP-201	Central Shark Slough	624	482-766	129.2	39.4%	48.4%
NP-202	Central Shark Slough	695	ND	147.9	37.6%	48.6%
NP-203	Central Shark Slough	577	ND	126.6	41.9%	44.9%
P-33	Central Shark Slough	462	420-504	91.8	65.1%	26.5%
P-35*	Central Shark Slough	427	391-463	89.8	54.9%	32.5%
P-35**	Central Shark Slough	9978	6918-13038	3477.9	5.8%	77.2%
P-36	Central Shark Slough	545	523-567	111.6	51.3%	38.7%
NP-206	Edge of Slough	321	210-431	76.1	79.9%	15.7%
P-34	Edge of Slough	401	362-440			
P-38	Edge of Slough	514	441-587	102.1	62.6%	32.4%
P-25	L-67 extended	612	374-850	131.4	47.5%	40.5%

Station Number	Location	$\bar{x}$ Specific Conductance (µmhos/cm)	90% Confidence Interval Specific Conductance	$\bar{x}$ Total Major Cations (mg/l)	$\bar{x}$ Calcium (% Total Cations)	$\bar{x}$ Sodium (% Total Cations)
P-26	L-67 extended	606	499-713	122.8	51.1%	38.0%
NE #1	Shark Slough	461	406-516	101.8	61.4%	31.6%
NE #2	Northeast Shark Slough	434	289-579	89.3	57.2%	33.9%

* Data for those dates without saltwater influence

** Data for saltwater influenced dates only

ND Not enough data available to set valid confidence interval

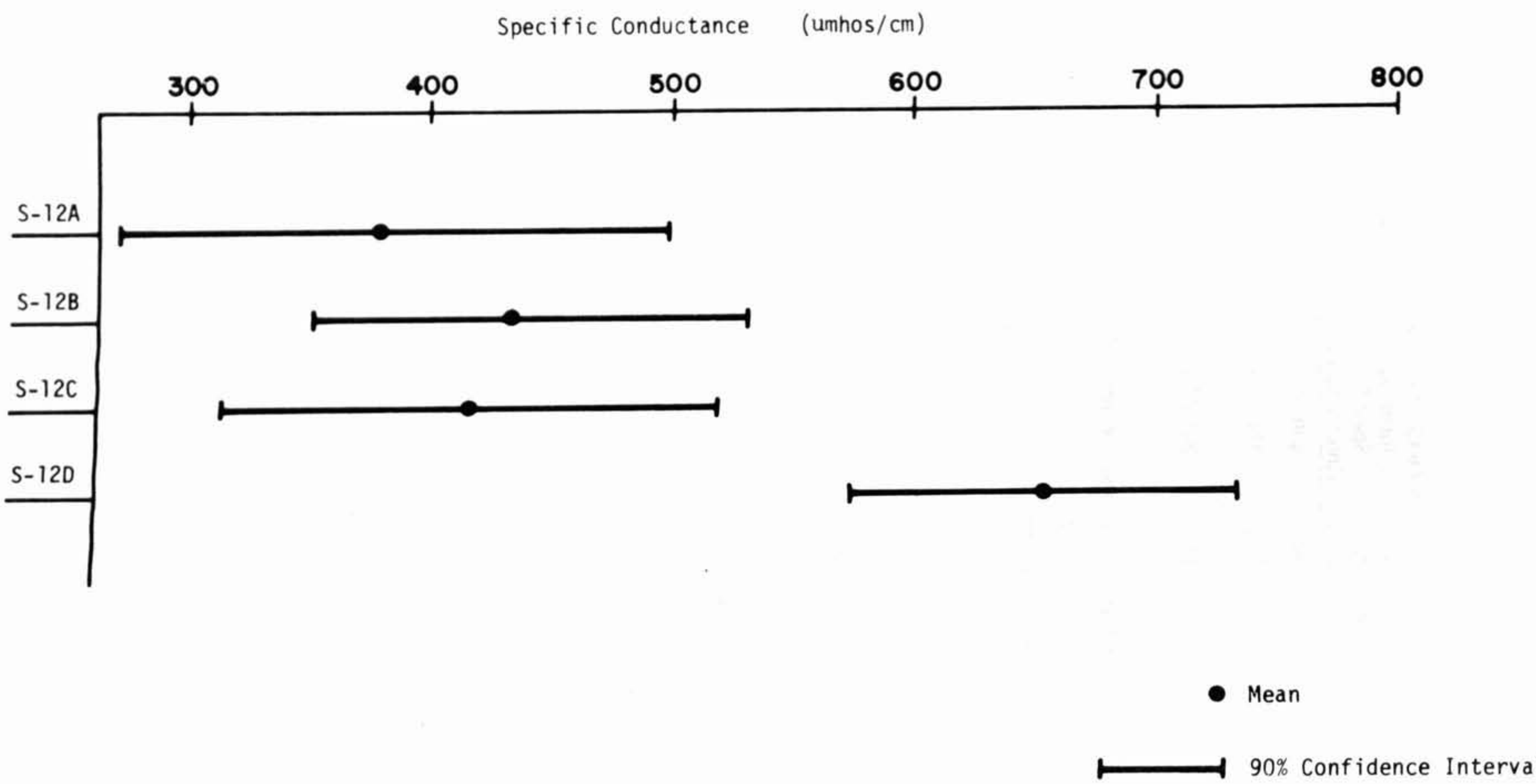

Figure 5. Specific conductance 90% confidence intervals for S-12 delivery water.

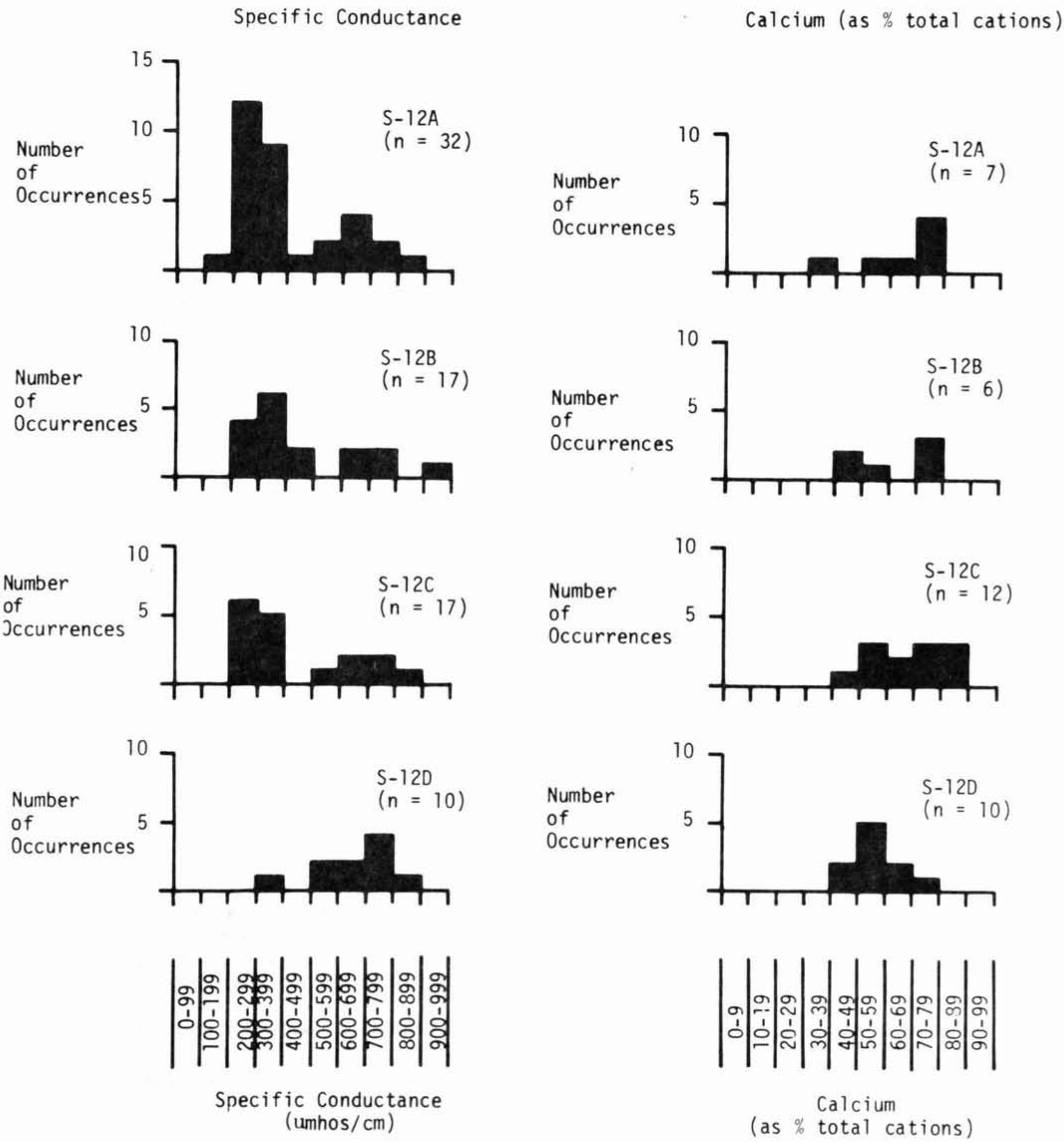

Figure 6. Specific conductance and % calcium frequency histograms for S-12 water delivery sampling sites.

B. Bridge 53 and Northeast Shark Slough

Bridge 53, located on the Tamiami Canal between Conservation Area 3B and Northeast Shark Slough, has the longest period of record of any water quality station adjacent to Everglades National Park (1950-present).

A series of culverts between L-67A and L-30 allows overflow from the Tamiami Canal into Northeast Shark Slough during periods of high water.

The character of water at Bridge 53 has been directly influenced by several man-made changes. Prior to 1961, the water at the Bridge 53 location was overland sheet flow. In 1961, the beginning of construction of Levee 29 disrupted this overland flow, impounding much of the sheet flow behind the levee in Conservation Area 3B. Again in 1978, another change took place with the completion of S-333, which allowed the flow of water from the L-67A canal eastward into this section of the Tamiami Canal. Because of these changes, the analysis of specific conductance and ionic composition of water at Bridge 53 is divided into three time periods, 1950-1961, 1962-1977, and 1978-present, each representing a period of different hydrological regime. More recent water chemistry data are also analyzed for a station in the Tamiami Canal just east of L-30 and for two stations in Northeast Shark Slough.

The specific conductance and ionic composition of water at Bridge 53 have changed significantly with the man-made changes (Table 4, Figure 7). Prior to the construction of Levee 29, the water at this location displayed the characteristics of a typical marsh water. Mean specific conductance was low ($\bar{x}$ = 304 micromhos/cm) and the cations, typically averaged 79 percent calcium and 15 percent sodium, close to the ratio that is found today at station 365-S in the Conservation Area 3A marsh. There was slight seasonal variation due to both dilution by rainfall during the wet season, and greater evapotranspiration during the dry season, but never did the specific conductance exceed 600 micromhos/cm.

Almost immediate increases in specific conductance were noted in 1962 with the construction of L-29. Mean specific conductance increased 68 percent ($\bar{x}$ = 512 micromhos/cm) and mean cation concentration increased 56 percent ($\bar{x}$ = 118.3 mg/l). Additionally, the 90% confidence interval for specific conductance (Figure 7) increased to 475-550 micromhos/cm, which is distinct from the pre-construction 90% confidence interval for specific conductance of 282-326 micromhos/cm. While the increase in cation concentration was significant, no change was found in cation composition (80% Ca:15% Na), suggesting that ground water may be taking precedence as the major source of water to the canal.

Prior to levee construction, the surface water was primarily overland sheet flow which would flow into Northeast Shark Slough. After the completion of the levee, surface water quality mirrored prevalent ground water quality. Levee construction impounded surface waters within Conservation Area 3B, creating a hydrostatic head across the levee tending to drive ground water into the adjacent Tamiami Canal. This ground water has a higher ionic concentration but similar ionic composition to the surface water which previously had been the major source water

Table 4. Specific Conductance and Ionic Concentration at Bridge 53.

Time Period/Regime	Sample Size	$\bar{x}$ Specific Conductance (μmhos/cm)	90% Confidence Interval (Specific Conductance)	$\bar{x}$ Total Major Cations (mg/l)	Calcium (as % total major cations)	Sodium (as % total major cations)
1950-1961/ Prior to construction of L-29	90	304	282-326	66.6	78.9%	15.4%
1962-1977/ Post L-29 Construction before S-333	31	512	474-550	118.3	80.6%	14.3%
1978-1979 Post S-333 operation	5	659	597-721	137.3	52.8%	36.2%

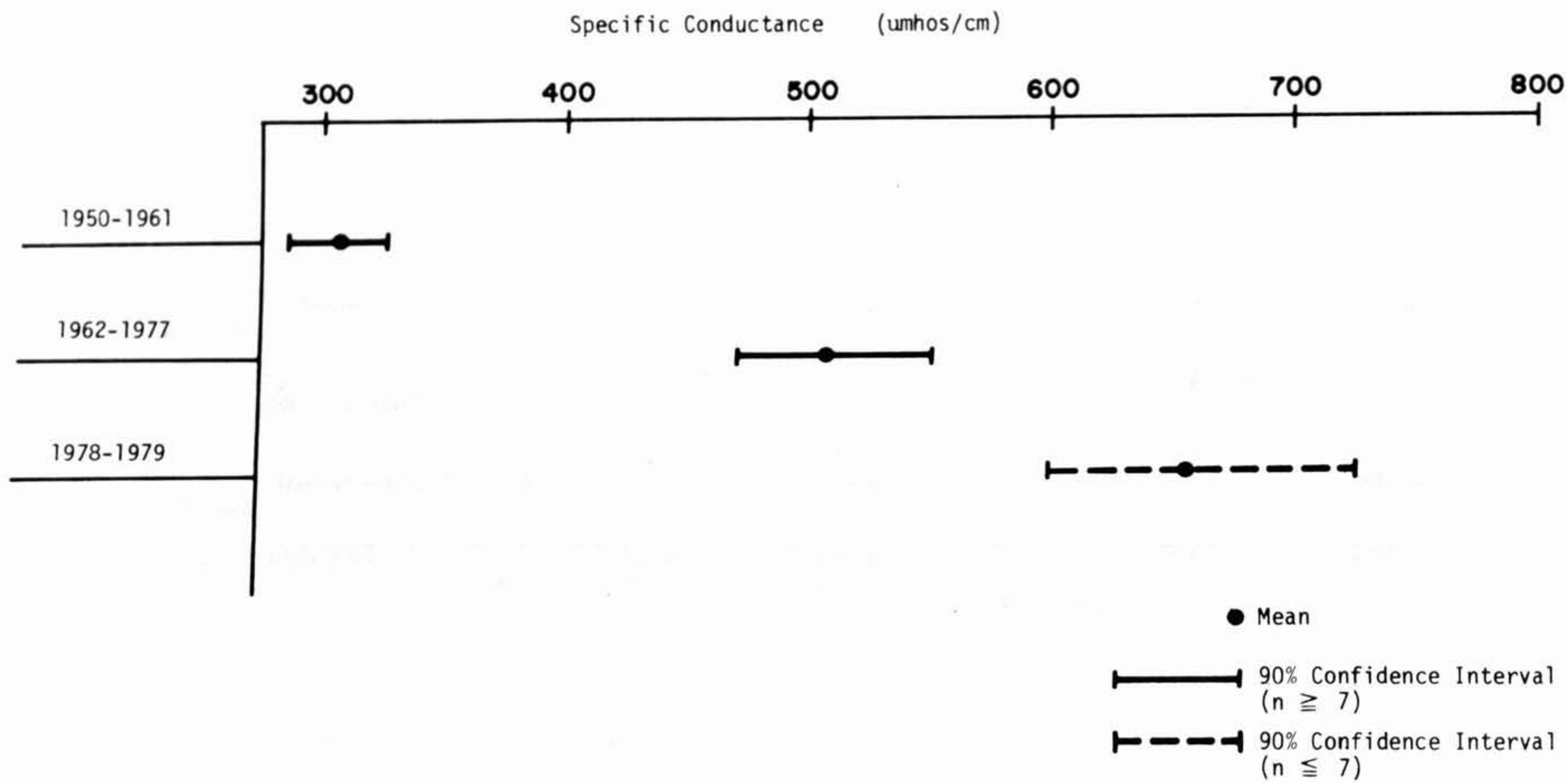

Figure 7. Specific conductance confidence intervals for water at Bridge 53 (1950 - present).

for the Tamiami Canal. This change of source water into the canal was important in that this water then became available for overflow into Shark Slough.

In 1978, with the completion of S-333, another significant change is seen in the water character at Bridge 53. Again, mean specific conductance increased ($\bar{x}$ = 659 micromhos/cm) as does mean cation concentration ($\bar{x}$ = 137.3 mg/l). As important a change is noted in cation composition. Instead of the 80 percent calcium:15 percent sodium composition noted before S-333 completion, the mean calcium:sodium ratio became 52 percent calcium:36 percent sodium. The frequency histogram for percent calcium (Figure 8) further shows that on 4 of 5 sampling dates, the percent calcium was between 40 percent and 49 percent, indicating a chemical character very similar to that found in the L-67A canal water.

The controlling mechanism after 1978 appears to be S-333 operation. Prior to the construction of S-333, eastward flow of L-67A water into the Tamiami Canal was restricted by an earthen plug. With S-333 completed, the capability was added to selectively allow water to flow eastward from L-67 along the Tamiami Canal towards Bridge 53 changing the chemical character of the water available to overflow into Northeast Shark Slough.

A limited amount of data have been available at NE #1 and NE #2 since 1978. These data indicate water with specific conductivities and ionic concentrations lower than those found on the same date at Bridge 53, but similar to those found in central Shark Slough. However, adequate data are not available for a comprehensive analysis of specific conductance/ionic changes in Northeast Shark Slough.

One additional station has been maintained in the Tamiami Canal east of L-30 since 1976. Specific conductance and ionic composition of water at this station show a water similar in character, though with slightly less sodium, than those in the L-67A canal. Apparently, the water at this station reflect the quality characteristics of the water in the L-30 canal, which like the L-67 canal brings water south from the Miami Canal.

C. Central Shark Slough

Three long-term (P-33, P-35, P-36) and three recent (NP-201, NP-202, NP-203) water quality stations located in central Shark Slough serve as a data base from which changes in water quality can be monitored as water flows through the slough. Of particular interest are stations P-33, P-35 and NP-203.

Station P-33, located in the northern portion of central Shark Slough is the station with the longest water quality period of record within Everglades National Park (1959-present). This long period of record, coupled with its strategic central location gives this station great importance in assessing temporal changes in water quality occurring in response to changes in the water delivery patterns to Shark Slough.

An analysis of specific conductance and inorganic ions at P-33 indicates that changes have occurred throughout the monitoring period of record (1959-1979). Long-term temporal changes are documented using wet season (June-December)

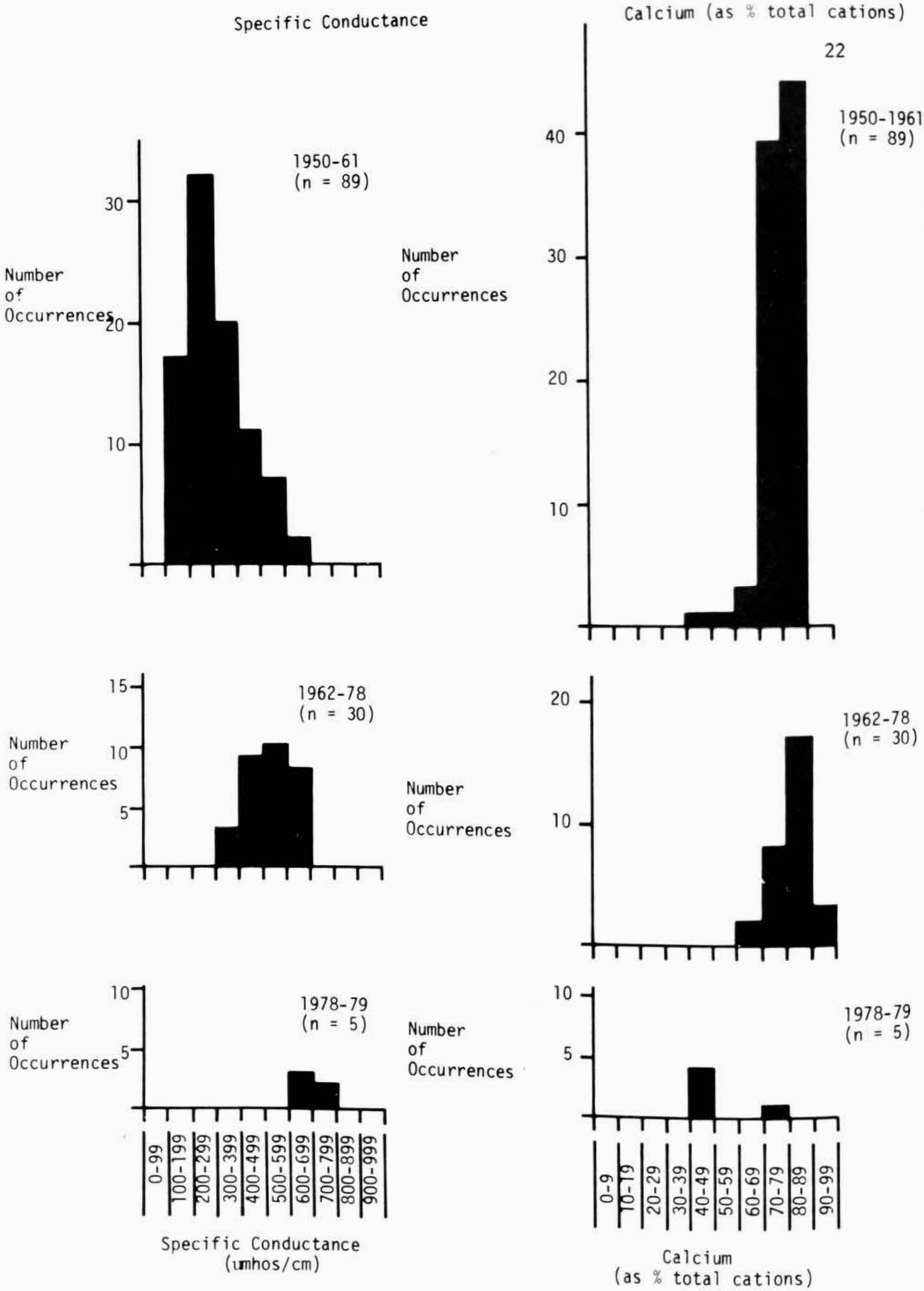

Figure 8. Specific conductance and % calcium frequency histograms for Bridge 53 (1950-61, 1962-78, 1978-79).

data only, since dry season values often reflected localized limnological conditions of isolated solution/alligator holes.

Specific conductance at P-33 has increased significantly (P = 0.05) throughout the monitoring period with mean specific conductance ranging from 250-290 micromhos/cm in the early 1960's increasing to greater than 500 micromhos/cm in recent years (Figure 9).

Associated with this increase in specific conductance has been a significant shift in ionic relationships, as reflected by the sodium:calcium ratio (Table 5). Prior to 1964, the wet season sodium:calcium ratio was always less then 0.2. After 1965, however, sodium concentration increased greatly, while calcium concentration remained about the same (Figure 9).

Shifts in both specific conductance and ionic character result from major changes in the hydrological regime influencing the source of water to Northern Shark Slough. As was the situation with Bridge 53, these shifts in water quality appear to be closely correlated with the completion of L-29 and L-67 which restricted the natural sheet flow that once was a major source of water flow into Shark Slough, and facilitated easier movements of canal waters from further north in the south Florida system, to the area of Shark Slough.

P-35, located in southern Shark Slough, is also of particular importance because of its location and its long period of record. P-35 is located near the freshwater/estuary interface where overland sheet flow becomes channelized into distinctive rivulets, fringed by extensive areas of mangrove. Chemically and biologically, this is a zone of transition which is dominated by freshwater flow south during most of the year, but which is influenced by salt water movements northward during the peak dry season.

The ionic characteristics of station P-35 differs significantly from that of station P-33 due to this station's location at the interface between the freshwater slough and the estuarine zone. From June through February, the station contains freshwater with a mean specific conductance (1960-1979) of 469 micromhos/cm. From March through May (1960-1979) the specific conductance increases to an average of 10,029 (micromhos/cm) indicating a change to estuarine characteristic (Figure 10). This change appears to be related to the amount of flow southward from northern Shark Slough. Typically, March through May is the period of lowest freshwater inflows due to reductions in both precipitation and S-12 discharges. As flow southward to P-35 is reduced, estuarine waters may flow northward through the channels of the Shark River system altering the chemical regime at P-35.

Presently, the data base is not sufficient to document the full extent of northward movements of estuarine conditions under all circumstances, but the data are adequate to indicate that water chemistry at P-35 is influenced by saltwater flow during the dry season of each year, with conductivities as high as 24,000 micromhos/cm reported at P-35 during extremely dry periods.

The effects of freshwater flow from the slough on the Shark River estuary for areas south of P-35 (Figure 11) have been partially documented. Wet and dry season analysis at locations south of P-35 show that there are seasonal changes in salinities throughout the estuary. Table 6 shows that during the wet season, when conductivities are low at P-35, water is typically fresh as far south as the vicinity

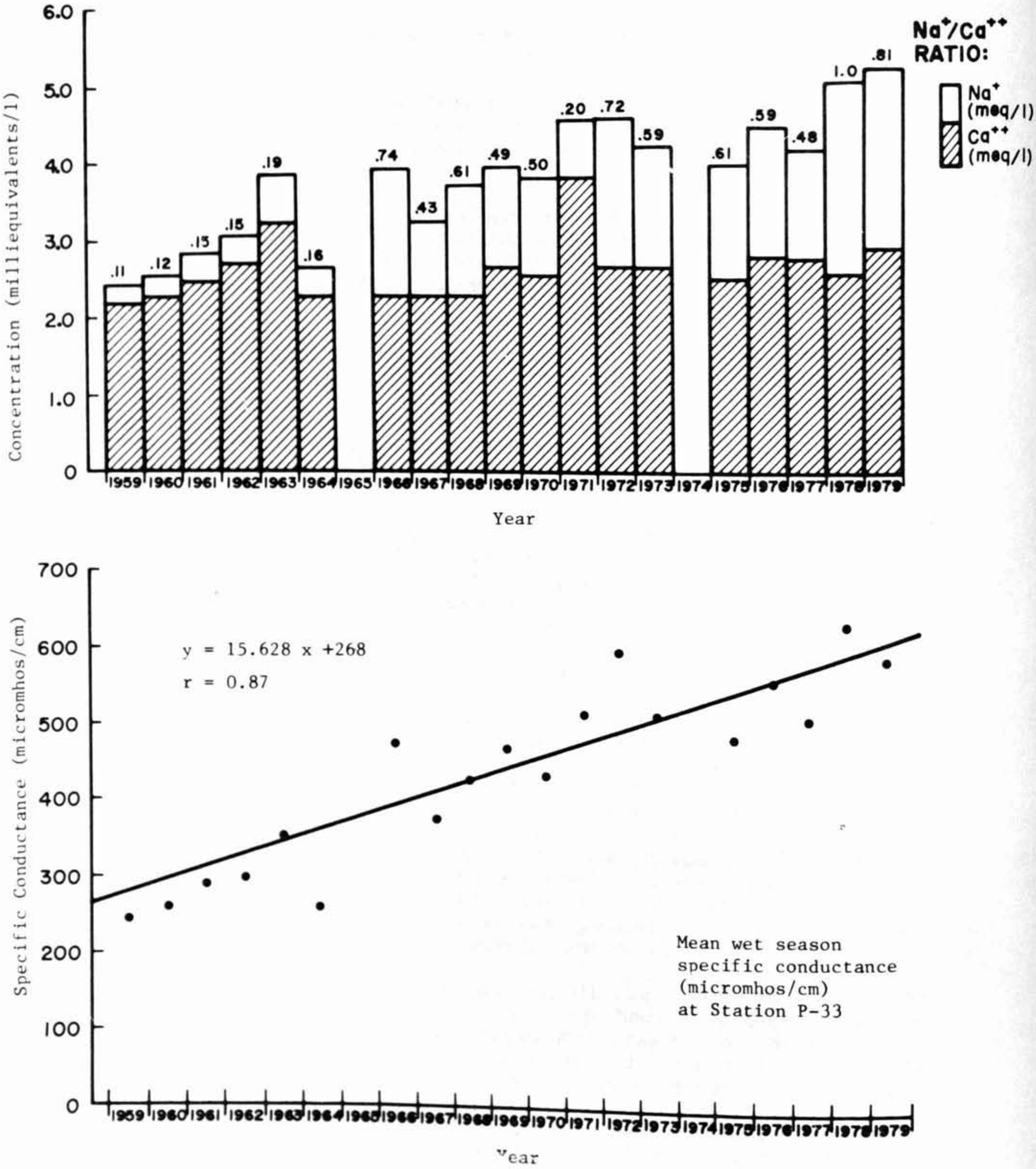

Figure 9: Specific conductance and Na:Ca relationships at Station P-33.

Table 5. Mean wet season specific conductance and sodium: calcium ratio at P-33.

Year	$\bar{x}$ Specific Conductance micro mhos/cm	$\bar{x}$ Na^{+}/Ca^{++} ratio
1959	243	.11
1960	261	.12
1961	289	.15
1962	296	.15
1963	353	.19
1964	260	.16
1965	-	-
1966	472	.74
1967	374	.43
1968	425	.61
1969	462	.49
1970	430	.50
1971	504	.20
1972	589	.72
1973	504	.59
1974	-	-
1975	479	.61
1976	550	.59
1977	500	.48
1978	620	1.00
1979	575	.81

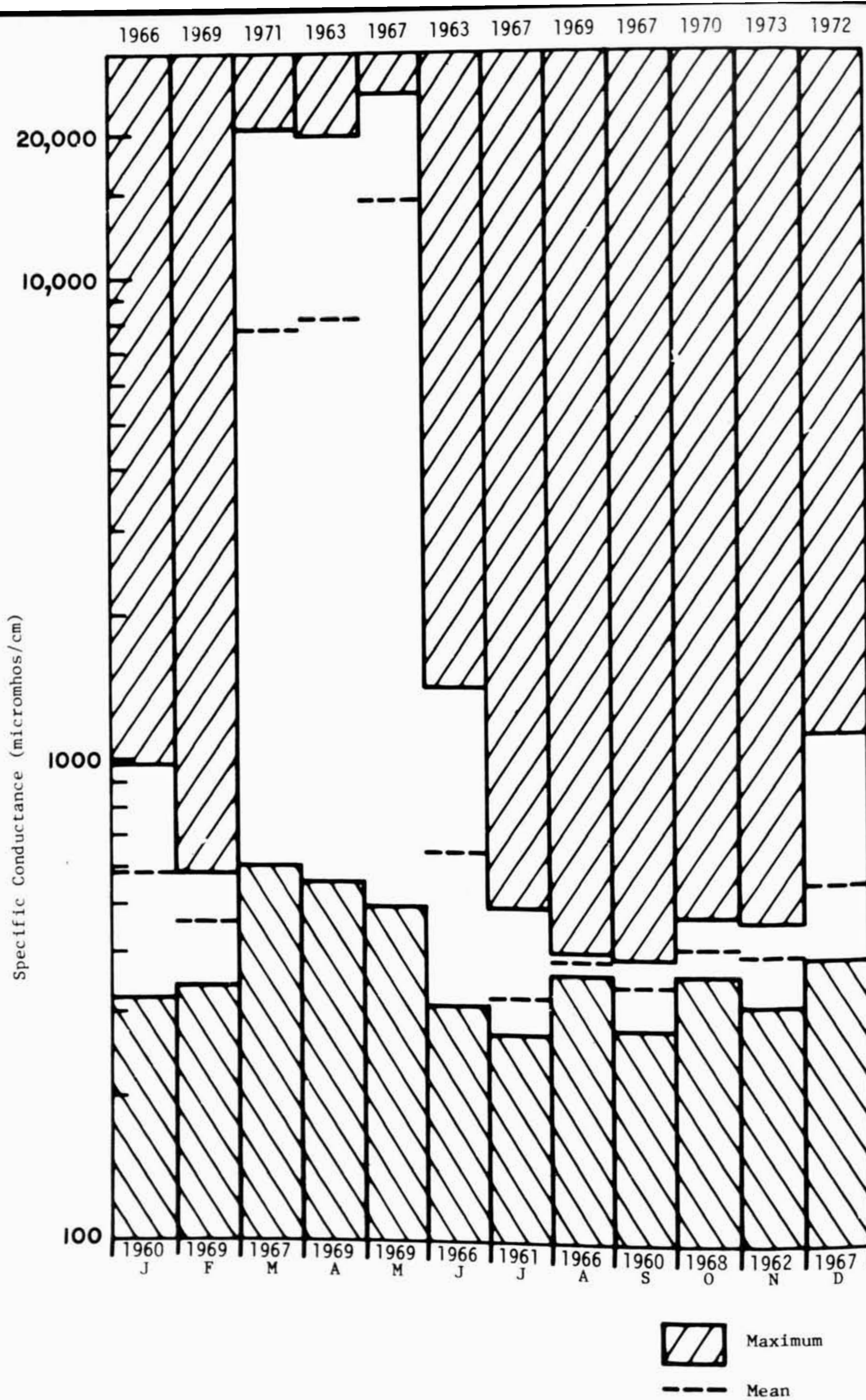

Figure 10: Monthly specific conductance (u mhos/cm) at Shark Slough station P-35 (1960-1979)

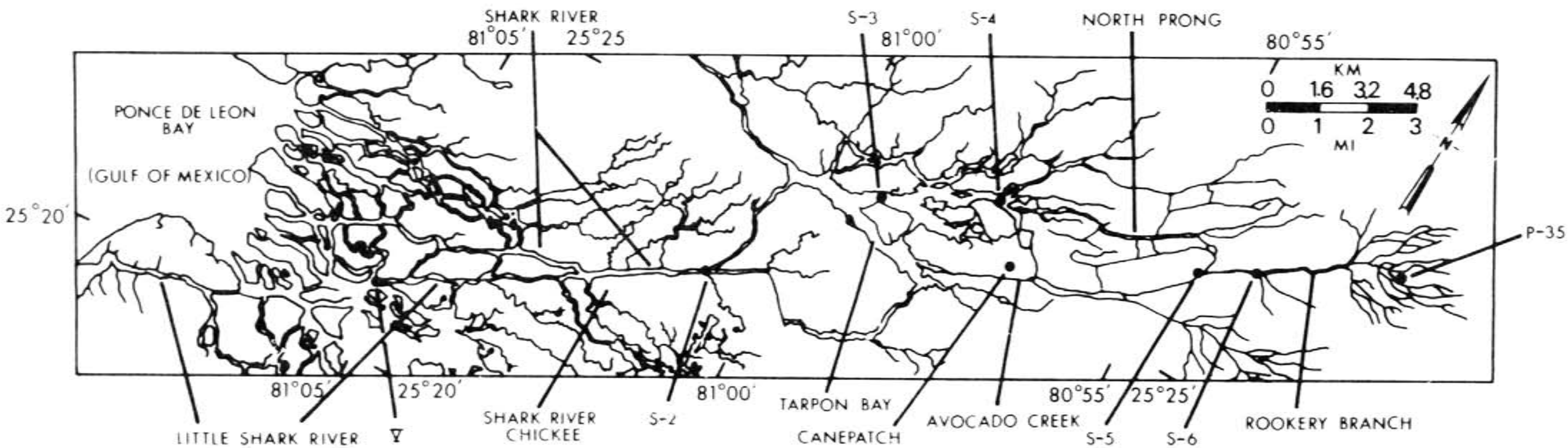

Figure 11: Map of the Shark River Estuary, Everglades National Park.

Table 6. Specific conductance/salinity distributions in the Shark River Estuary.

Date	Specific Conductance at P-35 (μmhos/cm)	Salinity (ppt) Station V	Shark River Chickee	S-2	S-3	S-4	Banana Patch S-5	Rookery Branch S-6	Comments
30 Mar 62*	13,300								
03 Apr 62**				20.0	19.0	15.0	10.0	9.0	dry season
23 Apr 63*	19,800								
24 Apr 63**				34.0	29.0	27.0	22.0	21.0	dry season
14 Apr 65**				23.0	19.0	18.0	13.0	13.0	
28 Apr 65*	7,200								
17 May 65**				26.0	21.0	19.0	15.0	15.0	dry season
13 July 66*	311								
26 July 66**				0.3	0.1	0.1	0.1	0.1	wet season
12 Nov 73***		24.4	12.3				0.4	0.2	wet season
19 Nov 73*	442								
14 May 74***		37.0	38.2				27.9	20.5	dry season
15 May 74*	18,000								

*Date supplied from WATSTORE, U.S. Geological Survey.

**Marshall and Jones, unpublished data, on deposit at South Florida Research Center, Everglades National Park, Homestead, Florida.

***Davis, G. E. and C. Hilsenbeck. 1974. The Effects of Watershed Management on the Shark Slough, Whitewater Bay Estuary of Everglades National Park, South Florida Research Center, Everglades National Park, Homestead, Florida. Mimeograph.

of the Shark River Chickee. During the dry season, however, estuarine brackish water extends as far north as P-35. The extent of the northernmost boundary of the estuarine zone will change responding to the length and severity of the dry season.

Figure 12 shows changes in salinity during 24 hour periods in both the wet season (October, 1978) and dry season (April, 1979) at two stations in the Shark River estuary. These data indicate that the salinity recorded at stations throughout the estuary change seasonally. Additionally, diurnal changes in salinity, related to the tidal cycle were seen at Station 66 (Shark River Chickee) during the wet season, and as far north as Station 71 (Canepatch) during the dry season. Apparently, the zone of diurnal tidal influence will change seasonally dependent upon the volume of freshwater flow entering the estuary from Shark Slough.

NP-203, a recently added station in northern Shark Slough, is important in that water level, water and air temperature, rainfall and specific conductance were monitored hourly, via satellite telemetry. This hourly record, available from October, 1978 to September 1980, allows for the analysis of short-term changes in basic physical and chemical parameters at a single location. This information is instructive in understanding the effects of short-lived, but often extreme, hydrological events in Shark Slough.

Figure 13 shows mean daily specific conductance at NP-203 from October 1978 through January 1980. As would be expected, the mean specific conductance at NP-203 is higher during the dry season than during the wet season.

Several factors are responsible for this overall increase in specific conductance. During the dry season, the primary source of water into Shark Slough is S-12 delivery water. Because the water level in the conservation areas are also low at this time, the predominant source of water entering via the S-12 structures is canal water from the L-67A canal, which typically has a higher specific conductance.

During the dry season the overall diluting influence of the rainfall is greatly reduced because of the sharp decrease in precipitation tending to raise ion concentrations and thus specific conductance. Flow into the slough is reduced, during the dry season separating much of Shark Slough into distinct pools where biological organisms congregate. Finally, during the dry season evaporation tends to further concentrate the ions which are present.

In 1979, extreme increases in specific conductance which are attributable to evaporative drying of the slough and concentraton of biological organisms did not occur at NP-203 until mid-March when sheet flow at this station was severed. At that time specific conductance increased from 470 micromhos/cm to 785 micromhos/cm in only 2 weeks. Presumably, this increase would have continued, except that a storm on April 24, 1979, contributed more than 4.8 inches of rain in less than 24 hours (SFWMD, 1979) resulting in an overnight lowering of specific conductance at NP-203 to less than 400 micromhos/cm.

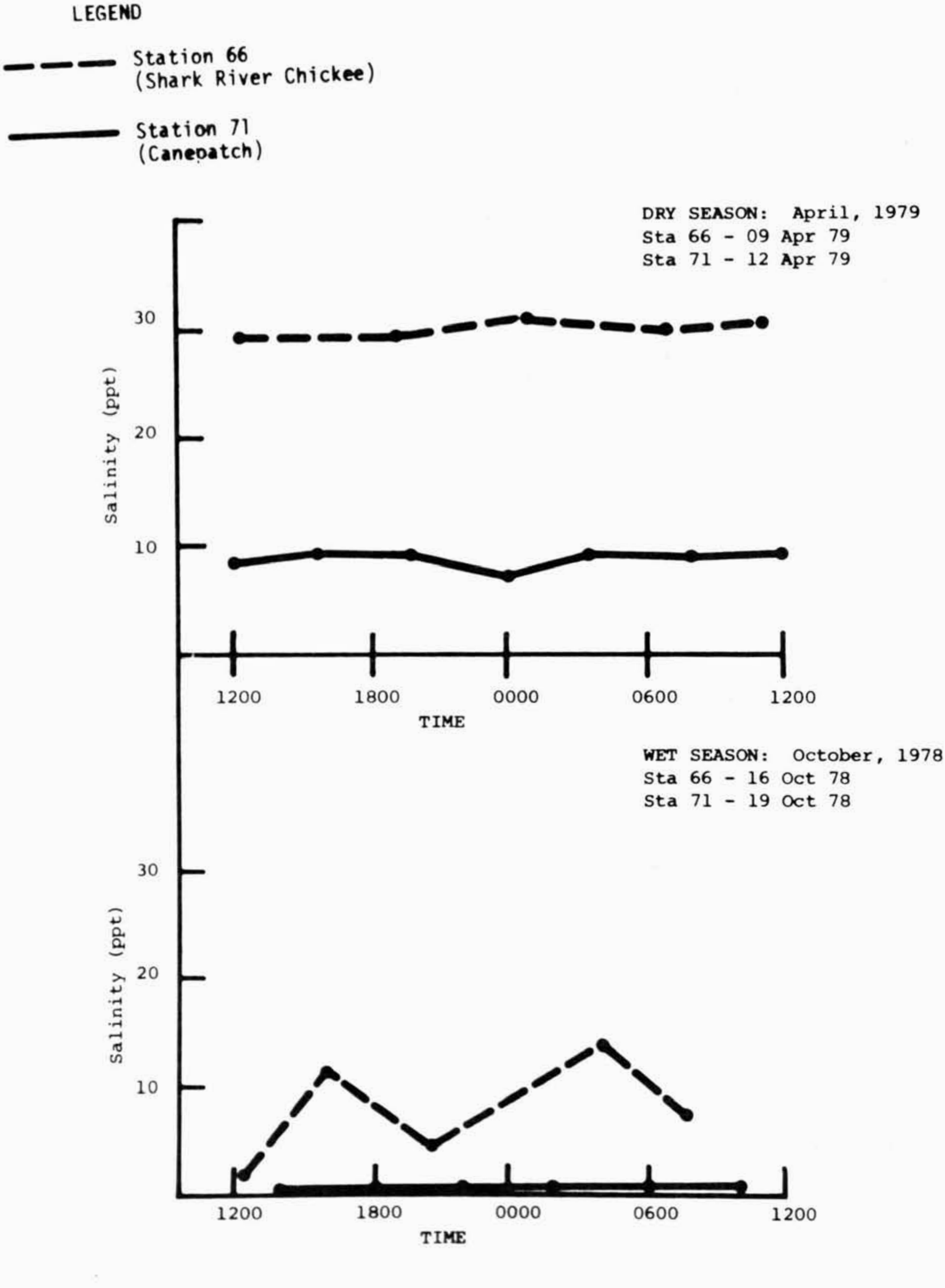

Figure 12: Wet season/dry season 24 hour salinity fluctuations in the Shark River estuary, Everglades National Park.

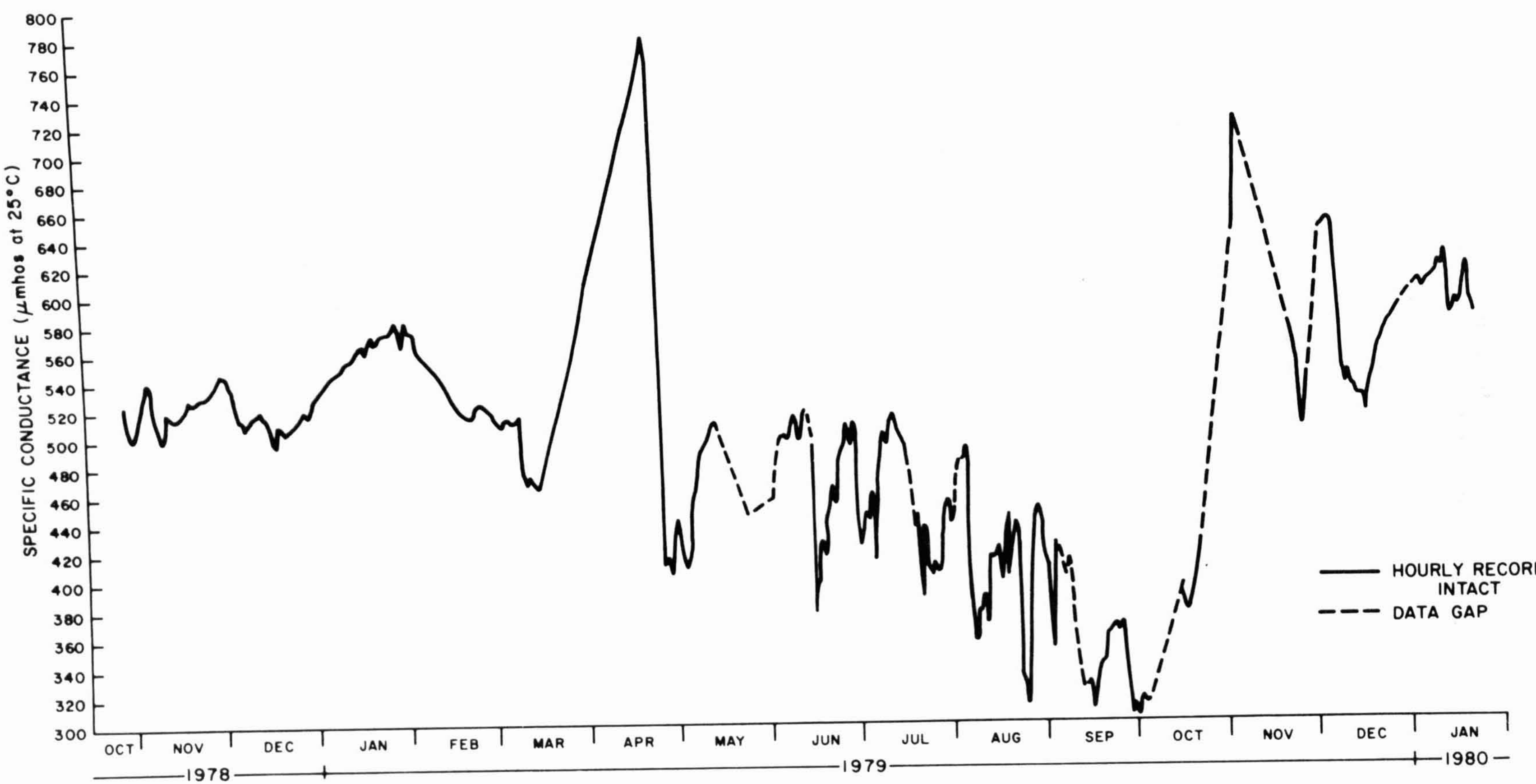

Figure 13. Daily specific conductance (umhos/cm at 25^{o}C) at NP-203, October 1978-January, 1980.

In October, 1979, specific conductance at NP-203, increased from about 300 micromhos/cm to approximately 700 micromhos/cm in less than 10 days. This unusual increase appears to be the result of flood releases into the park from water storage areas to the north. While specific conductance decreased significantly with the completion of the flood releases, a second series of flood releases again elevated the specific conductance at NP-203 during the last week of November. Because of these releases, specific conductance at NP-203 was higher during December, 1979 and January, 1980 than they were during the same months a year earlier.

Spatially, the analysis of specific conductance and ionic composition data for stations in central Shark Slough is quite complex, as there is a rapid response of both specific conductance and ionic concentration to changes in the hydrological regime including the amount and type of S-12 water delivery, rainfall, evaporation and periodic, dry season expansion of a salt wedge from the estuarine area in the lower extremes of Shark Slough. Because of the variation in water chemistry caused by both climatological and hydrological events, significant variability is found seasonally within the data set for each individual station, as well as spatially, among the stations. Because of this, cause and effect analysis is complex with the resultant specific conductance and ionic composition being a function of several independently operating variables. Therefore, a single measurement of specific conductance at a single site reveals little. When specific conductance data are collected periodically over a large area and these data are related to data gained from occasional complete chemical analysis, the resultant information can be of great value in assessing the results of changes in the hydrological regime on the water in Shark Slough (See Section IV).

D. Shark Slough: Edge of Slough

Factors influencing the specific conductances and ionic composition of two additional long-term stations (P-34 and P-38) located along the periphery of Shark Slough may be different from those influencing the water in the central slough.

Mean specific conductance at P-34 ($\bar{x}$ = 401 micromhos/cm) and P-38 ($\bar{x}$ = 505 micromhos/cm) do not vary significantly from those found in central Shark Slough. In some years, however, dry down will occur earlier at these stations because of the higher ground elevation than in central Shark Slough. When this occurs, the specific conductance in remaining pools and depressions may be higher than that found in the central slough proper though most of the area will remain dry until the following wet season.

Station P-38 is located in a depression which retains water even when the surrounding slough is dry. While the water quality at this station reflects that found in the central slough during the wet season, the effects of evaporation are amplified in the dry season and the specific conductance at this station is elevated relative to the central slough locations (Figure 14).

IV. Shark Slough Biweekly Specific Conductance Monitoring Program

From December 1977 through September 1979, specific conductance and accumulated rainfall were monitored at 97 locations throughout Shark Slough. The specific conductance data were analyzed, plotted and contoured at intervals of

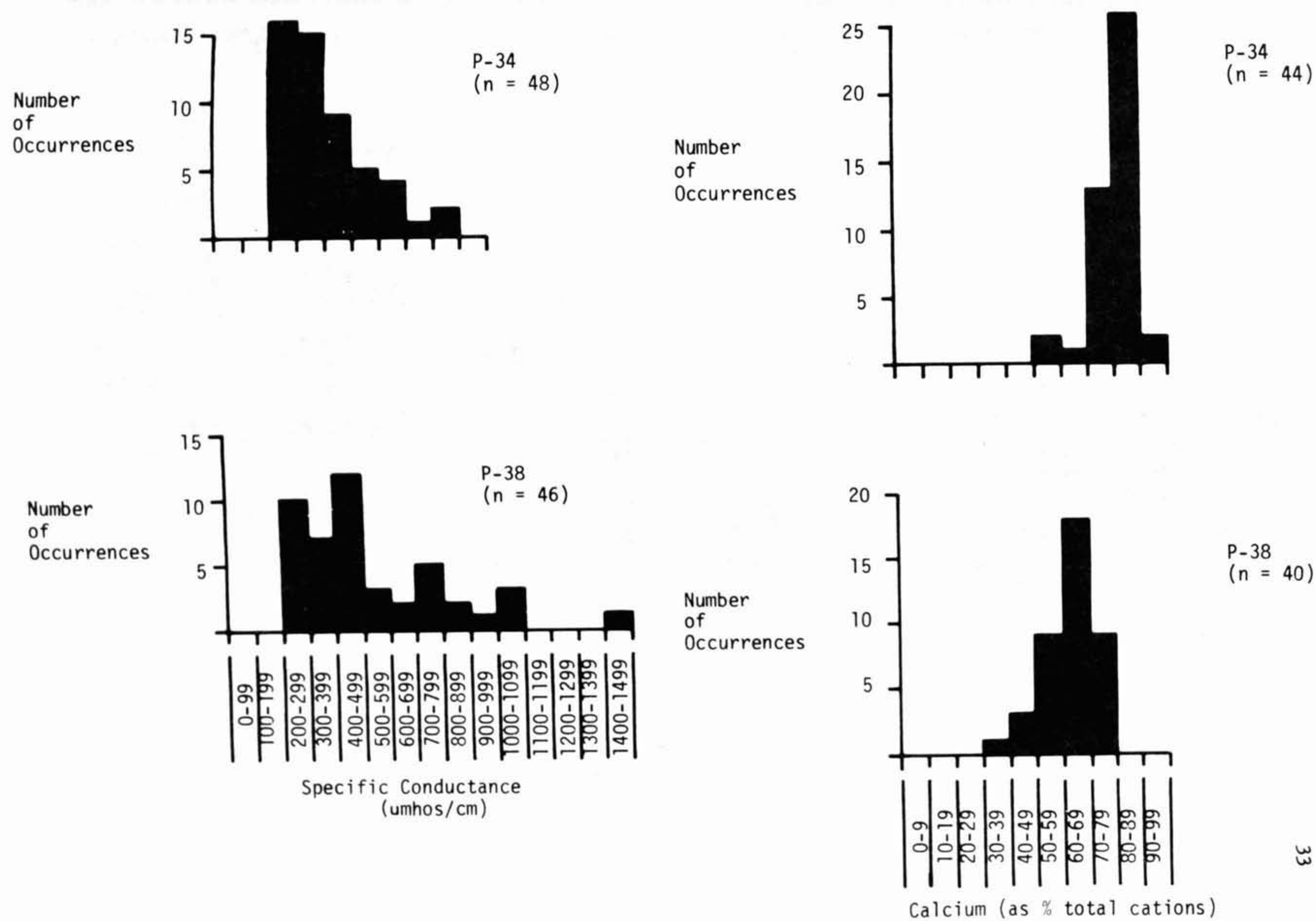

Figure 14. Specific conductance and % calcium frequency histograms for long-term stations at the edge of Shark Slough.

100 micromhos/cm while total biweekly rainfall in Shark Slough was calculated using the Thiessian Polygon method (Lew et al., in prep.). Additionally, the total amount of water delivery at each S-12 structure was ascertained from the U.S. Army Corps of Engineers reports in order that changes in spatial specific conductance patterns in Shark Slough could be related to rainfall and S-12 water delivery patterns.

Biweekly rainfall amounts and S-12 water delivery patterns are summarized over this period of time (Figure 15). To further simplify analysis, these biweekly data were grouped into 11 distinct time periods (I-XI), of 2-12 weeks duration, during which similar patterns of hydrologic inputs existed. The hydrological conditions during each of these periods are summarized in Table 7.

Iso-conductivity contour maps were constructed for each biweekly sampling (Figures 16-19, Appendix I) and are analyzed with respect to the prevailing hydrological conditions. An analysis of these contours show that several factors influence the spatial distribution of specific conductance in Shark Slough. The most important factors in determining specific conductance appears to be rainfall and changes in the amount of S-12 water delivery.

From December 1, 1977 to February 8, 1978 (Period I) water inputs to Shark Slough consisted of 61 percent rainfall and 39 percent S-12 delivery, and were quite low. The specific conductance contours for December 28, 1977 (Figure 16A) and February 9, 1978 (Figure 16B) show that specific conductance slowly increased, as Shark Slough began to dry down.

While most areas of the slough had specific conductance levels of approximately 400-500 micromhos/cm in late December 1977, all inundated areas were more than 500 micromhos/cm by February 1978, with localized pockets having specific conductance values greater than 1000 micromhos/cm. The dominant controlling mechanism during this period appears to be a lack of precipitation and reduced water deliveries causing a gradual drawdown, with the effects of evaporation becoming most obvious in areas cut off from sheet flow.

Between February 6, 1978 and March 9, 1978 (Period II), Shark Slough rainfall inputs increased threefold while S-12 discharge decreased significantly. The effects of this increased water input can be seen in the Shark Slough specific conductance contours for February 23, 1978 (Figure 16C), where specific conductance has decreased, overall, to 300-500 micromhos/cm and the pockets of high conductivity seen on February 9, 1978 (Figure 16B) have disappeared. The important controlling mechanism during Period II was an unseasonably high rainfall, which served both to raise water levels and to dilute the ionic constituents in the surface water.

The hydrological regime from March 10, 1978 through April 5, 1978 (Period III) was influenced by greatly reduced rainfall and moderately increased S-12 delivery. During this time, specific conductance began to rise, as a response to increased S-12 delivery and continued evaporation. Specific conductance contours for March 22, 1978 (Figure 16D) document overall increases in specific conductance to between 500 micromhos/cm and 700 micromhos/cm. By April 7, 1978 (Figure 17A)

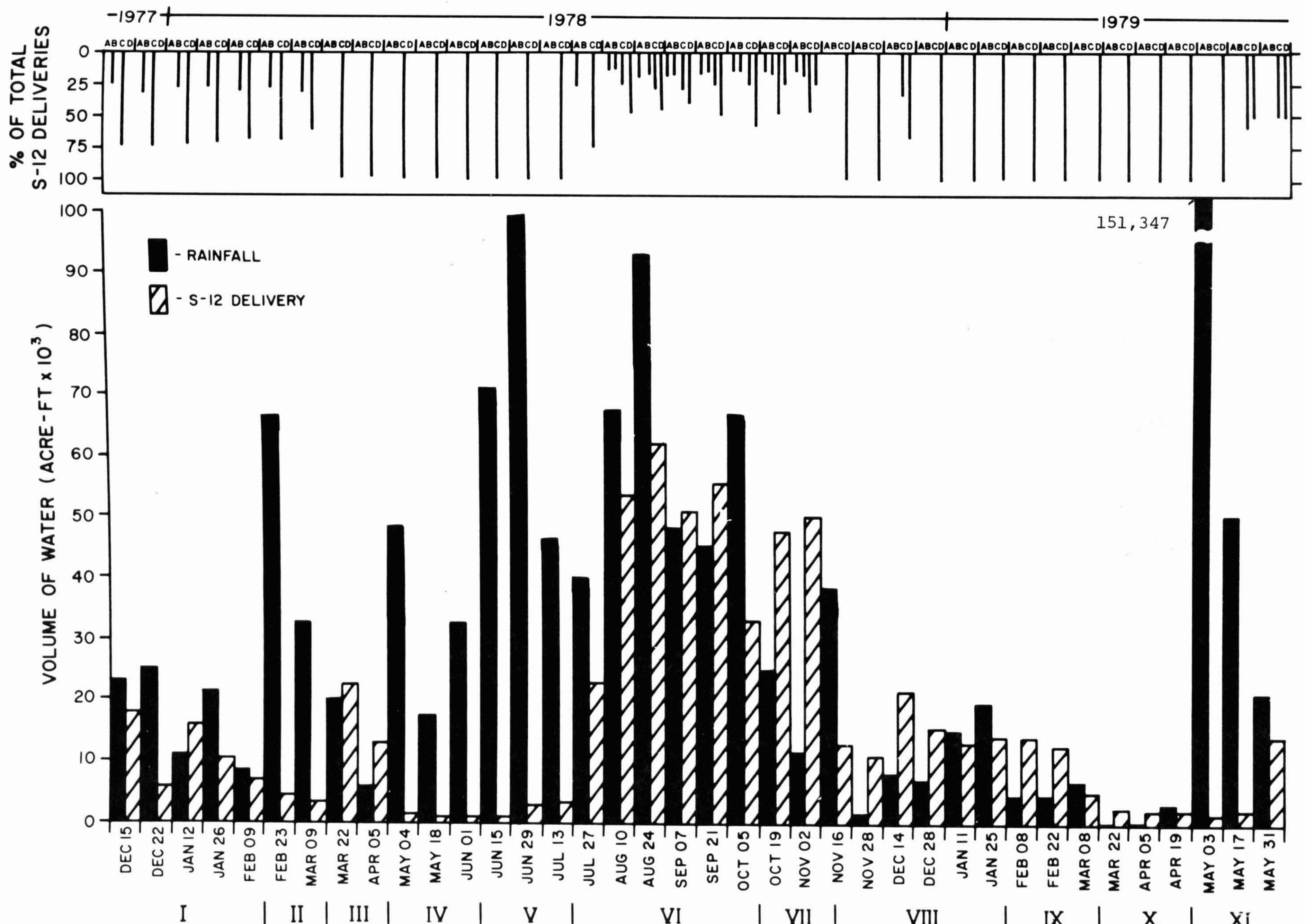

Figure 15. Biweekly water contribution to Shark Slough via S-12 delivery and rainfall (December 1977-May 1979).

Table 7. Summary of S-12 Deliveries and Rainfall Accumulation for Shark Slough (December 1977-May 1979)

Number	Dates Included	Mean Rainfall per 2 week period (ACFT x 10^3)	Mean S-12 Delivery per 2 week period (ACFT x 10^3)	% Delivery through each S-12 Structure	Changes
I	01 DEC 77 - 09 FEB 78	18.4	11.5	B: 30% C: 70%	
II	10 FEB 78 - 09 MAR 78	51.4	4.0	B: 30% C: 70%	Large increase in rainfall Moderate decrease in S-12 Delivery
III	10 MAR 78 - 05 APR 78	13.1	17.8	C: 100%	Large decrease in rainfall Moderate increase in S-12 delivery Change in gate opening
IV	06 APR 78 - 01 JUNE 78	24.9	0.8	C: 100%	Moderate increase in rainfall Large decrease in S-12 delivery
V	02 JUNE 78 - 13 JULY 78	71.9	2.7	C: 100%	Large increase in rainfall
VI	14 JULY 78 - 05 OCT 78	60.2	46.3	A: 12.5% B: 12.5% C: 25% D: 50%	Slight decrease in rainfall Large increase in S-12 Delivery Change in gate opening
VII	06 OCT 78 - 02 NOV 78	18.2	48.8	A: 12.5% B: 12.5% C: 50% D: 25%	Large decrease in rainfall Change in gate opening

Number	Dates Included	Mean Rainfall per 2 week period (ACFT x 10^3)	Mean S-12 Delivery per 2 week period (ACFT x 10^3)	% Delivery through each S-12 Structure	Changes
VIII	03 NOV 78 - 25 JAN 79	15.2	14.6	D: 100%	Slight decrease in rainfall Large decrease in discharge Change in gate opening
IX	26 JAN 79 - 08 MAR 79	5.2	10.7	D: 100%	Slight decrease in rainfall Slight decrease in discharge
X	09 MAR 79 - 19 APR 79	1.2	2.2	D: 100%	Decrease in rainfall Decrease in discharge (Very Dry)
XI	20 APR 79 - 31 MAY 79	74.4	5.8	C: 50% D: 50%	EXTREME RAINFALL EVENT

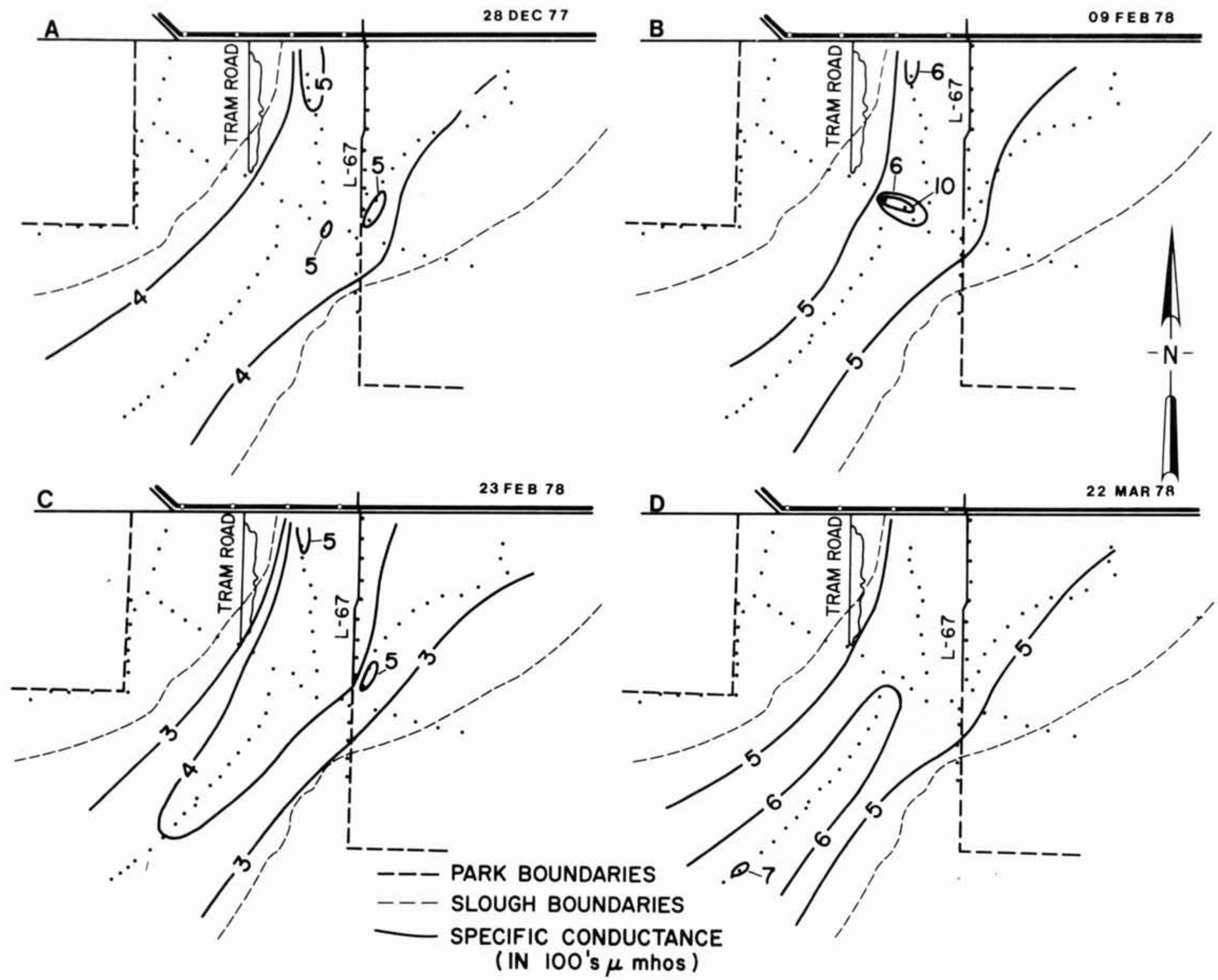

Figure 16. Specific conductance contours for Shark Slough (December, 1977 - March, 1978).

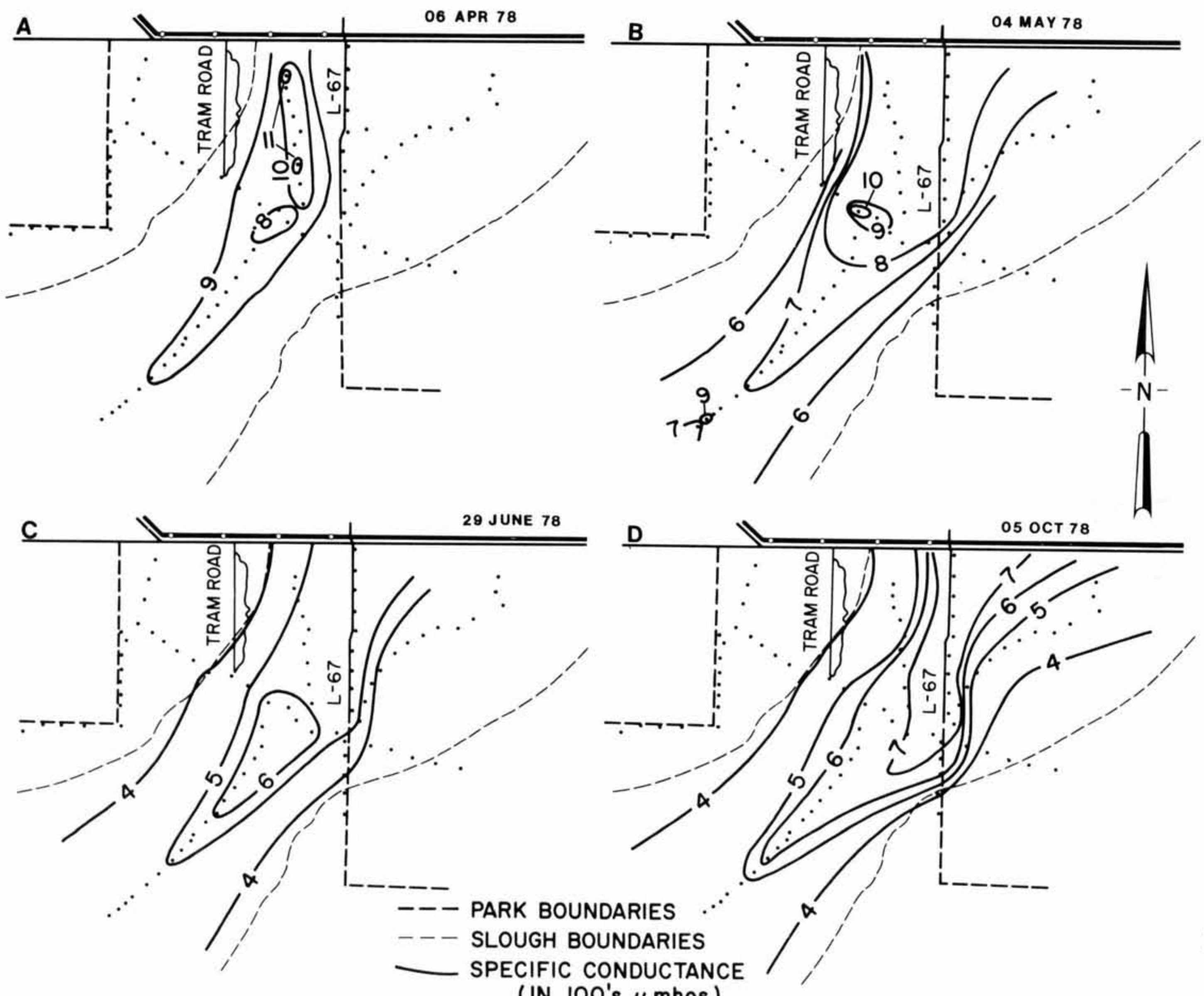

Figure 17. Specific conductance contours for Shark Slough (April, 1978 - October, 1978).

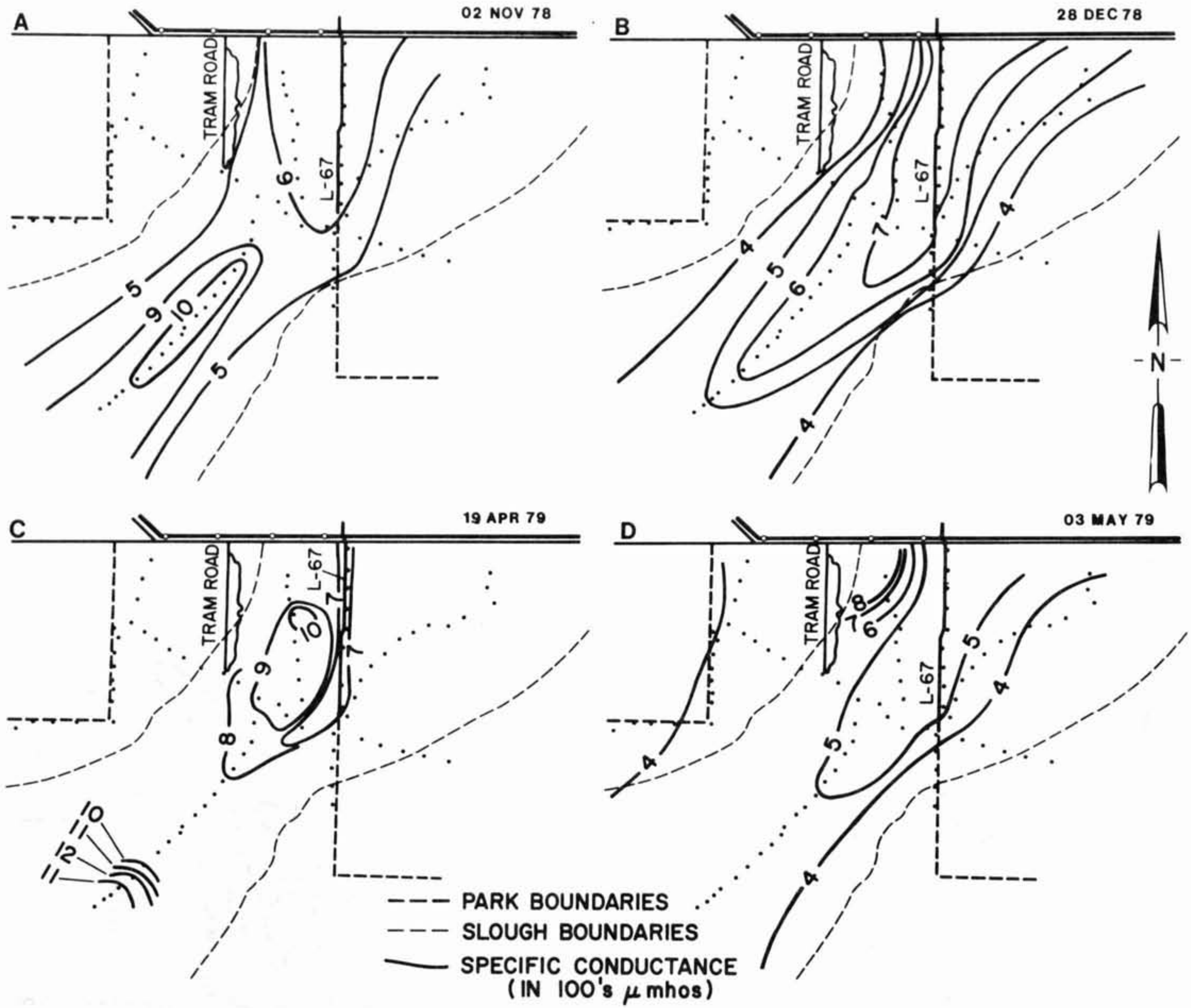

Figure 18. Specific conductance contours for Shark Slough (November, 1978 - May, 1979).

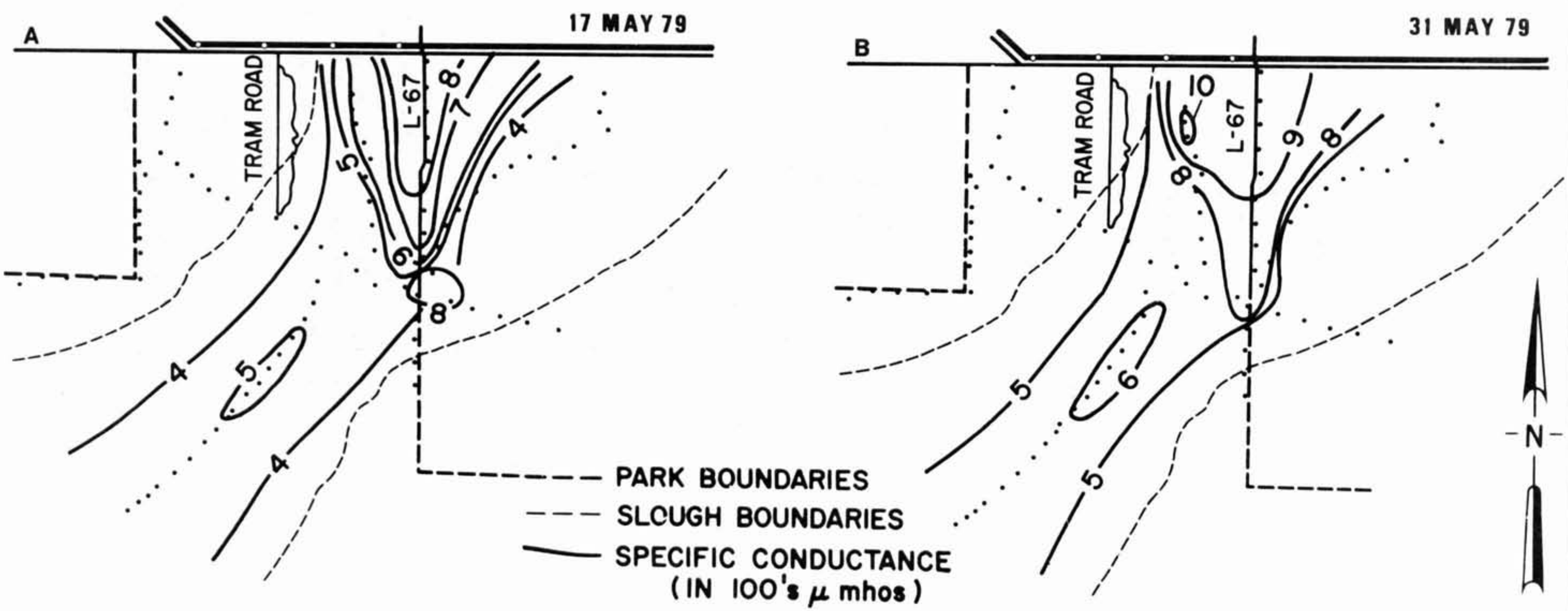

Figure 19. Specific conductance contours for Shark Slough (May, 1979).

specific conductance had increased greatly, to greater than 900 micromhos/cm, in response to evaporation greatly outpacing new water delivery. Additionally, the area of the slough inundation had been greatly reduced.

Period IV, lasting from April 6, 1978 to June 1, 1978 is characterized by more than a doubling in rainfall and an almost total stoppage of S-12 delivery. While the overall amount of water entering the slough is approximately equal in Periods III and IV, the specific conductance character changes significantly. On May 4, 1978 (Figure 17B), high specific conductance levels still exist, though somewhat lower than those previously found on April 6, 1978 (Figure 17A). The area of inundation has increased, and pockets of very high conductivities are beginning to decrease. These changes signal change from "falling" water conditions to "rising" water conditions brought about by the beginning of the wet season.

From June 2, 1978 to July 13, 1978 (Period V), Shark Slough experienced a large increase in rainfall and a slight increase in S-12 water delivery, typical of the hydraulic regime of the wet season. Specific conductance during this period dropped sharply throughout the slough (Figure 17C).

The largest annual total water input to the slough occurred from July 14, 1978 through October 5, 1978 (Period VI). While both rainfall and S-12 water delivery were high throughout this time, it is interesting that this was not the period of lowest specific conductance for the year. Because of the large increase in S-12 delivery, more and more canal waters reach Shark Slough.

By October 5, 1978, specific conductance values are low in the southern part of the slough (Figure 17D), yet remain high near the point of S-12 delivery and along the L67 (extended) canal. Dilution of the S-12 delivery water occurs as the surface waters move southward and are diluted by rainfall, resulting in a conductivity gradient decreasing from north to south.

The dry season began in early October 1978. The time period extending from October 6, 1978 through November 2, 1978 (Period VII) was characterized with a threefold decrease in rainfall, but S-12 discharges continued to be high. Specific conductance contours for November 2, 1978 (Figure 18A) show specific conductances of greater than 600 micromhos/cm in northern Shark Slough, increasing to more than 900 micromhos/cm in southern Shark Slough.

From November 3, 1978 through January 25, 1979 (Period VIII) S-12 water delivery is also reduced. In response to this reduction, specific conductance patterns on December 28, 1978 (Figure 18B) change. While specific conductance remains greater than 700 micromhos/cm along L-67 (extended), the areal extent of canal water influence is reduced and the specific conductance of water in southern slough are slightly reduced.

Further reductions in both rainfall and discharge occur throughout the remainder of the dry season (Period IX and Period X) resulting in the seasonal drydown of Shark Slough. The specific conductance contours for April 19, 1979 (Figure 18C) show Shark Slough during the peak of the 1979 dry season. Specific conductance exceeds 700 micromhos/cm throughout the slough with areas cut off from the reduced sheet flow exceeding 1000 micromhos/cm. Additionally the southern portion of the slough is influenced by estuarine waters moving northward in response to reduced freshwater flow.

The hydrological regime changed abruptly on April 24, 1979 with an extreme precipitation event, described earlier, reflecting the large increase in the area of inundation and a great reduction in specific conductance levels throughout the slough (Figure 18D). There is an unusual area of high specific conductance immediately south of the S-12 structures which may indicate increased S-12 discharge in response to this extreme rainfall event. By May 17, 1979 (Figure 19A) the extent of this area of higher specific conductance has increased due to canal inflows, a trend which continued (Figure 19B) until wet season rain contribution exceeded canal delivery near the end of June.

CONCLUSIONS

The inorganic ion concentration of the source water to Shark Slough and amount of rainfall in Shark Slough were determined to be the most important factors influencing ionic concentrations within the slough itself.

The major sources of water delivered to the slough include rainfall and surface waters entering via the S-12 delivery structures, the quality of this latter source having changed over the years. Prior to the construction of Levee L-29 in 1962, the major source of overland flow to Shark Slough was a calcium bicarbonate type marsh water, having a mean specific conductance of 272 micromhos/cm and a sodium:calcium ratio of 0.34. Since levee completion, the character of the surface water delivered to Shark Slough has changed, now having a mean specific conductance of 653 micromhos/cm and a sodium:calcium ratio of 0.88.

These shifts in water quality were attributable to anthropogenic changes in the hydrological system of south Florida, especially the development of Levee 29 and the Miami and L-67 canals allowing water to largely bypass the marsh system and flow southward via a series of canals. Although shifts in ionic concentrations were noted, the effects of these subtle changes in specific conductance and ionic composition on the productivity and food web structure in Shark Slough are not known.

Rainfall, another input of water to the slough, has also been found to be important in the determination of overall water quality. It was found that rainfall serves to dilute the surface water in Shark Slough enhancing the overall quality of the water. During the wet season, the overall specific conductance of the slough was found to be lower, and somewhat dependent on the frequency and magnitude of storm events.

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Appendix A: Specific conductance isocontours for Shark Slough November 1977-May 1979

A-1. 16 Nov 77-28 Dec 77

A-2. 11-12 Jan 78-23 Feb 78

A-3. 08-09 Mar 78-04 May 78

A-4. 18 May 78-29 Jun 78

A-5. 10 Aug 78-05 Oct 78

A-6. 20 Oct 78-28 Dec 78

A-7. 25 Jan 79-08 Mar 79

A-8. 22 Mar 79-03 May 79

A-9. 17 May 79-26 Jul 79

A-10. 09 Aug 79-20 Sep 79

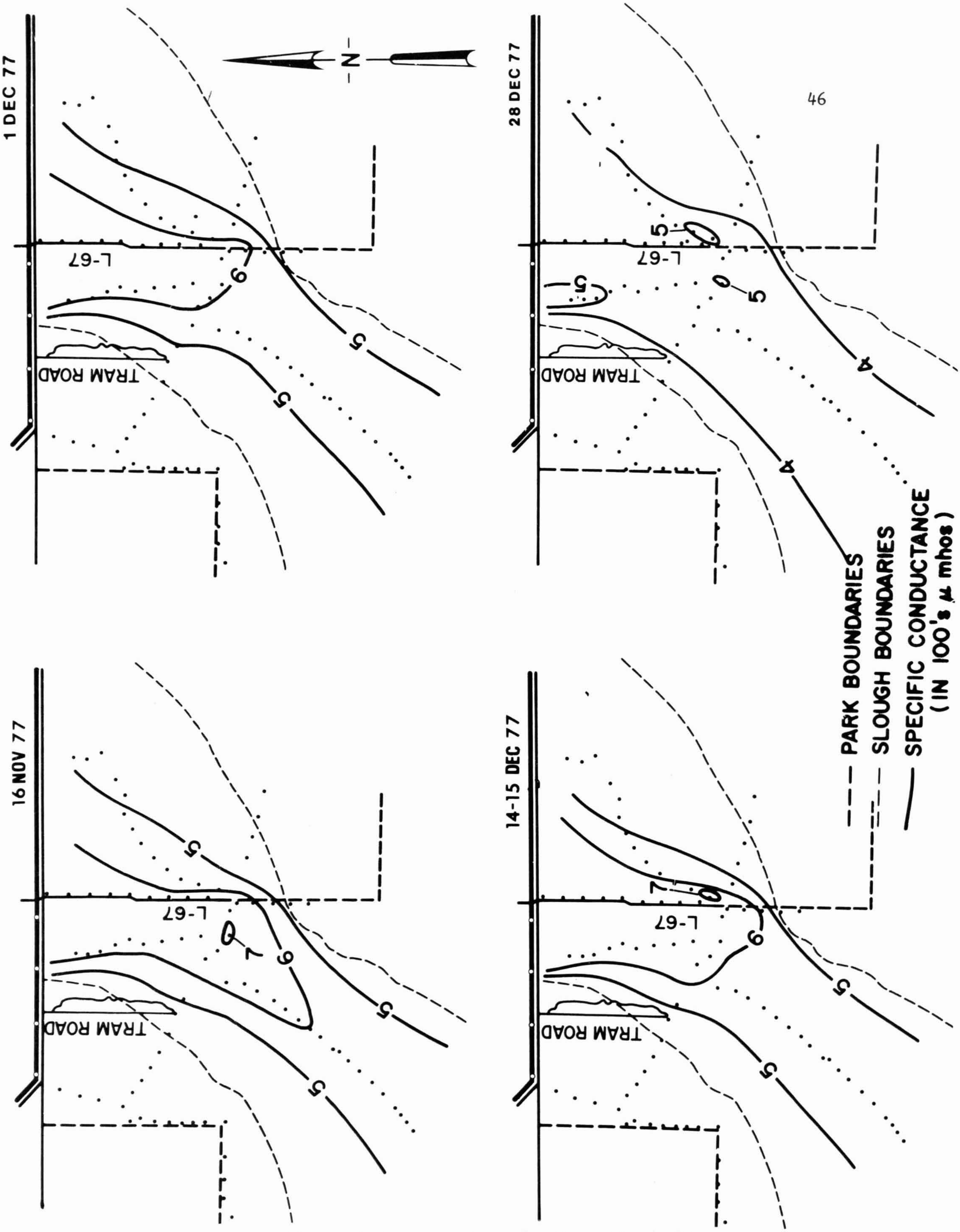

Figure A-1. Specific conductance contours for Shark Slough (November 16, 1977-December 28, 1977).

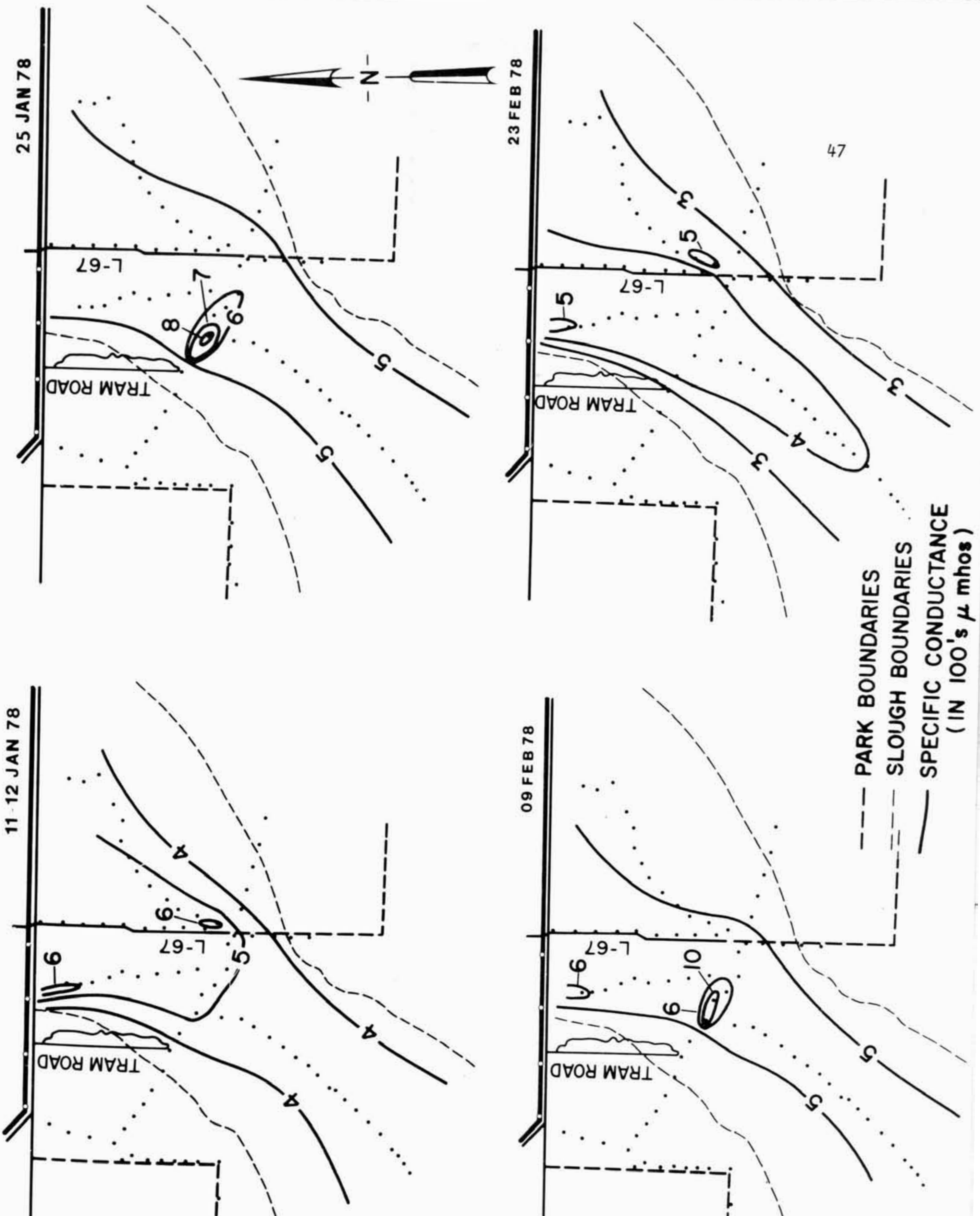

Figure A-2. Specific conductance contours for Shark Slough (January 11-12, 1978-February 23, 1978).

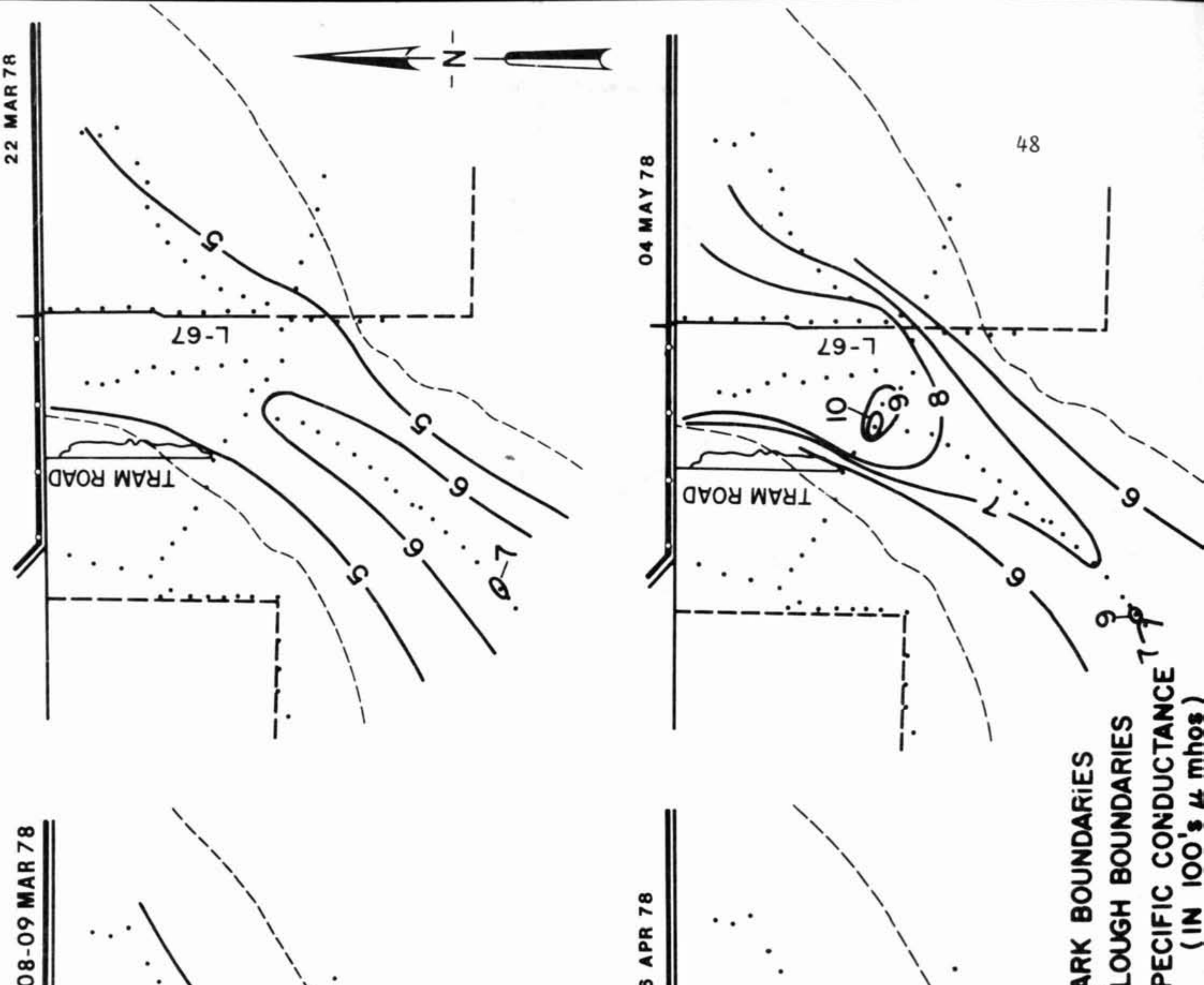

Figure A-3. Specific conductance contours for Shark Slough (March 8-9, 1978-May 4, 1978).

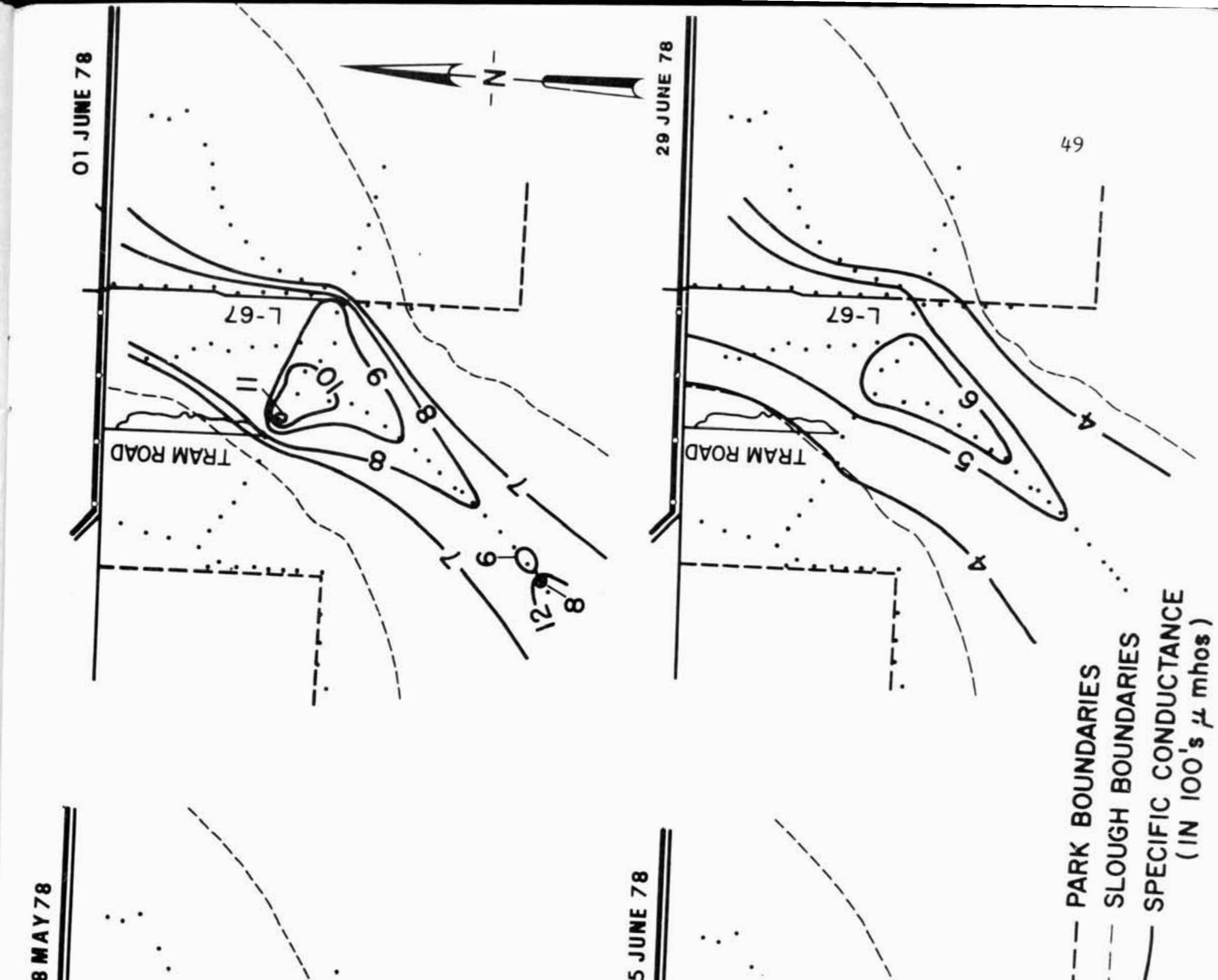

Figure A-4. Specific conductance contours for Shark Slough (May 18, 1978-June 29, 1978).

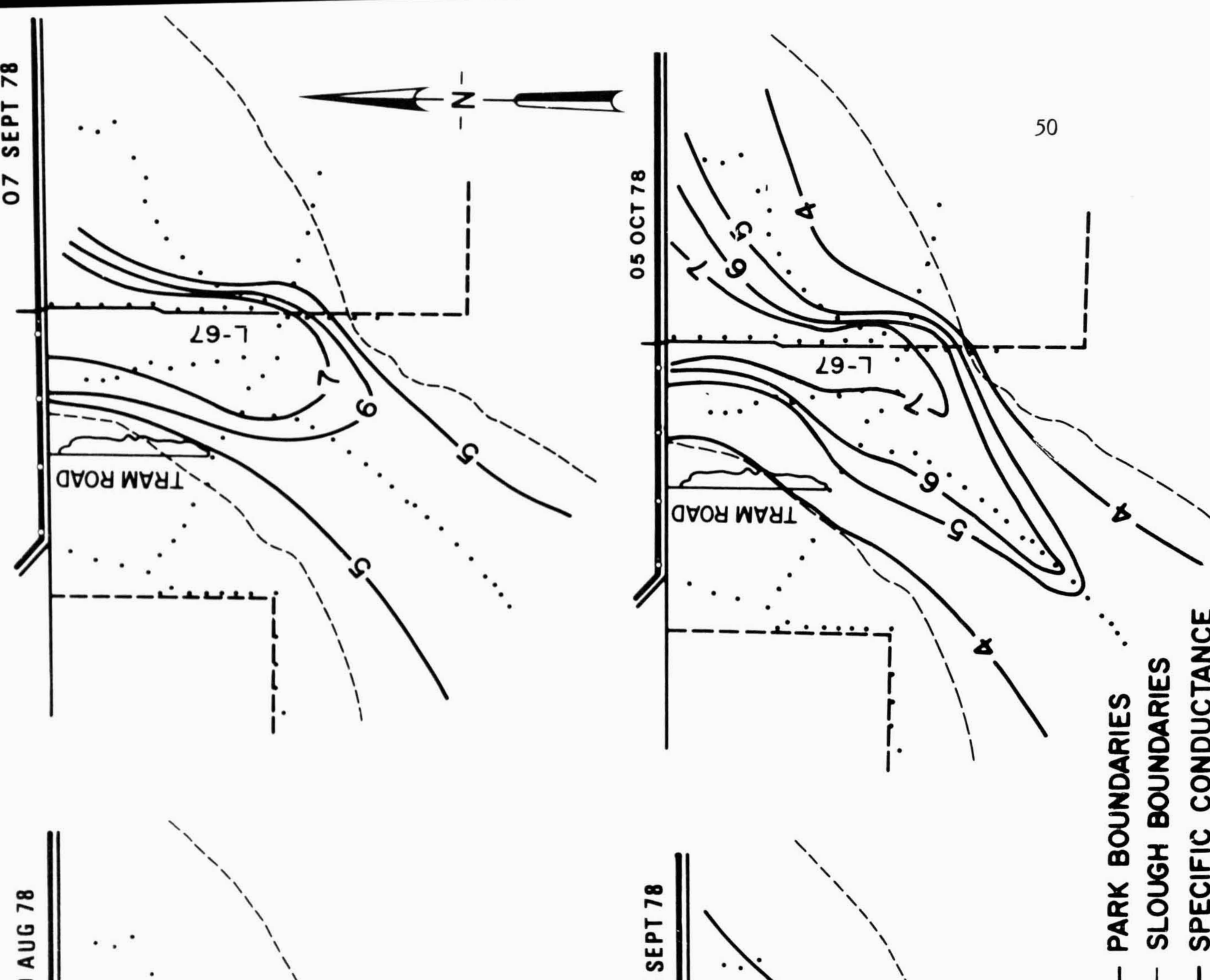

Figure A-5. Specific conductance contours for Shark Slough (August 10, 1978-October 5, 1978).

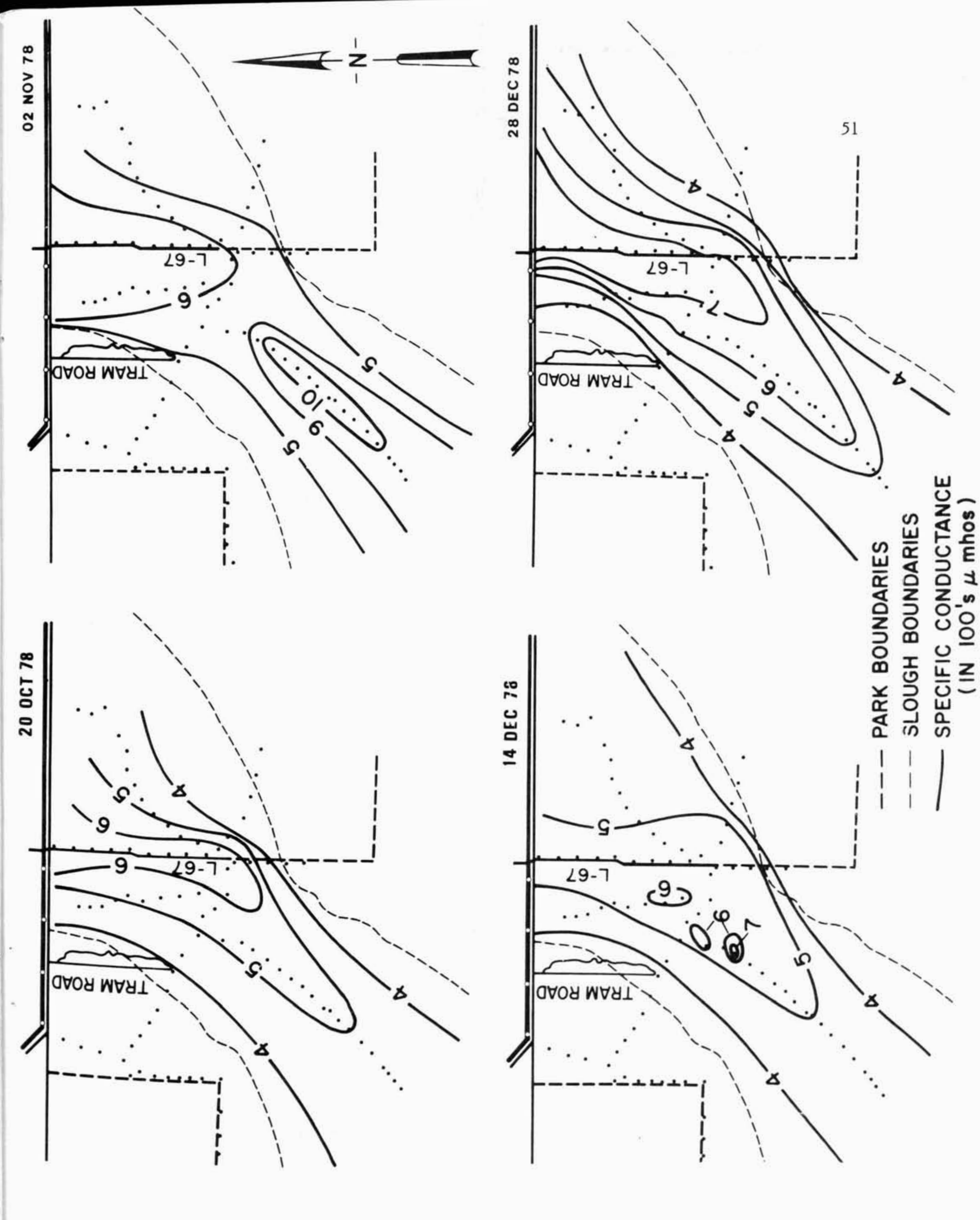

Figure A-6. Specific conductance contours for Shark Slough (October 20, 1978-December 28, 1978).

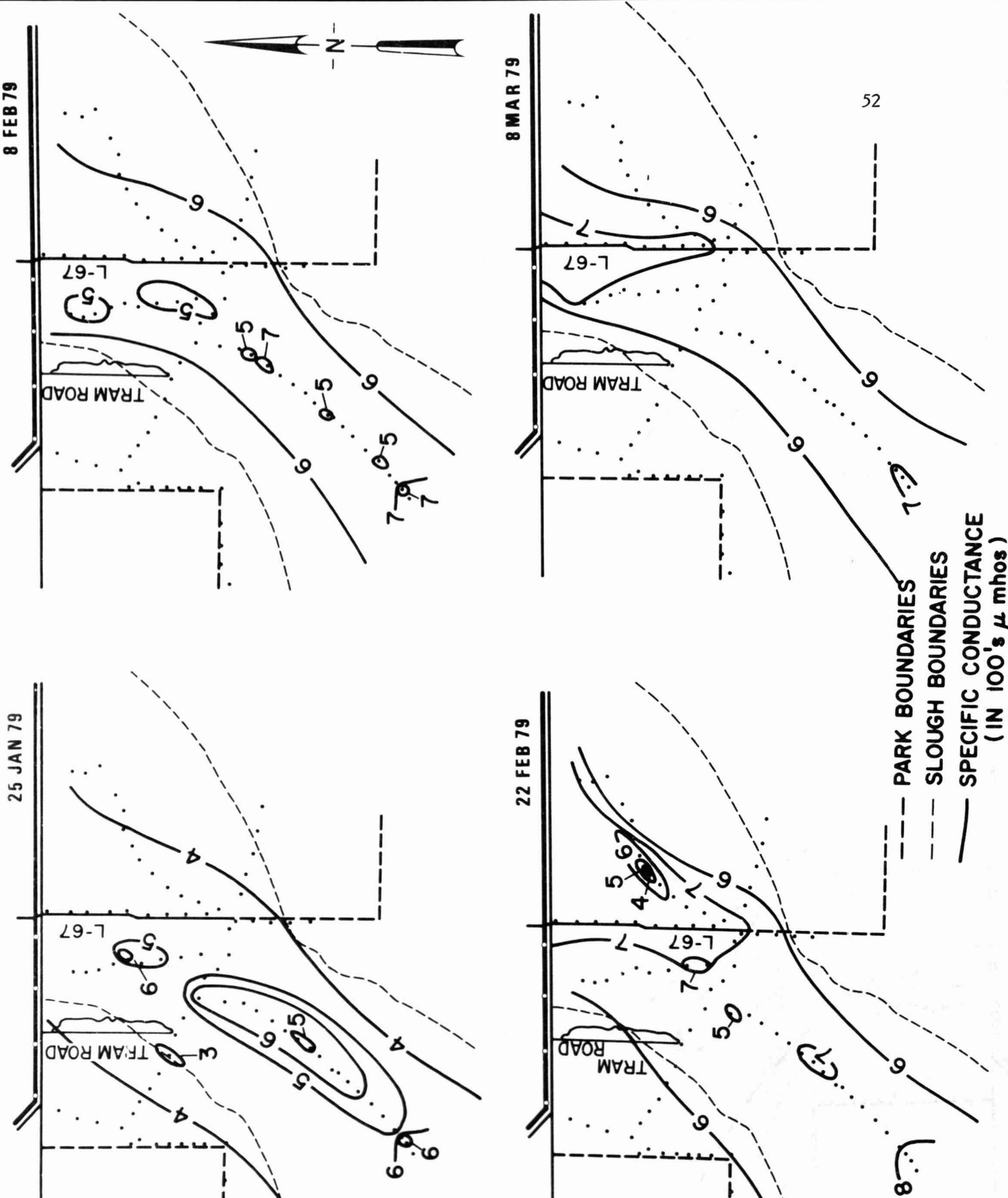

Figure A-7. Specific conductance contours for Shark Slough (January 25, 1979-March 8, 1979).

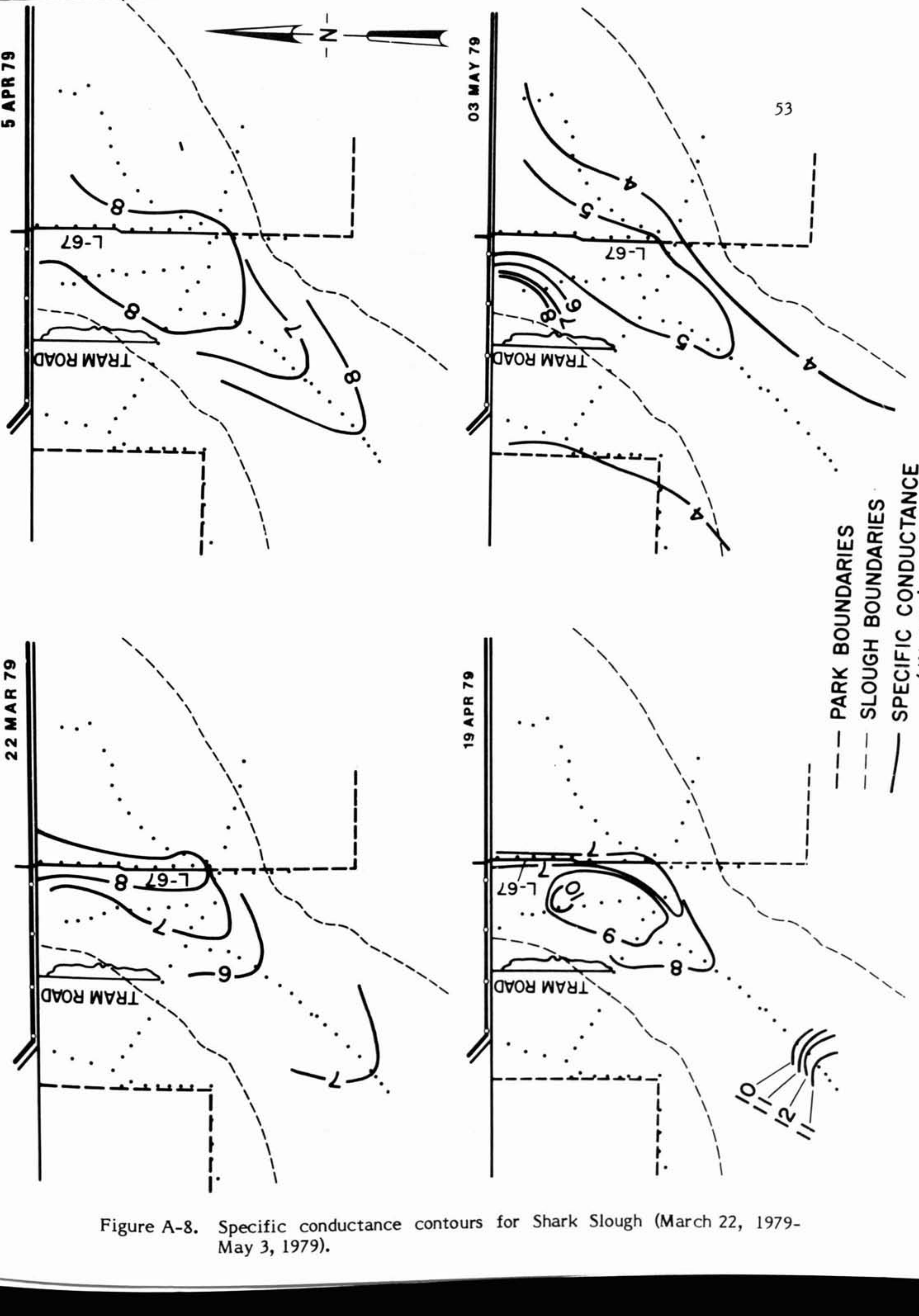

Figure A-8. Specific conductance contours for Shark Slough (March 22, 1979-May 3, 1979).

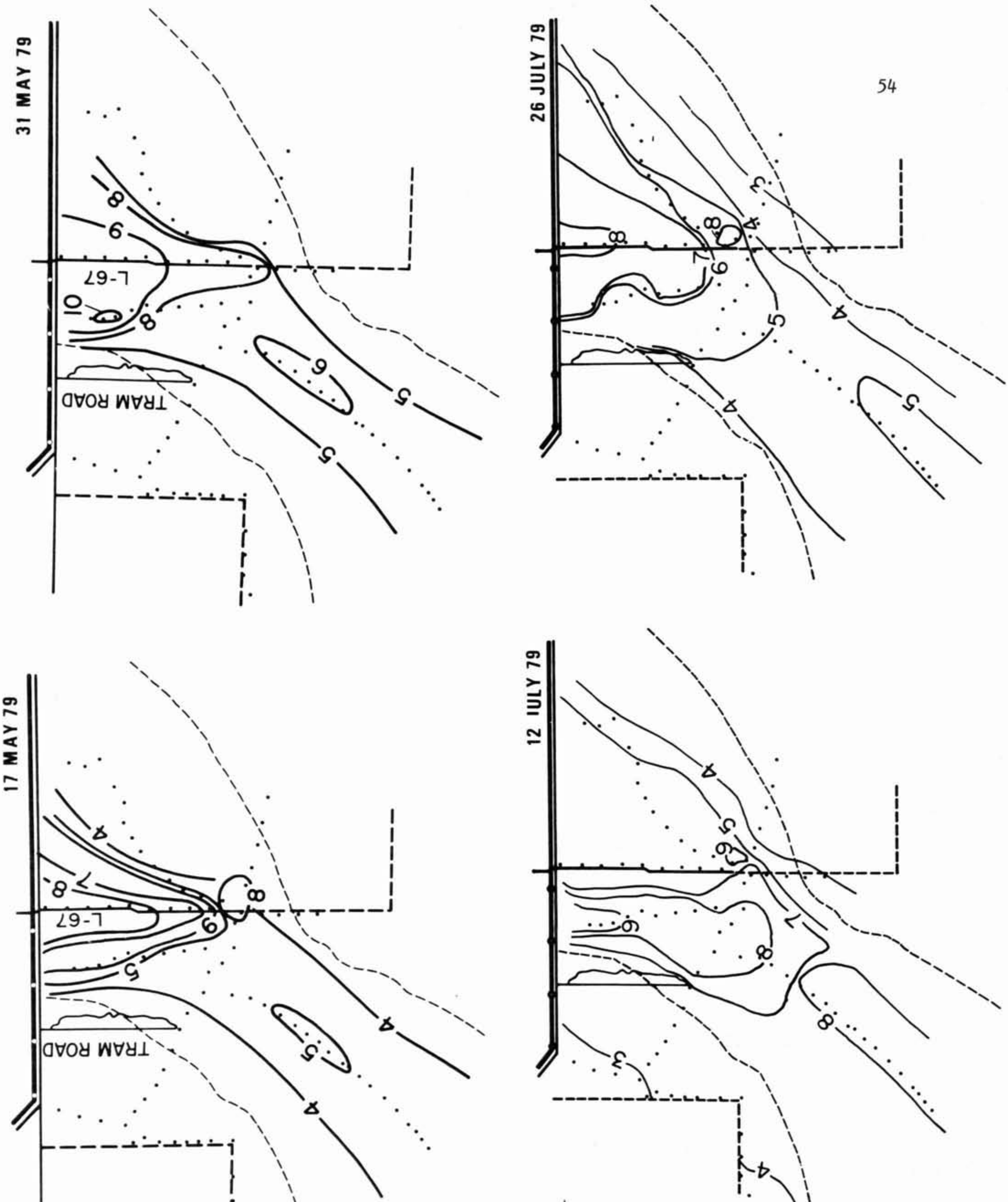

Figure A-9. Specific conductance contours for Shark Slough (May 17,1979 - July 26,1979).

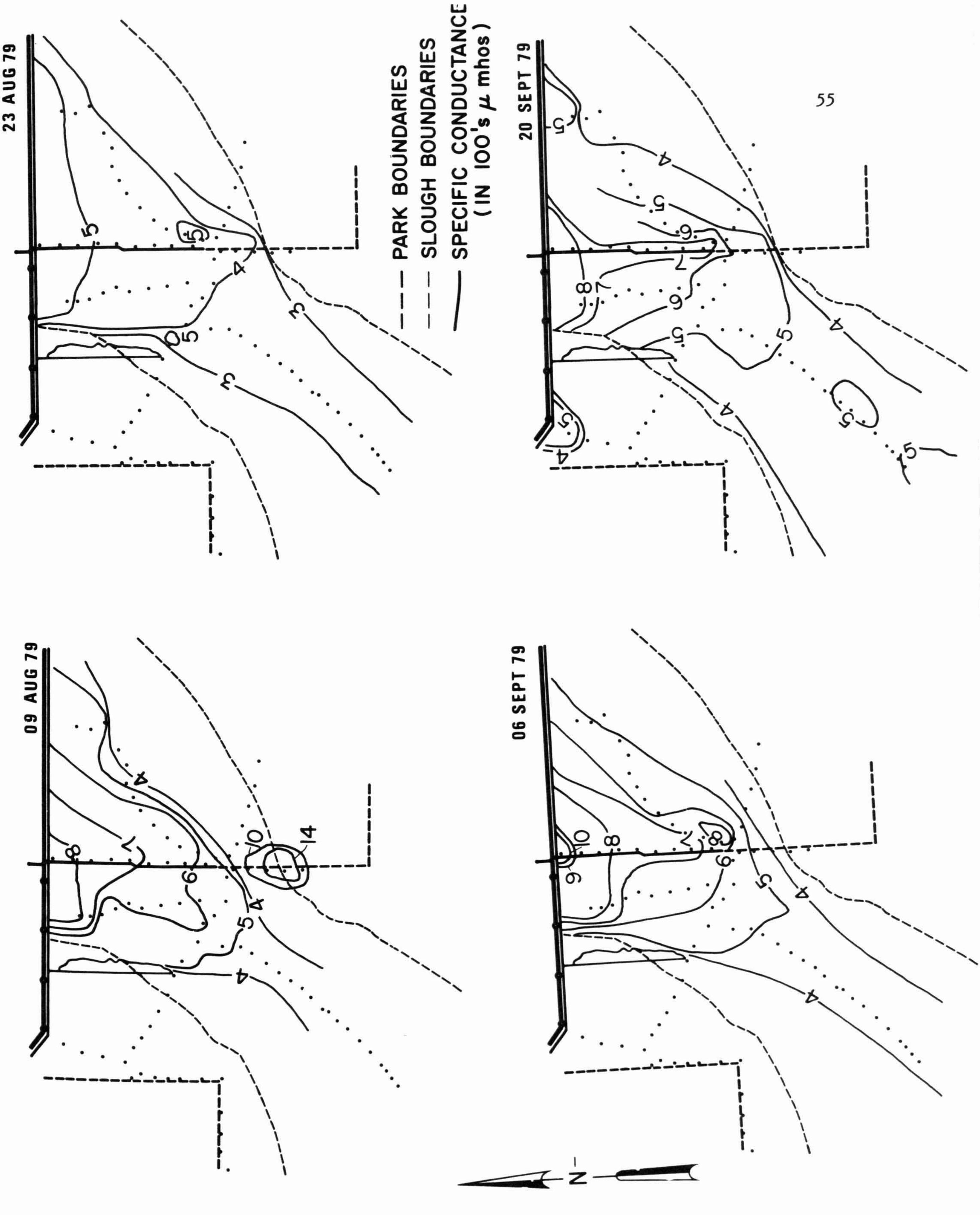

Figure A-10. Specific conductance contours for Shark Slough (August 09, 1979 - September 20, 1979).