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MONITORING SEASONAL AND ANNUAL WETLAND CHANGES IN A FRESHWATER MARSH WITH SPOT HRV DATA

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by

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ABSTRACT

Eleven dates of SPOT HRV data along with near-concurrent vertical aerial photographic and phenological data for 1987, 1988, and 1989 were evaluated to determine seasonal and annual changes in a 400-hectare, southeastern freshwater marsh. Early April through mid-May was the best time to discriminate among the cypress (Taxodium distichum)/water tupelo (Nyssa aquatica) swamp forest and the non-persistent (Ludwigia spp.) and persistent (Typha spp.) stands in this wetlands. Furthermore, a ten-fold decrease in flow rate from 11 cubic meters per sec (cms) in 1987 to one cms in 1988 was recorded in the marsh followed by a shift to drier wetland communities.

INTRODUCTION

Study Area

The Savannah River Site (SRS), maintained by the U.S. Department of Energy, is a 777 km^2 area located in south central South Carolina. Five tributaries of the Savannah River run southwest through the SRS and into the floodplain swamp of the Savannah River. This swamp comprises 3.8 km^2 of which approximately half is bald cypress (Taxodium distichum)-water tupelo (Nyssa aquatica) swamp and half is hardwood islands or ridges (Jensen et al., 1984). The swamp is flooded frequently in later winter or early spring from the Savannah River. Additional water also enters the swamp from once-through, secondary cooling water from nuclear reactors on the SRS. Water temperatures are elevated in creeks receiving the cooling effluents and can exceed 40°C during the summer months. Elevated temperatures, plus water volumes approximately ten times the natural flow of the creeks, resulted in erosion from the stream channels and sediment deposition in the adjacent swamp. Cypress-tupelo vegetation has been replaced in these "delta" areas by a variety of algal, herbaceous, and woody shrub and vine species varying with the history and duration of the reactor operations (Sharitz et al., 1974a; Jensen et al., 1983, 1984). This paper describes the use of SPOT HRV data to monitor seasonal and annual trends in one of these swamp deltas, Pen Branch Delta, during a three-year period, 1987-1989.

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Previous Studies

The Pen Branch Delta, as with the other delta areas of the SRS Savannah River swamp, are dynamic areas undergoing both seasonal and annual changes. The development of vegetation types on the Pen Branch Delta are dependent on a variety of factors, including reactor operations, thermal conditions on the delta, and flooding patterns of the Savannah River (Scott et al., 1985; Sharitz and Lee, 1985; Jensen et al., 1987). In addition to these influences, once reactor operations are halted, rapid revegetation of exposed mud flats and sandbar islands occurs (Jensen et al., 1986a; Martin et al., 1977). These revegetation patterns consist of a variety of annual herbaceous plants, including both persistent and non-persistent wetlands, as well as the development of scrub-shrub wetlands within a few years following reactor shutdown (Sharitz et al., 1974a, 1974b). Therefore, very heterogeneous mixtures of wetland communities can be found in the SRS Savannah River swamp.

Several evaluations of the wetland patterns of the Pen Branch Delta have been conducted in recent years using aerial photographic surveys (Sharitz et al., 1974b; Repaske, 1981; Tinney et al., 1986), multispectral scanner (MSS) aircraft surveys (Christensen, 1987; Christensen et al., 1986, 1988; Jensen et al., 1987), and ground based surveys (Dunn and Scott, 1987; Huenneke and Sharitz, 1986; Scott et al., 1985; Sharitz and Lee, 1985; Christy and Sharitz, 1980). In general, these surveys indicate that the Pen Branch Delta, at least through 1985, was continuing to expand at a rate of about 5 to 10 hectares per year, primarily along a terrace bordering the northern edge of SRS Savannah River swamp (Jensen et al., 1987; Scott et al., 1986). Expansion into this Pen Branch Delta "tail" area may be primarily related to thermal effluent from Pen Branch being directed along the terrace edge in a southeastern direction by flood waters from the Savannah River during late spring and summer floods (Scott et al., 1985; Jensen et al., 1987).

PROCEDURES AND RESULTS

Wetland Patterns, 1985-1989

Few followup evaluations have been conducted on the Pen Branch Delta wetlands since the photographic and aircraft MSS surveys of 1985. In 1985, a series of phenological observations were begun on the Pen Branch Delta. One location was at the Pen Branch Delta "boardwalk" and the second was at the Pen Branch Delta "tail" area (Figure 1). Data on percent leaf emergence and/or expansion primarily of cypress in these locations was recorded. Data on the principal herbaceous wetland plants included relative height, flowering and emergent status, and reference photography.

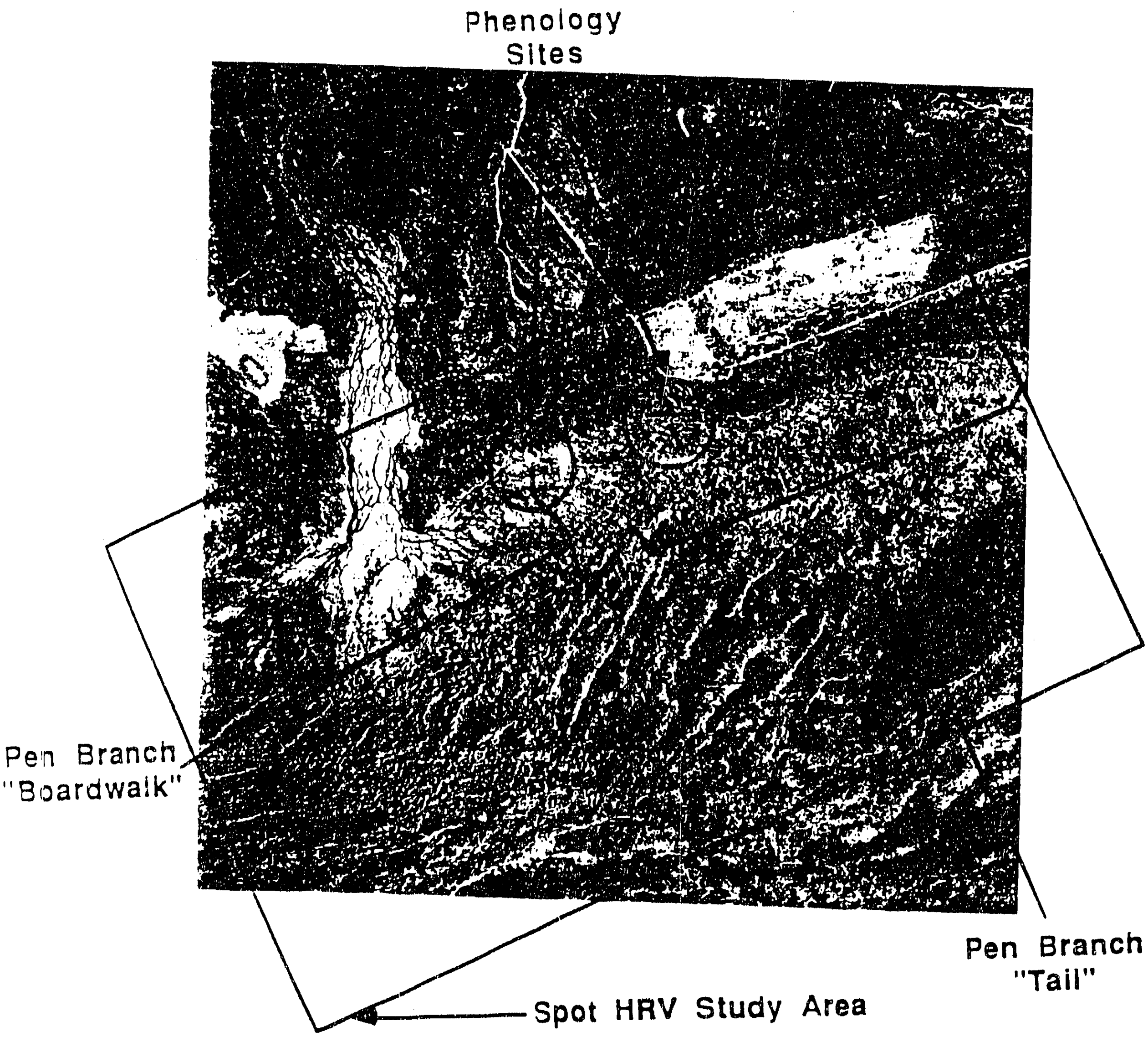

FIGURE 1. Pen Branch Delta Area Evaluated for Wetlands Using SPOT HRV Data for 1987, 1988, and 1989. Locations of phenology sites are shown also.

Figure 2 gives a summary of the status of cypress leaf expansion, as well as the relative height of Ludwigia spp. [water primrose (non-persistent herbaceous community)] and cattail [Typha spp. (persistent herbaceous community)] which occur at the Pen Branch "boardwalk". Ludwigia spp. is a common annual dominant on the elevated mudflats and sandbar islands of the thermally influenced streams and deltas of the (SRS Irwin, 1975; Christy and Sharitz, 1980; McCaffrey, 1982). Since 1985 a band of cattails has developed along the Pen Branch Delta from the "boardwalk" southeast along the Pen Branch "tail". In addition to ground based phenological data, vertical aerial photography of the Pen Branch Delta area were available.

As can be seen from Figure 2, cypress underwent leaf emergence and expansion mid-to-late March each year and was fully leafed out by mid-April. Cypress is deciduous and along with water tupelo lost its leaves in mid-fall of each year. Ludwigia spp. emerged later than the cattails by three to four weeks with both reaching a height of about 2 meters. Neither the cattails, nor Ludwigia spp., appeared to emerge as soon, nor develop as tall in 1987 as in the other years (Figure 2). An examination of the flows in the Savannah River from 1985 to mid-1989 indicated that frequent flooding of the SRS Savannah River swamp occurred from February through late March of 1987 (Figure 3). Flooding of the SRS Savannah River swamp occurs at a flow rate of about 15,000 cubic feet per sec (cfs) in the Savannah River. Frequent flooding of the Savannah River in the spring of 1987 combined with a startup of K-Reactor in early March of 1987 (Figure 4) probably lead to a delay in the development of the herbaceous wetlands of the Pen Branch Delta in 1987. McCaffrey (1982) in a series of field observations and greenhouse experiments indicated that germination of seeds of Ludwigia leptocarpa (the principal dominant water primrose of the thermal deltas of the SRS) is delayed by flooding and/or slight burial by sediments. Once seeds of Ludwigia germinate and the plants become established, they are more resistant to changing conditions of flooding and sedimentation (McCaffrey, 1982). Note from Figure 2 that development of both the Ludwigia and cattails at the "boardwalk" area was not as suppressed in 1986, 1988, and 1989 as in 1987. Both Ludwigia and the cattails began to enter senesence in mid-fall of each year.

Wetland Areal Estimates 1987-1989

To estimate the relative quantities of wetlands in the Pen Branch Delta, both seasonal and annual SPOT HRV satellite data were obtained. Table 1 lists the dates of SPOT HRV data, as well as the dates and types of vertical aerial photography which were available to assist in evaluation of the wetlands mapped with the SPOT HRV data. The SPOT HRV data were collected in the green (0.50 - 0.59 μm), red (0.61 - 0.68 μm), and near-infrared (0.79 - 0.89 μm)

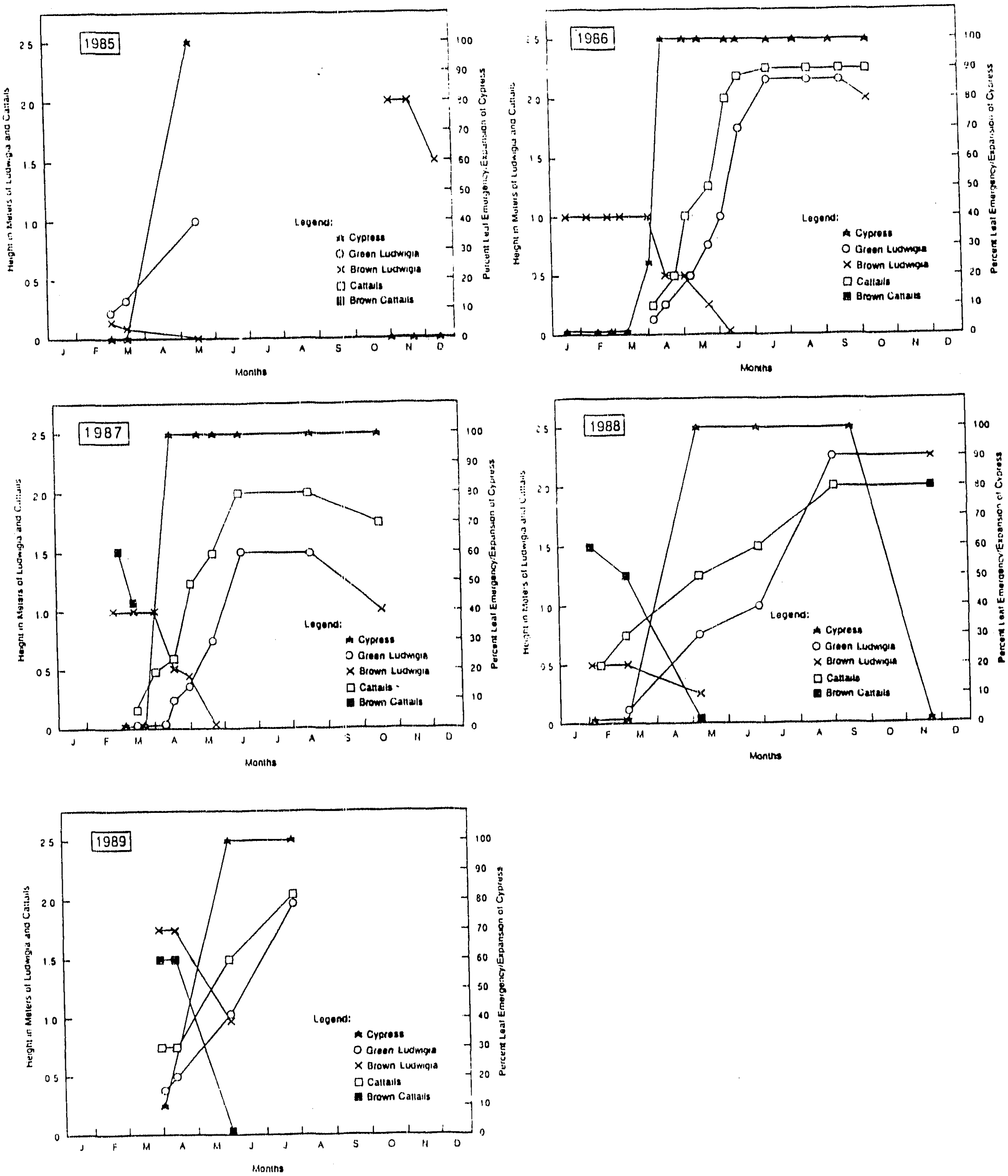

FIGURE 2. Summary of Phenology Data for the Primary Wetland Communities Near the Pen Branch Delta "Boardwalk" for 1985 Through Mid-1989.

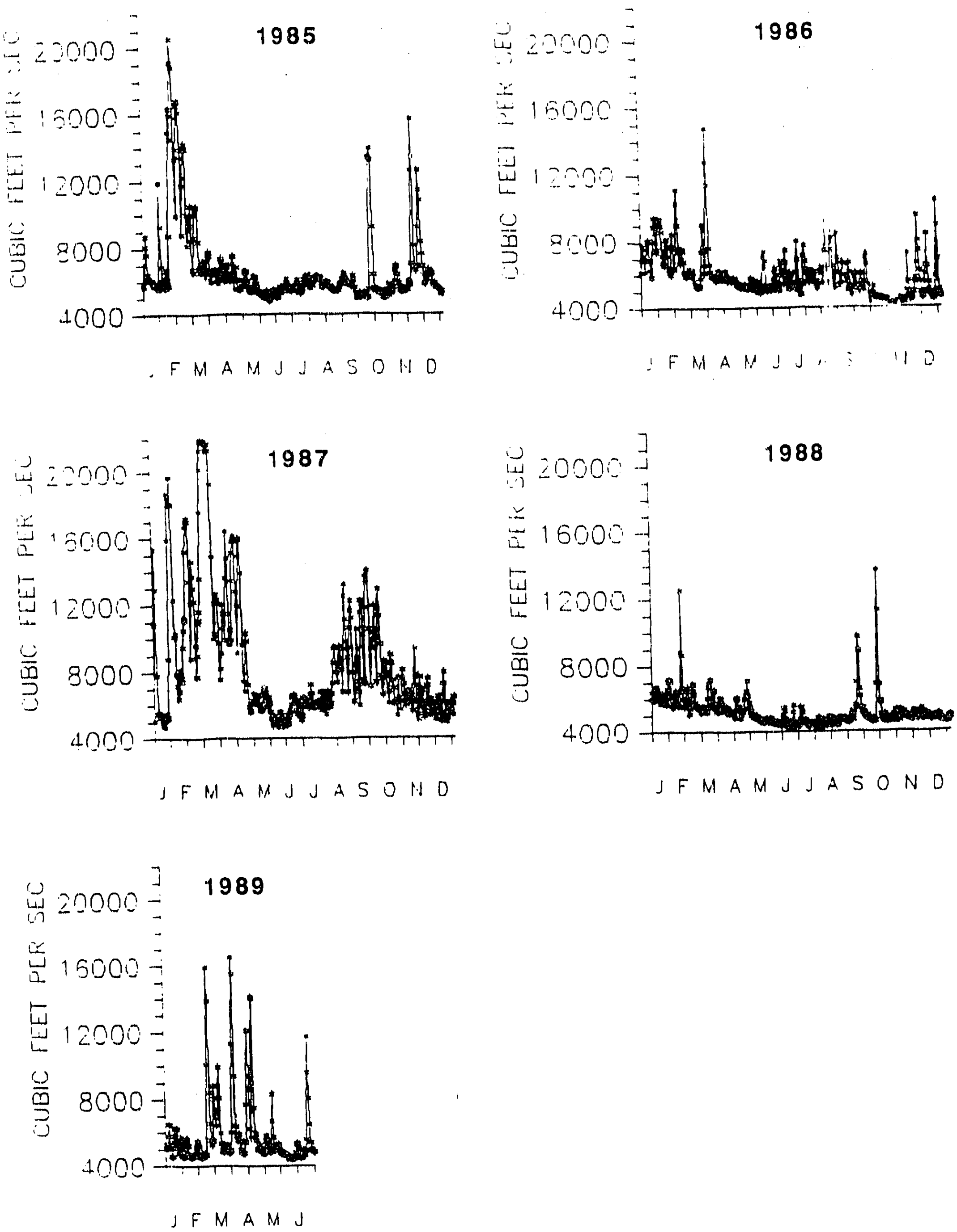

FIGURE 3. Flow in Savannah River from January 1985 Through June 1989

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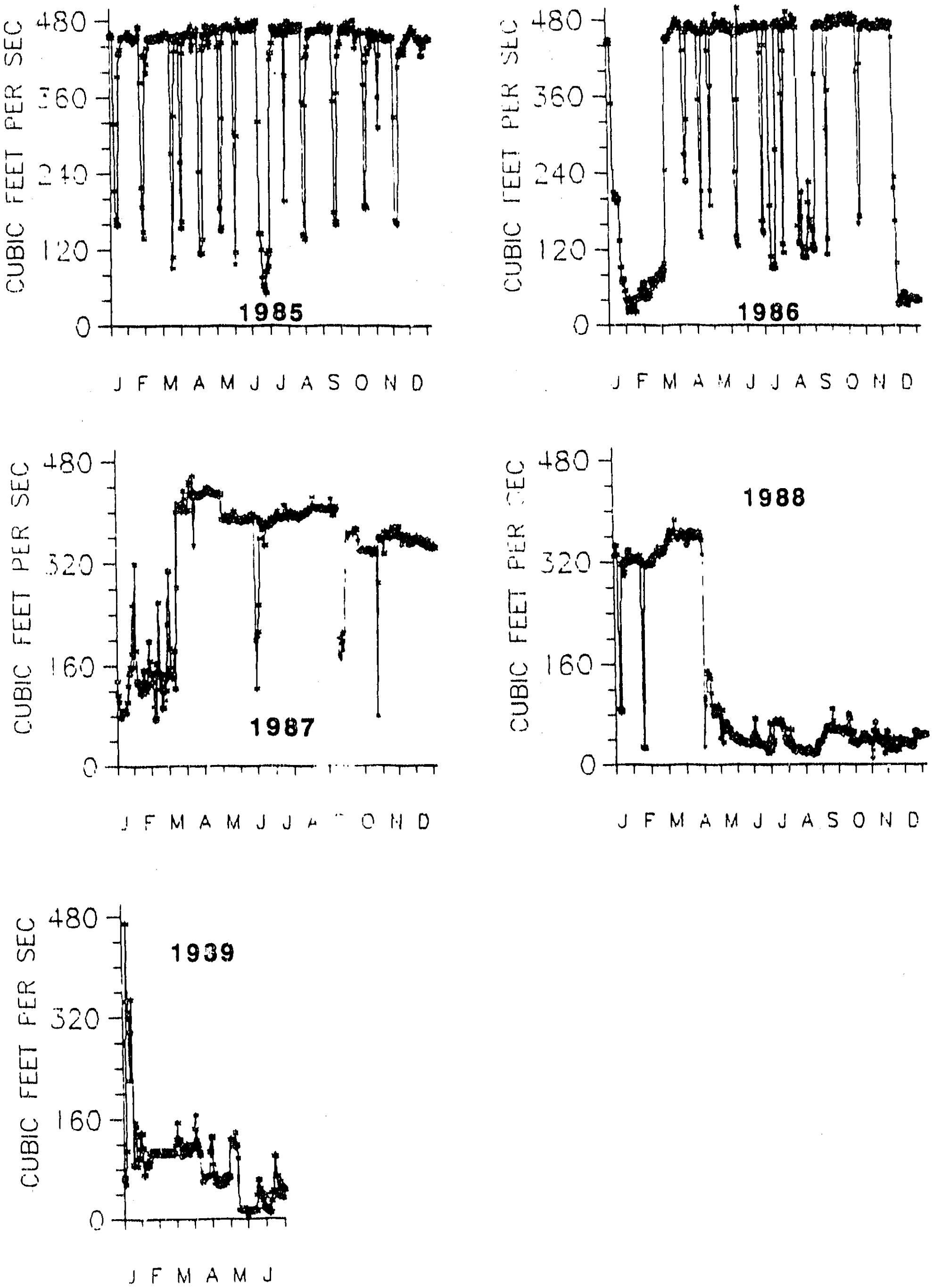

FIGURE 4. Flow to Pen Branch Creek from January 1985 Through June 1989

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TABLE 1

Dates of SPOT HRV Data and Supplementary Vertical Aerial Photography Used for Classification of Pen Branch Delta Wetlands

Year	SPOT HRV Data	Vertical Aerial Photography Data	Type	Scale	Source
1987	Apr 09	Apr 20	NC	1:16700	EG&G
	Apr 24	Apr 21	NC	1:20500	EG&G
	May 04	Apr 21	NC	1:20700	EG&G
	Aug 22	–	–	–	–
	Oct 22	Oct 27	FCIR	~1:20000	NASA
1988	Apr 17	Apr 29	NC	1:15900	EG&G
	May 02	Apr 29	NC	1:19900	EG&G
	–	Apr 29	NC	1:7960	EG&G
	May 18	May 18	NC	1:19900	EG&G
	Oct 25	–	–	–	–
1989	Jan 28	Jan 28	NC	~1:20000	FS
	May 17	May 02	NC	~1:19900	EG&G

NC = natural color
FCIR = false color infrared
EG&G = EG&G Energy Measurements, Inc., Las Vegas, NV
FS = Forest Service, SRS, Aiken, SC

bands, with a nominal pixel size of 20 meters. All data were obtained at the 1B processing level. Subsets of the data were processed for an area of the Pen Branch Delta as shown in Figure 1, using unsupervised classification techniques (Jensen, 1986). Cluster maps were generated for each date of SPOT HRV data, grouped, and recoded to one of several landcover types with special interest given to those listed in ~~Tables~~ 2 and shown in Figure 5. Comparisons to aerial photography were made where possible (Table 1). The use of satellite thematic mapper data and/or aircraft MSS data (especially in the green, red, and mid-infrared bands) to provide wetlands data of the SRS has proven valuable in the past (Jensen et al., 1986a). Accuracies of 70 to 85% for mapping wetland cover types from open water, freshwater marsh, scrub-shrub, to cypress-tupelo swamp forest have been realized (Jensen et al., 1983; Christensen et al., 1986, 1988; Jensen et al., 1986a; Christensen, 1987; Brewster and Tinney, 1984). Similar accuracies would be expected with SPOT HRV data (Tateishi and Mukouyama, 1987).

DISCUSSION

Other than bottomland hardwood and cypress-tupelo, three types of wetland cover types dominate the Pen Branch Delta area. These included deep and/or open water areas, non-persistent emergent marsh (NPE), and persistent marsh. Since Ludwigia frequently overgrows shallow water, mudflats, and sandbars on the Pen Branch Delta by late summer or early fall (Figure 2), these cover types were included with the NPE cover class along with areas of duckweed. April-May proved to be the best time of year to distinguish the wetland types from each other with discrimination in the summer and early fall more difficult (Jensen et al., 1986a). In 1987, K Reactor operated at nominal half-power and there was an increase in the expansion of the Ludwigia and cattail communities. Ludwigia expanded into the shallow water, mudflat areas of the central delta and the cattails expanded primarily in the "tail" area. In mid-April 1988, K Reactor was shut down and flows to Pen Branch decreased (Figures 4 and 6). This decrease in flow is reflected in a decline in the deep/open water areas as evaluated with the SPOT HRV data (Table 2 and Figures 5 and 6). The continued "drying" of the delta was also seen in 1989. As the Pen Branch Delta became drier in 1988 and 1989, it also became more difficult to distinguish areas of Ludwigia dominance from cattail beds. Furthermore, some areas in the lower Pen Branch stream corridor north of the upper delta began to resemble "old field" sites. Similar invasion of "old field" species has been observed in the drier portions of the Four Mile Creek corridor and delta on the SRS since C-Reactor shutdown in late June 1985. The preliminary data indicate that the Pen Branch Delta is likely to develop into drier more persistent wetland communities with invasion of scrub-shrub species [i.e., willow (Salix spp.) and buttonbush (Cephalanthus occidentalis)] occurring as this delta remains drier.

TABLE 2

Major Wetland Cover Types Based on Classification of SPOT HRV Data for the Pen Branch Delta, 1987 Through Spring 1989 (units in hectares)

	Date and Year of HRV Data Used										
	1987					1988				1989	
Wetland Cover Type	Apr 09	Apr 24	May 04	Aug 22	Oct 22	Apr 17	May 02	May 08	Oct 25	Jan 28	May 17
1. Deep/Open Water	10.4	13.1	13.6	1.5	11.8	4.8	4.0	1.2	0.6	0.0	0.0
2. Non-Persistent Emergent Marsh (NPE)											
2a. Shallow-Water/Mud Flats	82.1	65.5	33.4	12.7	75.0	44.4	29.0	0.2	56.2	0.1	0.4
2b. Ludwigia spp.	13.6	34.0	43.5	55.4	-	30.9	56.8	88.2	53.9	155.9[a]	97.4[a]
2c. Duckweed	-	3.2	-	-	0.3	7.5	10.1	0.3	-	-	3.6
Total NPE	95.7	102.8	76.9	68.1	75.3	82.8	95.9	88.7	110.1	156.0	101.4
3. Persistent Emergent Marsh (PE)											
3a. Cattails	10.7	31.2	28.5	65.7	21.0	23.0	38.5	*	*	*	*
4. Total	116.8	147.0	119.0	135.3	108.1	110.6	138.4	89.9	110.7	156.0	101.4

[a] After mid-May 1988, it was not possible to distinguish between the non-persistent beds of Ludwigia spp. and stands of cattails with the SPOT HRV data.

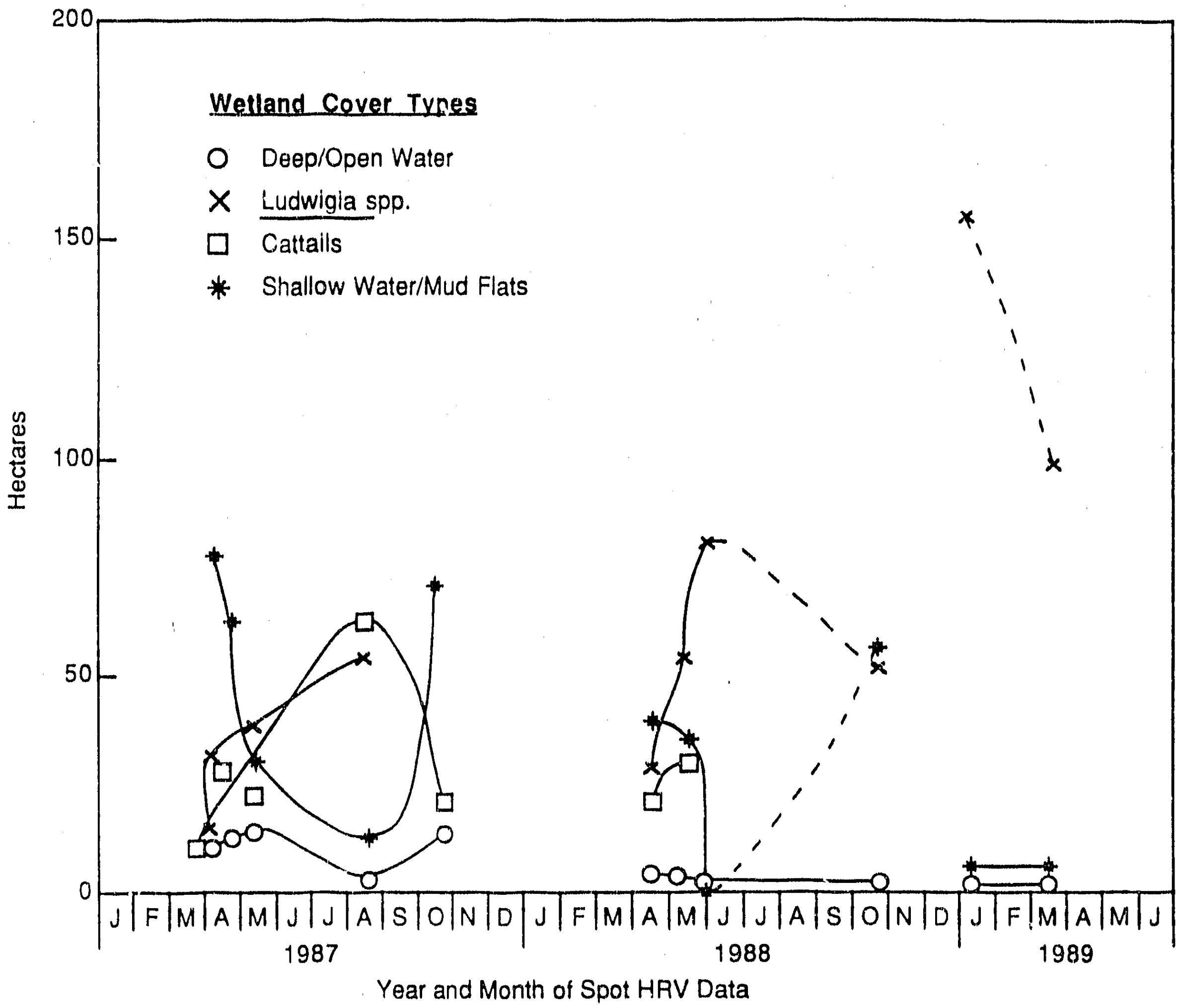

FIGURE 5. Major Wetland Cover Types Based on Classification of SPOT HRV Data for the Pen Branch Delta Vicinity, 1987 Through Spring 1989

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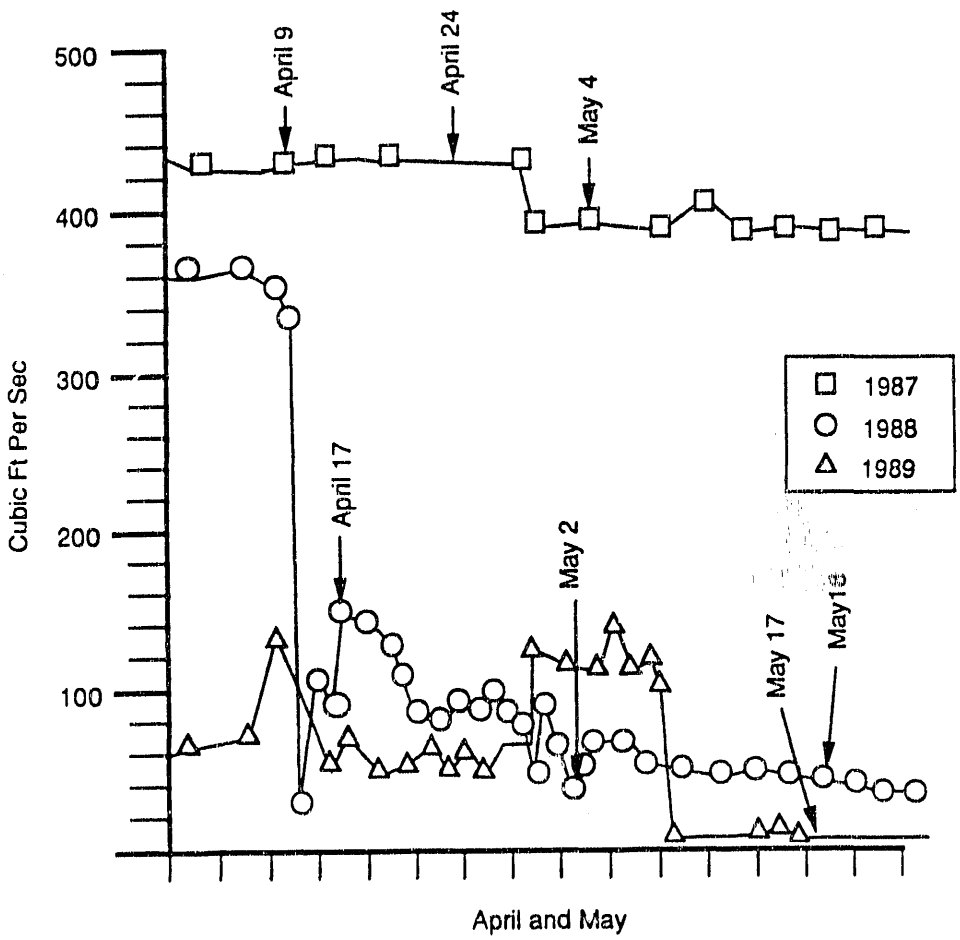

FIGURE 6. Pen Branch Flow During April and May of 1987, 1988, and 1989 with the Dates of SPOT HRV Data Indicated

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