DPST-83-1087

Pen Branch Delta Expension

by

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DOE Contract No. **DE-AC09-89SR18035**

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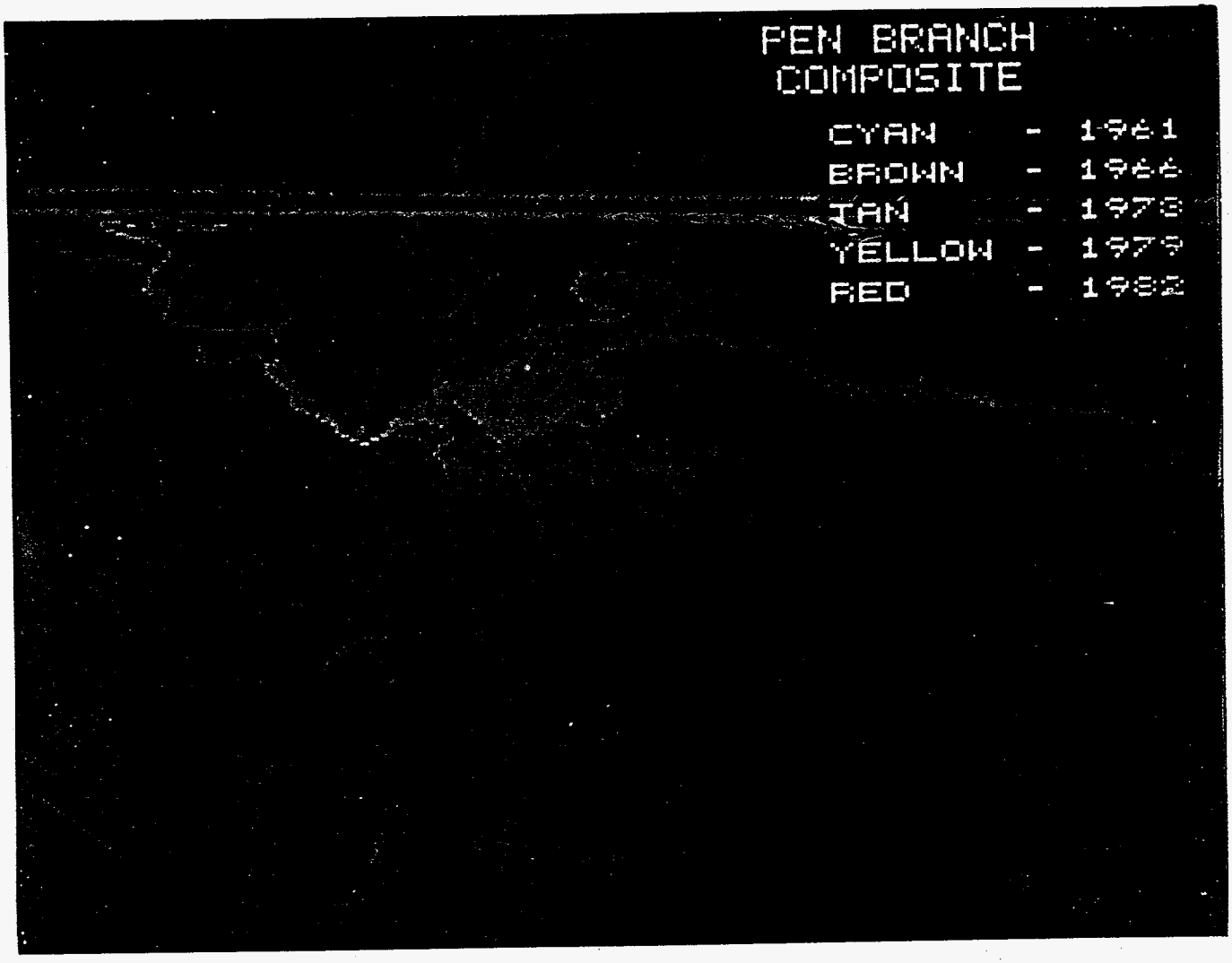

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Publication Date: February 1984

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INTRODUCTION AND SUMMARY

Since 1954, cooling water discharges from K Reactor ($\bar{X}$ = 370 cfs @ 59°C) to Pen Branch have altered vegetation and deposited sediment in the Savannah River Swamp forming the Pen Branch delta (Figure 1). Currently, the delta covers over 300 acres and continues to expand at a rate of about 16 acres/yr.

Examination of delta expansion can provide important information on environmental impacts to wetlands exposed to elevated temperature and flow conditions. To assess the current status and predict future expansion of the Pen Branch delta, historic aerial photographs were analyzed using both basic photo interpretation and computer techniques to provide the following information:

1) past and current expansion rates

2) location and changes of impacted areas

3) total acreage presently affected.

Delta acreage changes were then compared to historic reactor discharge temperature and flow data to see if expansion rate variations could be related to reactor operations.

Canopy defoliation first became apparent in 1961 where Pen Branch enters the swamp. By 1966, a 126-acre impact zone had formed, at an average rate of 23 acres/yr. From 1965 to 1979,

annual reactor discharge temperatures were reduced by 5-20°C, and for most of the period (1966-1973) the rate of delta growth slowed to 4 acres/yr. However, toward the end of the period (1974-1979), the delta expansion rate accelerated to 16 acres/yr, even though reactor discharge temperatures did not change appreciably and flows actually decreased slightly. For the most part, changes in delta growth can be related to temperature variances, while at other times expansion rates have changed independent of temperature and may have been influenced by other factors.

Most of the recent canopy defoliation has occurred southeast of the main delta zone and is probably related to channeling of thermal effluents during spring river flooding. At the present growth rate (16 acres/yr), the impact zone is expected to include 350 acres by the end of 1984.

METHODOLOGY

Aerial photographs of the Pen Branch delta area were taken at intervals between 1951 to 1982. Photos from nine different years were examined which covered the period before and during reactor discharges to Pen Branch: 1951, 1955, 1956, 1961, 1966, 1973, 1974, 1979 and 1982. Areas where cypress-tupelo swamp forest canopy had been damaged were interpreted from the photographs using stereo pairs and optical photogrammetric techniques. Boundaries were drawn on the photographs outlining the following vegetation impact classification zones:

1) no apparent damage

2) partial damage (5 - 95% canopy loss)

3) complete damage (95 - 100% canopy loss)

The damage area boundaries and other landmarks (Figure 2) were digitized and placed in a raster-based Geographic Information System (GIS). A computer extracted information from the GIS to produce color-coded images showing changes in canopy defoliation for 1961, 1966, 1973, 1979 and 1982 (Figure 3 and Table 1). The images and acreage statistics (Tables 2 and 3) were then compared to historic reactor flow and effluent temperature data. For more detailed information on methodology, see Christensen et al. (1984).

RESULTS

In 1951, the SRP Savannah River Swamp was a closed canopy forest (Sharitz et al., 1974) (Figure 3A). Although portions of the forest had been previously logged, second-growth bald cypress, water tupelo and bottomland hardwoods had restored the swamp canopy (Mackey, 1982).

In 1954, K Reactor began discharging heated effluent to Pen Branch. The discharge volume (approximately 100 cfs) and temperature (26-42°C) were relatively low (Table 4). No canopy change was visible in the 1955 and 1956 aerial photographs.

Swamp canopy defoliation first became apparent in 1961, seven years after reactor startup (Figures 3B, 4 and 5). The affected area was small (11 acres) and had received an average flow of

of 228 cfs, with a discharge temperature of 66°C, since 1956 (Table 4). During the next five years, Pen Branch delta experienced its most rapid growth, averaging 23 acres/yr, and reached a size of 127 acres by 1966 (Figures 4 and 5). Average flow (395 cfs) and temperature (64°C) remained relatively high.

In 1965, an experimental program (Curium II) lowered K Reactor power, and as a result, discharge temperatures were reduced to 53°C by 1966 (Table 4). The delta expansion rate also decreased to 4 acres/yr. Reduced power operation and discharge temperatures continued through 1974 when SRP began an energy conservation program in all reactor areas. Energy savings were partially achieved by shutting down two large river water intake pumps. Since less cooling water was used, K-Reactor discharges dropped an average of 20 cfs (Table 4). However, delta growth accelerated to 16 acres/yr after 1973 despite the reduced flows and temperatures.

After 1979, reactor power levels began to return to normal, effluent temperatures increased ($\overline{X}$ = 65°C) and Pen Branch delta growth remained at 16 acres/yr. Currently, the impact zone is greater than 300 acres and is expanding at a rate of about 16 acres/yr.

DISCUSSION AND CONCLUSIONS

Only seven dates of aerial photography are available to evaluate Pen Branch delta growth over the last 29 years. Therefore, growth rate variations in response to reactor operational changes are only averages (Figure 6), and delta expansion alterations may have been more dramatic on a year-to-year basis. Nevertheless, some important conclusions and observations concerning delta growth can be made.

- As of February 1982, the Pen Branch delta impact area covered 299 acres (Figure 4 and Table 2). The exact size of the current delta is unknown. But, based on the delta expansion rate from 1979-1982, 16 acres/yr, the impacted area should total approximately 350 acres by the end of this summer (1984).
- Some correlation exists between discharge temperature and delta expansion. Delta growth rate modifications have occurred after K-Reactor effluent temperatures have changed, except during one time period. Beginning in 1965, K-Reactor effluent temperatures decreased. Correspondingly, delta growth dropped from 23 acres/yr to 4 acres/yr (Figure 7). Flow did not change appreciably during this period. After 1974, delta expansion increased to 16 acres/year, even though temperatures remained relatively constant and the flow actually decreased an average 20 cfs (Figure 7). When higher temperatures returned after

1979, the delta growth rate continued at 16 acres/yr. The post-1973 increase in delta growth cannot be explained by a rise in reactor discharge temperature, but may have been influenced by swamp flooding.

- Much of the recent swamp canopy defoliation near Pen Branch delta has been expanding in a southeasterly direction, adjacent to the upland terrace along the Savannah River Swamp (Figures 2 and 5). Over the years, cypress/tupelo canopy has been replaced by open water and willow. The historic aerial photos, aerial multispectral scanner vegetation maps and ground observations from 1981-1983 have confirmed these changes. Since the late 1970's, ground measurements made by SREL during swamp flooding have recorded a distinct water temperature rise in the area below Pen Branch delta that is undergoing the most rapid change. Recent EG&G thermal infrared surveys have shown that during river flooding, thermal effluents from both Four Mile Creek and Pen Branch are channeled along the northeast bank of the swamp (away from the river). Recent river flooding activity seems to correlate with Pen Branch delta's southeastern progression. From 1966 to March 1973, the southeastern "arm" changed little (Figure 4 and 5). Spring flooding frequency and duration was also low during this period (Figure 8). After 1973, the "arm" began to increase in size along with springtime flooding frequency (Figures 4, 5 and 8). The channeling of thermal effluents during the spring/summer growing season may be occurring when the cypress/tupelo forest

is most sensitive, resulting in increased mortality. The post-1973 rise in flooding intensity may have caused the unexplained increase in the delta expansion rate from 4 to 16 acres/yr, while reactor discharge temperatures and flows remained relatively constant.

Reactor discharge temperature and flow, local swamp morphology, and duration, intensity and timing of river flooding all can be important factors in determining the rate, direction and extent of delta growth. For Pen Branch delta, reactor cooling water temperatures seem to have played a major role in the initial formation. However, in recent years, both heat loads and river flooding have probably influenced delta progression most.

Similar investigations of Four Mile Creek and Beaver Dam Creek deltas are underway and should provide additional evidence concerning the relative importance of factors regulating SRP swamp delta growth. Future delta expansion will be monitored by a combination of ground studies, aerial photography, and aerial multispectral vegetation change detection and thermal dispersion measurements.

ACKNOWLEDGEMENTS

Thanks to Ann Dicks for providing river flow data, USFS-SR for furnishing early aerial photography, Ed Wilde for supplying reactor discharge data and Carolyn Nichols for typing the report.

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Sharitz, R. R., J. W. Gibbons and S. C. Gause (1974). Impact of production-reactor effluents on vegetation in a southeastern swamp forest. In Thermal Ecolgy. J. W. Gibbons and R. R. Sharitz (eds.). AEC Symposium Series (CONF-730505) pp. 356-362.

Table 1: Pen Branch Delta Aerial Photography Characteristics

Date	Spectral Sensitivity	Format	Nominal Scale
03-15-61	Panchromatic	B&W Positive	1:20,000
05-05-66	Near infrared	B&W Positive	1:12,000
03-18-73	Panchromatic	B&W Positive	1:12,000
03-07-79	Panchromatic	B&W Positive	1:12,000
02-20-82	Color	Positive	1:12,000

Table 2: Number of Pixels in each Damage Category*

Date	Partial Damage Zone	Total Damage Zone	Total Affected Area
1961	200	0	200
1966	1757	526	2283
1973	1475	1336	2811
1979	1234	3317	4551
1982	1741	3642	5383

* Each scene was composed of 240 x 256 pixels. Each pixel (picture element) was 15m x 15m or 225 square meters. This was equal to 2,421 square feet or 0.06 acre. 1 acre = 43,560 square feet.

Table 3: Acres (Hectares*) in each Damage Category

Date	Partial Damage Zone	Total Damage Zone	Total Affected Area †
1961	11 (4)	0	11 (4)
1966	98 (40)	29 (12)	127 (51)
1973	82 (33)	74 (30)	156 (63)
1979	69 (28)	184 (74)	253 (102)
1982	97 (39)	202 (82)	299 (121)

* 1 hectare = 2.47105 acres
† includes 5 percent and greater canopy loss.

Table 4: Pen Branch Delta Growth and Reactor Discharge Conditions

Year	Total Impacted Area (acres)	Average Delta Expansion Rate (acres/yr)	Average Daily Discharge (cfs)	Average Annual Temperature (°C)	Average
1954			100†	26	
1955	0		100†	42	
1956	0		131	63	
1957		2	183	64	57
1958			214	66	
1959			277	70	
1960			334	66	
1961	11		398	63	
1962			399	63	
1963			394	66	
1964		23	394	67	64
1965			392	62	
1966	127		389	53	
1967			389	58	
1968			389	63	
1969			389	57	
1970		4	386	46	56
1971			388	57	
1972			390	55	
1973	156		388	59	
1974			324	61	
1975			373	58	
1976		16	376	57	
1977			375	57	58
1978			378	57	
1979	253		379	61	
1980			380	64	
1981		16	380	64	65
1982*	299		381	66	
		$\bar{X}$ =	370	59	

* includes only January to April
† approximate

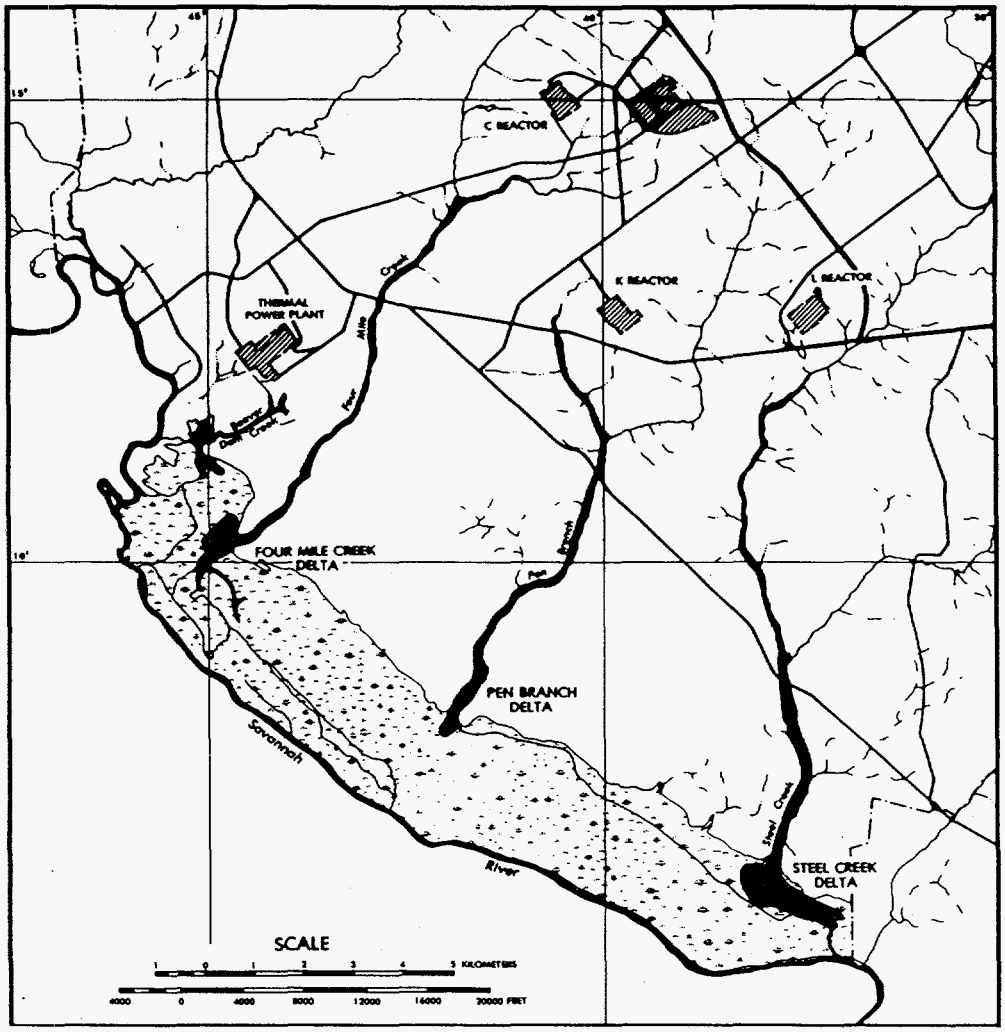


FIGURE 1. Location of SRP swamp deltas, thermal streams and production reactors.

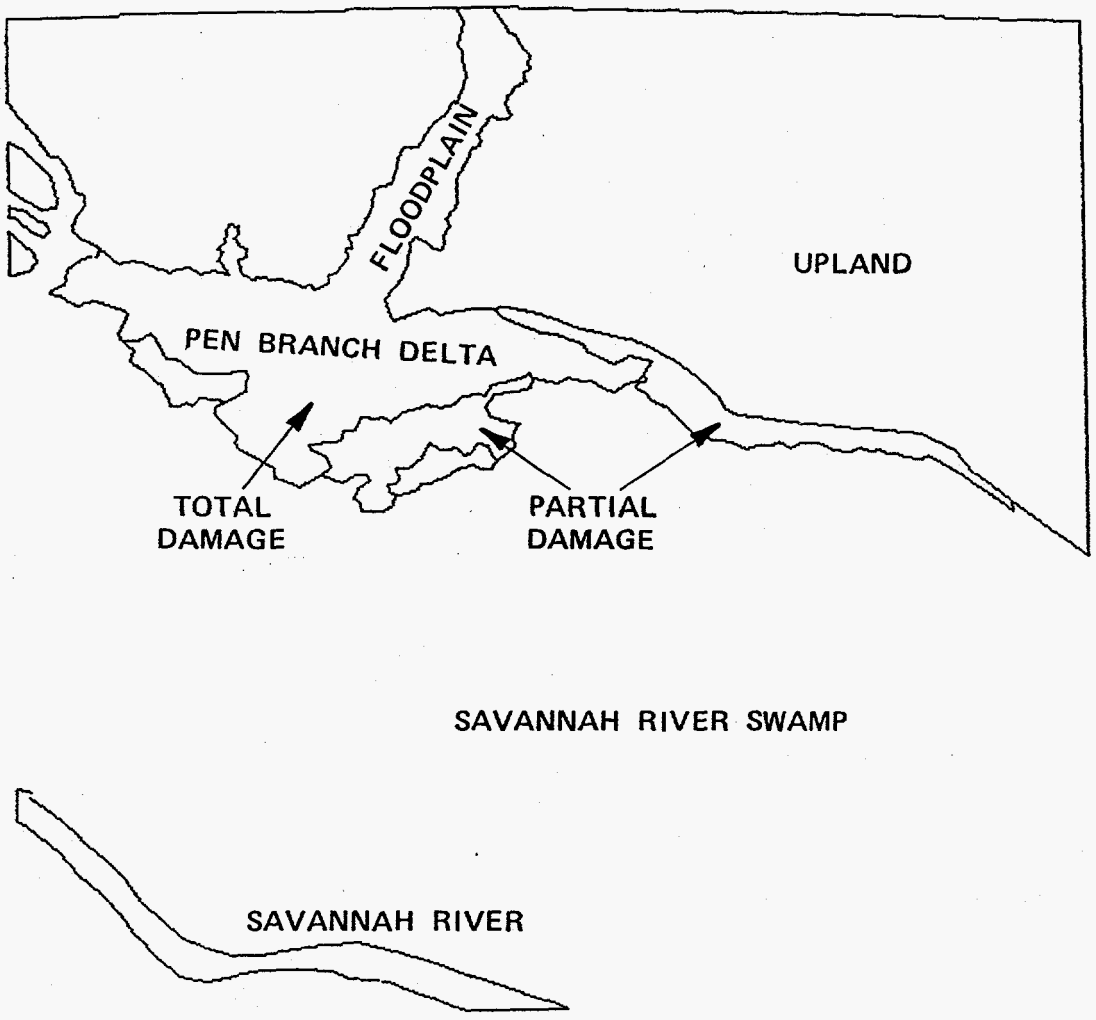


FIGURE 2. Plotter output of the original polygons which were coordinate digitized. The data is based on interpretation of the 1982 natural color aerial photography. Each polygon in the data base was then transformed into its appropriate location in a 240 by 256 matrix using a polygon-to-raster conversion program.

FIGURE 3. Original Photography Used for Damage Assessments

A = 1951
B = 1961
C = 1966
D = 1973
E = 1979
F = 1982

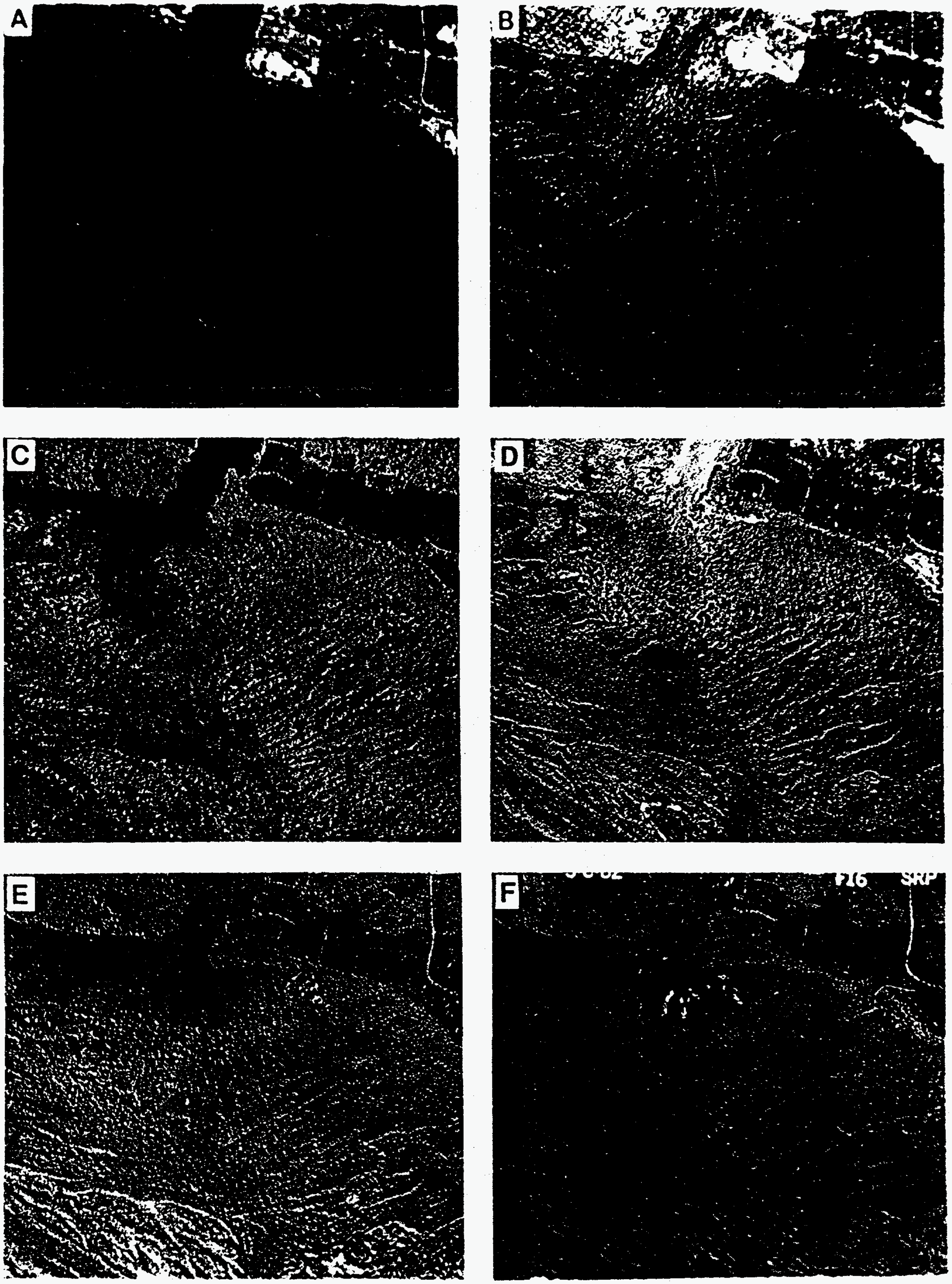
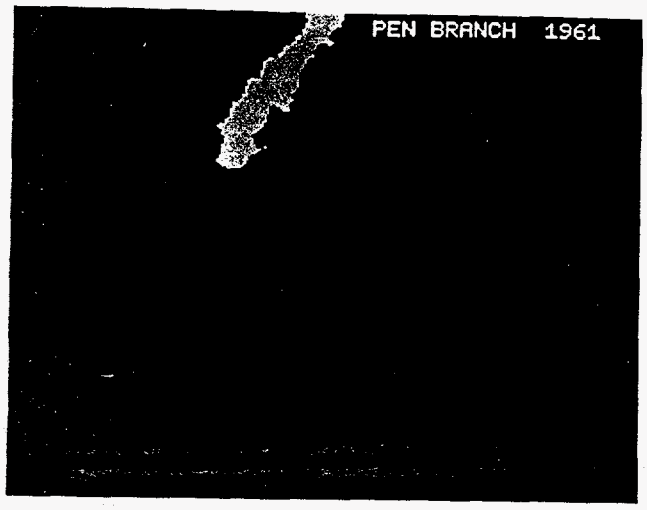

A
B
C
D
E
F
F16
SRP

FIGURE 4. Pen Branch Delta Change Detection Images from 1961 to 1982.

Blue - river
Light Green - unimpacted swamp forest
Dark Green - upland hardwood/pine
Brown - total canopy defoliation
Yellow - partial canopy defoliation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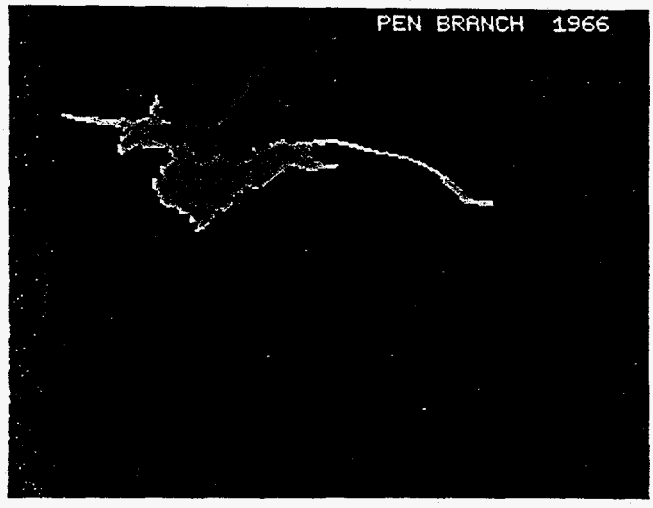
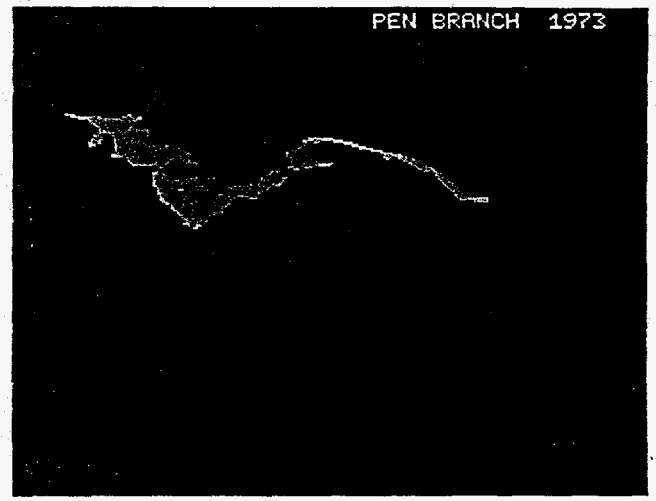
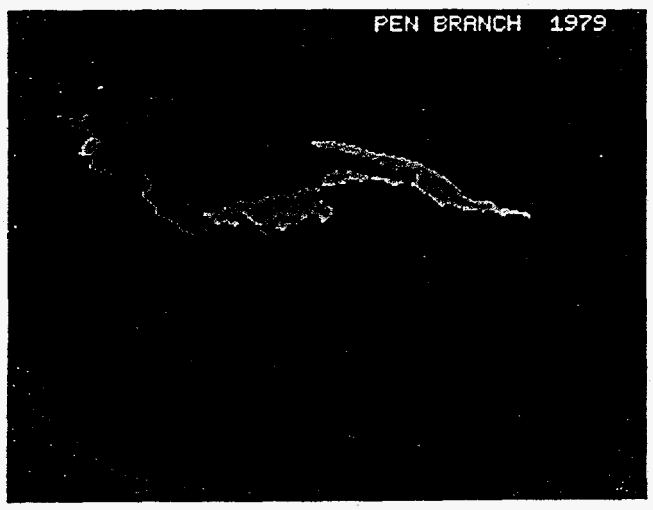
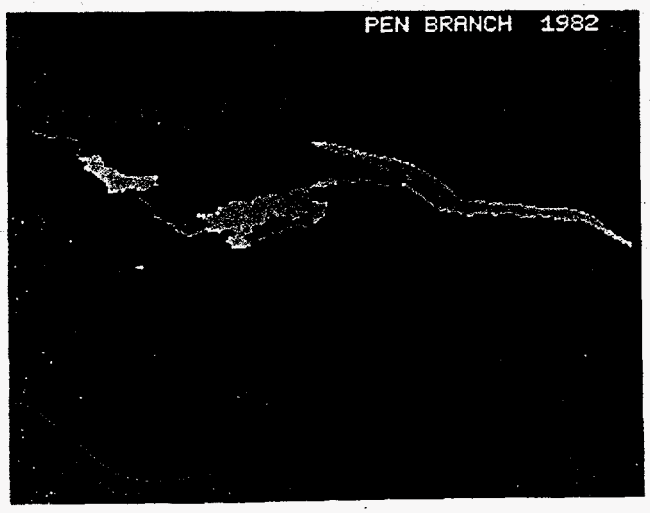

PEN BRANCH 1966


PEN BRANCH 1973


PEN BRANCH 1979


PEN BRANCH 1982

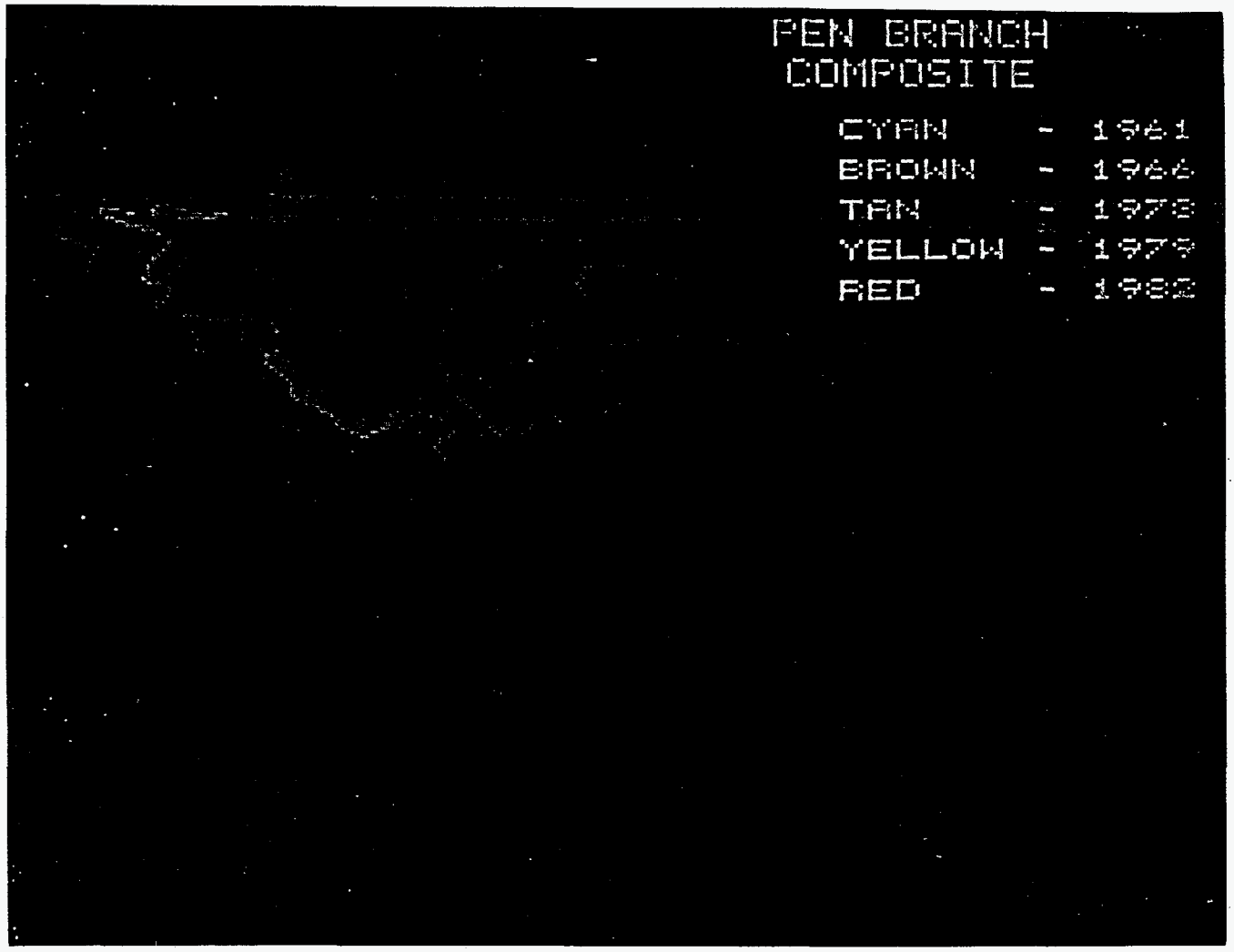


FIGURE 5. Pen Branch Delta Expansion Composite Image.

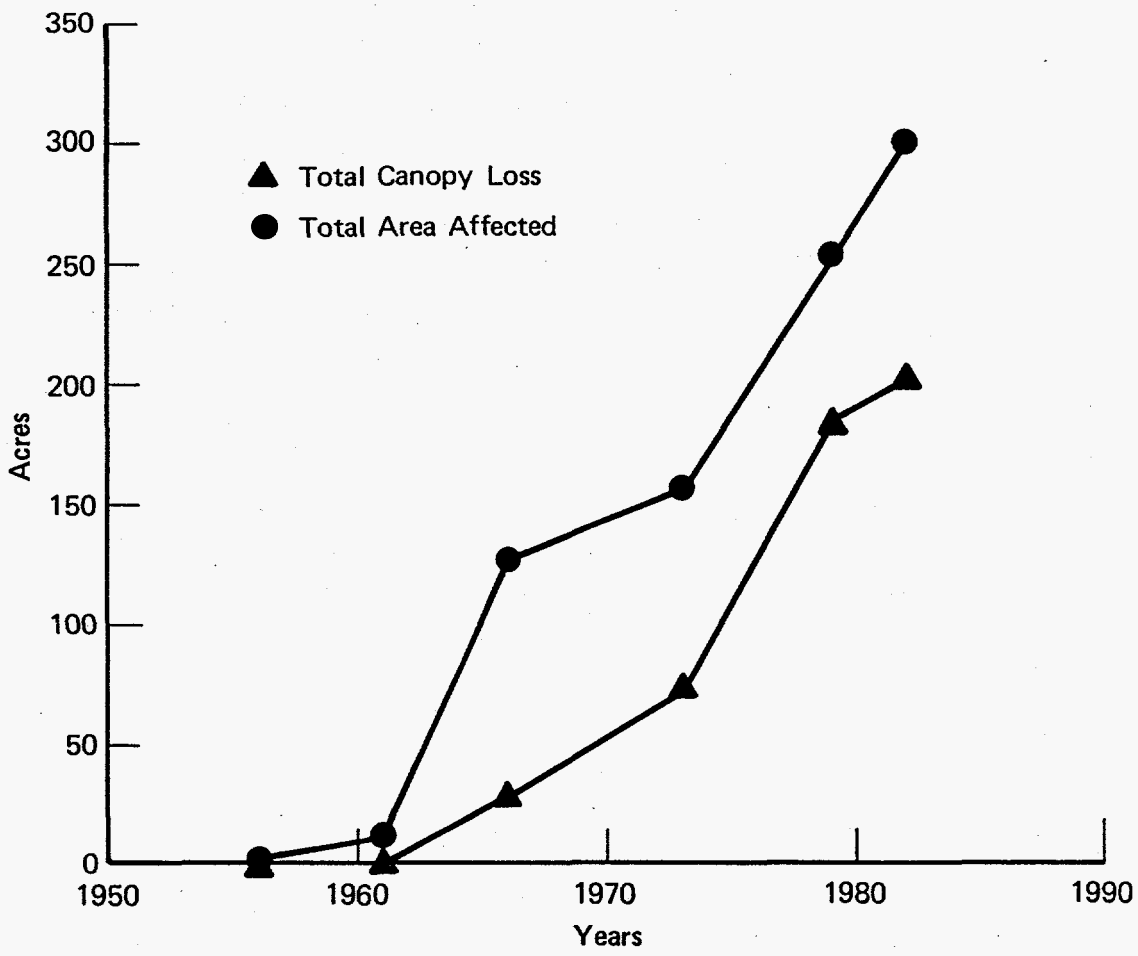


FIGURE 6. Pen Branch Delta Expansion.

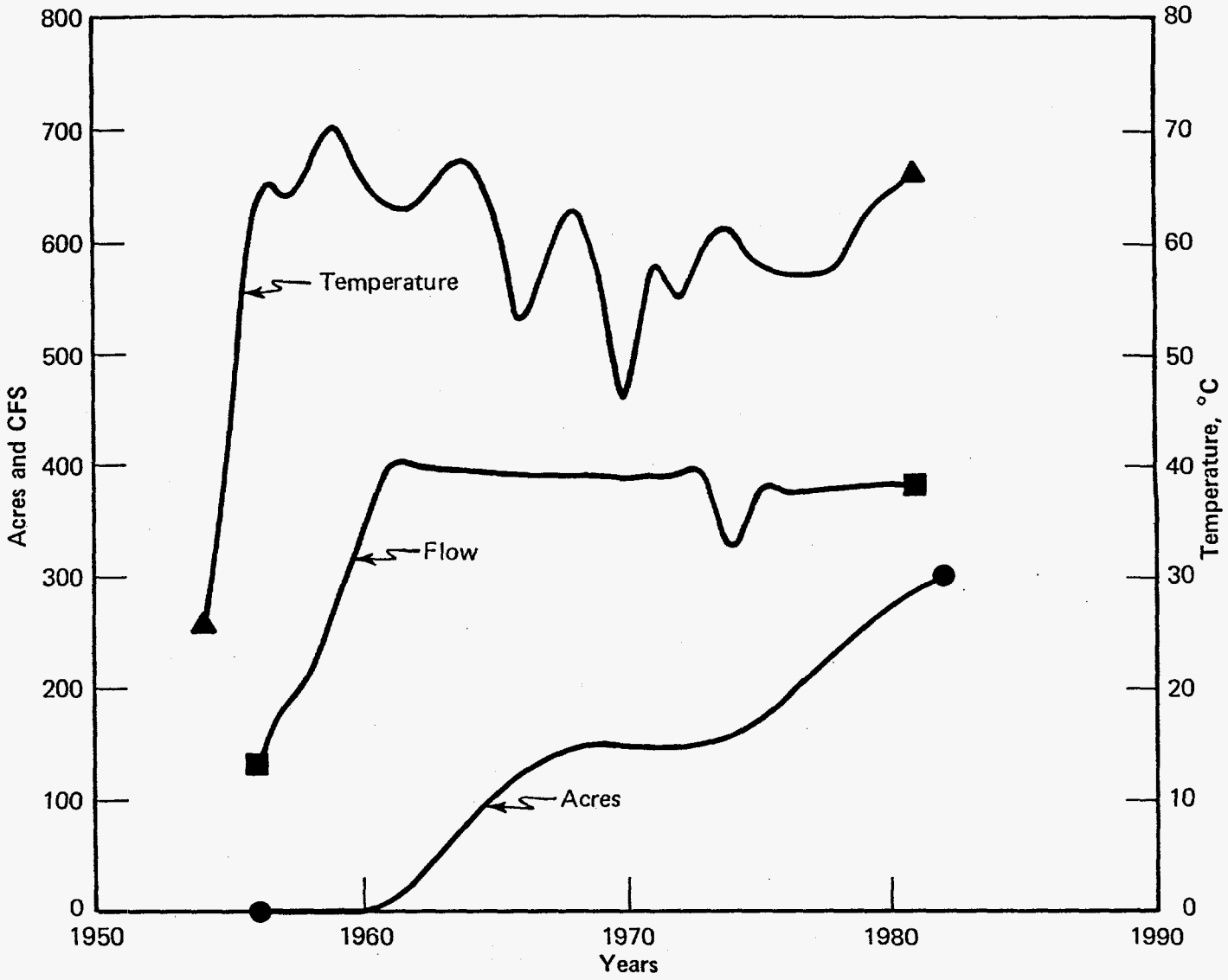


FIGURE 7. Pen Branch Temperature, Flow and Delta Growth.

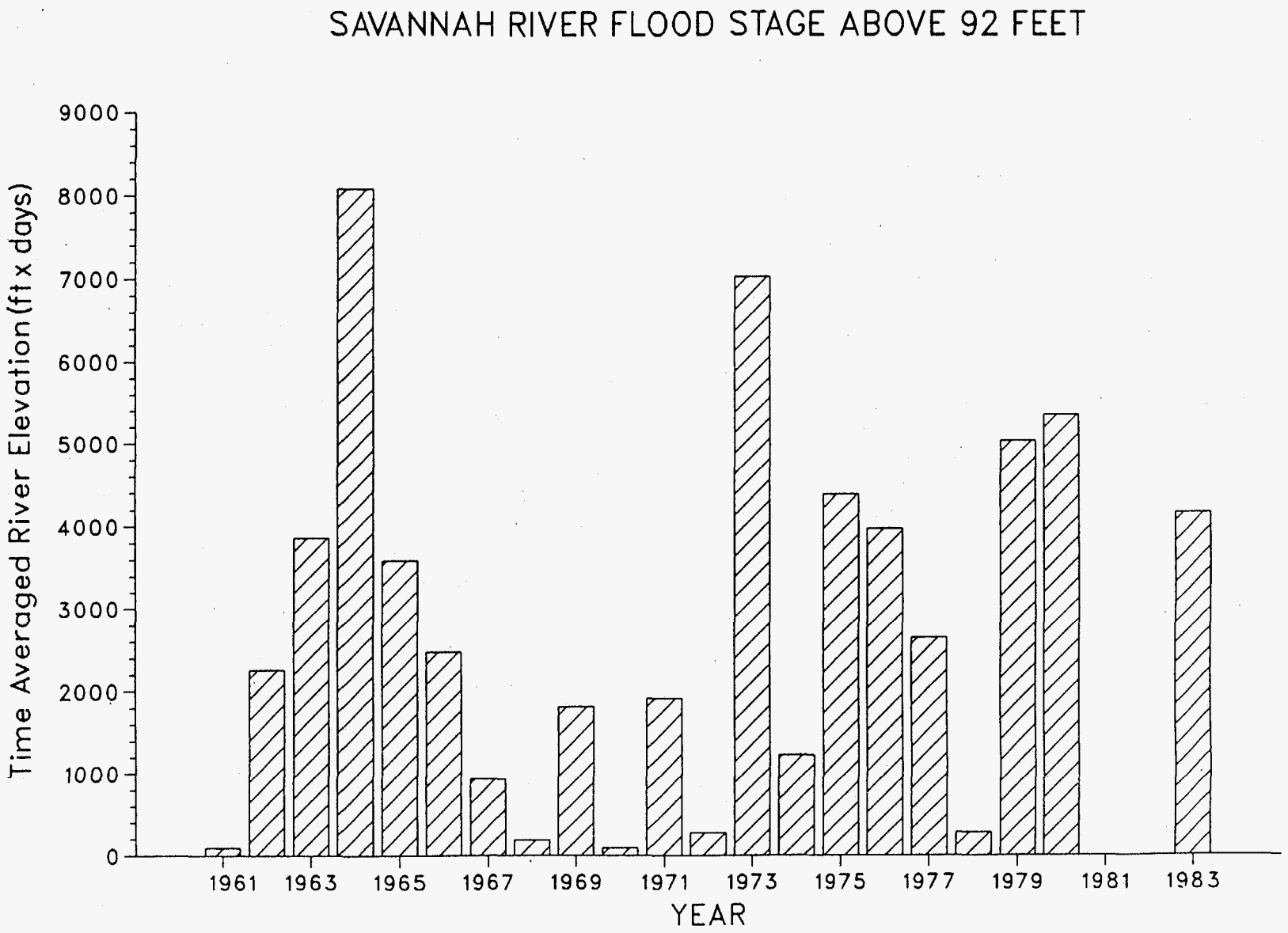


Figure 8. Flooding intensity during the growing season (March-July).

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