THERMAL PLUME STUDIES IN THE SUSQUEHANNA RIVER AT THE DISCHARGE DIFFUSER OF THE SUSQUEHANNA STEAM ELECTRIC STATION 1986-87

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19 November 1987

INTRODUCTION

The Susquehanna Steam Electric Station (Susquehanna SES) is a nuclear power station with two boiling water reactors that have a total generating capacity of 2,100 megawatts. The station is located along the Susquehanna River in northeastern Pennsylvania (Figure 1). Commercial production of electricity at the Unit 1 reactor began on 8 June 1983 and at Unit 2 on 12 February 1985. The Pennsylvania Power and Light Company (PP&L) owns 90% of the Susquehanna SES and the Allegheny Electric Cooperative, Inc. retains title to 10%.

Water from the Susquehanna River is used to cool the Susquehanna SES in an essentially closed circuit cooling system. When both reactors are generating at 100% capacity, approximately 38,000 gallons/minute of river water is used to replace about 30,000 gallons/minute that is lost to the atmosphere by evaporation from two natural draft cooling towers. The remaining 8,000 gallons/minute of cooling tower blowdown is discharged back into the Susquehanna River through a diffuser pipe located on the river bottom about 200 feet from the west bank. The diffuser is constructed from a 42-inch diameter pipe that is 115 feet long. Blowdown water is released into the river through a series of 72 ports which are 4 inches in diameter. These ports are spaced at 18-inch intervals along the upper edge of the downriver side of the diffuser. Over the past 15 years, records at the Susquehanna SES Biological Laboratory show that river flow has varied from about 900 to 250,000 cubic feet/second, and that ambient river temperature has ranged from 32.0 to 86.0 F.

An earlier environmental report, written before construction of the Susquehanna SES, theorized that a sizable thermal plume would be created by

this blowdown water before it reached ambient river water temperature below the diffuser (PP&L 1972). Initial temperature measurements at the diffuser, after both units of the Susquehanna SES became operational, revealed that the thermal plume was much smaller than originally anticipated. The edge of the plume (0.5 F isotherm) rarely extended more than 300 feet downriver from the diffuser, and this occurred only during conditions of low river flow. More commonly, the plume edge was found within 150 feet of the diffuser and often it was located within 25 feet during average to high river flows. Therefore, a formal study of the thermal plume was never conducted because it was so limited in size.

In 1985, a review of the ecological monitoring programs for the Susquehanna SES was conducted by Drexel University (Allen et al. 1986). During this review, the water temperature of the river below the discharge diffuser was discussed at length. As a result, it was recommended that "a special study be made to determine by measurement exactly what the temperature change in the river is, even if it is measurable only within inches of the diffuser." In order to fulfill this recommendation, a study of the thermal plume was begun in November 1986, with the objective of defining its size.

METHODS

Three thermal plume studies were conducted at the discharge diffuser of the Susquehanna SES. Autumn, winter, and spring studies were done on 5 November 1986, 9 January 1987, and 14 May 1987, respectively. All studies were conducted when both reactors were at least 85% operational.

Temperatures were measured with a Hydrolab FT-3M Marine Thermometer (thermistor) which was calibrated immediately before each study with a NBS traceable thermometer. All temperatures were measured to the nearest 0.5 F. The temperature of the blowdown was measured in both cooling tower basins prior to the autumn and winter studies. In the spring study, blowdown temperature was measured at the discharge by a scuba diver who inserted the thermistor probe into several diffuser ports.

A plane-table mapping technique was used to draw a profile of the thermal plume in each study. The plane table, with drawing paper attached, was positioned along the west river bank about 150 feet downstream from the diffuser. It was oriented with various prominent structures, such as power poles and the intake building, using a Watts Microptic Alidade. The alidade was used to sight a stadia rod held at various points along the shoreline. Angles and distances to these points were measured and a base map of the shoreline and study area was drawn at a scale of 1 inch = 40 feet.

Two crews in boats, each equipped with a thermistor, measured ambient river temperature and located the diffuser. One of the boats was anchored about 100 feet upriver from the diffuser, and the ambient temperature was measured from surface to bottom at one-foot intervals. From shore, the boat was sighted with the alidade (stadia rod mounted on the boat) and its location was marked on the base map. In the meantime, the other boat was driven to one of two float-ropes that a scuba diver had previously attached to either end of the diffuser. By pulling the float-rope very tightly, it was possible to situate the boat directly above the end of the diffuser. This location was sighted from shore with the alidade and marked on the map.

The other end of the diffuser was marked in the same manner. The diffuser was then drawn on the map by connecting these two points with a line.

Both crews then proceeded to measure the temperature of the plume. In each study, vertical temperature series were determined at from 20 to 27 sites throughout the probable location of the plume downriver from the diffuser. The boats were anchored at each site and the thermistor was used to measure temperatures at one-foot intervals from surface to bottom. Air temperatures were also recorded. All sites were numbered and located on the base map using the alidade. Upon completion of temperature measurements within the plume area, ambient temperature was determined again at the original location. This was done to determine if a change had occurred during the time period in which the plume temperatures were recorded. When ambient changed, plume temperatures were adjusted accordingly.

In each study, the edge of the plume (0.5 F isotherm above ambient river temperature) was drawn on the base map by interpolating its location among the vertical series of temperature measurements at each site. Both planar and three-dimensional drawings were made of the plume.

RESULTS

Autumn Study

The autumn thermal plume study was conducted on 5 November 1986. On this date, the river level was stable at 487.8 feet above mean sea level (msl) which is equivalent to a flow of 4,840 cubic feet/second (2,173,000 gal/min). The water temperature of the cooling tower blowdown (approximately 8,000 gal/min) was 62.0 F. The weather was partly cloudy with a light breeze.

The location of each vertical temperature determination for ambient river temperature and for the 20 sites within the vicinity of the plume, are shown relative to the diffuser in Figure 2. The ambient temperature was 47.0 F and temperatures at the sites ranged from 47.0 to 47.5 F (Table 1). Air temperature decreased from 36.5 to 34.5 F throughout the 71-minute study.

The limits of the thermal plume are presented in Figure 3. The plume was within 5 feet of the diffuser along the inner half of the pipe. However, it extended downriver about 130 feet along the outer half of the diffuser. This portion of the plume remained near the bottom until about 75 feet downriver when it began to billow toward the surface.

Winter Study

The winter plume study was done on 9 January 1987 when the river level was 489.0 feet above msl. This level is equal to a flow of 9,250 cubic feet/second (4,152,000 gal/min). The approximately 8,000 gallons/minute of cooling tower blowdown was 61.0 F. The weather was partly cloudy and calm.

Determinations of ambient river temperature and the temperatures at the 21 plume sites are shown relative to the diffuser in Figure 4. The ambient river temperature was 33.5 F and temperatures within the vicinity of the plume ranged from 33.5 to 34.0 F (Table 2). Air temperature decreased from 39.0 to 35.5 F during the 1-hour and 53-minute study.

The thermal plume remained within 10 feet of the diffuser along the inner half of the pipe, and then extended downriver about 25 feet along the outer half (Figure 5). It tended to billow upward, but it was always less than 10 feet below the surface.

Spring Study

The spring thermal plume study was conducted on 14 May 1987. The river level on this date was stable at 487.9 feet above msl. This level is equivalent to a river flow of 5,120 cubic feet/second or 2,298,000 gallons/minute. The water temperature of the cooling tower blowdown (approximately 8,000 gal/min) was 75.0 F. The weather was cloudy during the first 30 minutes of the study and sunny throughout the remainder.

The locations of each temperature series recorded for ambient river temperature and for temperatures at the 27 sites near the plume are shown relative to the diffuser in Figure 6. Ambient river temperature increased from 65.5 to 66.0 F when the sunlight warmed the river throughout the 1-hour and 40-minute study (Table 3). This natural warming of the river necessitated the adjustment of the temperatures at the last 16 sites by subtracting 0.5 F from each measurement (Table 3). Temperatures within the plume ranged from 65.5 to 66.5 F.

The extent of the thermal plume is presented in Figure 7. Most of the plume was located downriver from the outer half of the diffuser where it extended about 80 feet in length. The plume tended to billow upward, but never reached closer than 7 feet of the surface.

DISCUSSION

The thermal plumes in all three studies were relatively small. This finding in itself is particularly interesting because the temperature of the cooling tower blowdown was 15.0, 27.5, and 9.5 degrees F above ambient river temperature in autumn, winter, and spring, respectively. In spite of these

sizable delta t's, none of the plume temperature determinations were greater than 1 degree F above ambient, and most of the recordings were only 0.5 degree F above ambient. At some point in the river, within a few inches of the diffuser ports, the temperature of the blowdown water was reduced to within 1 degree F or less of ambient. The results of these studies did not detect the exact location of this gradient; however, even if it was found, it would be of only minor interest environmentally. The far more important finding is that, during these studies, the diffuser of the Susquehanna SES quickly mixed thermally-enriched water from the cooling tower blowdown with river water so that impact to the Susquehanna River was negligible.

The size of the plume seemed to be more a function of river flow than the difference in temperature between blowdown and ambient when results of the autumn and winter studies were evaluated. Of all the studies, plume size was largest in autumn when river flow was lowest and the delta t was 15.0 F. In the winter study, the delta t was nearly twice as large (27.5 F), but the plume was several fold smaller in a river-flow condition about twice as great as that measured in the autumn study. Results of the spring study were intermediate.

All three studies were conducted at river flows near the low end (9,250 cubic feet/second or 262 cubic meters/second) of the range of flows documented for this portion of the Susquehanna River over an 8-year period (Figure 8). It is doubtful that a plume of any consequence would be detected at river flows greater than those evaluated during the winter study. In the future, however, it may be of some value to conduct a fourth thermal plume study at low river flow in the summer. When this study is completed, the

thermal plume will have been profiled once in each of the four seasons for a more complete evaluation.

REFERENCES CITED

Allen, H. E., W. O. Pipes, and C. A. Silver. 1986. Review of ecological monitoring program for the Susquehanna Steam Electric Station. H. E. Allen & Associates, Ltd., Bala Cynwyd, PA.

Pennsylvania Power and Light Company. 1972. Susquehanna Steam Electric Station, Applicant's Environmental Report, Vol. 1. Pa. Power & Light Co., Allentown, PA.

Table 1

Temperatures (F) recorded at 1-foot intervals from surface to bottom at 20 sites on the Susquehanna River near the discharge diffuser of the Susquehanna Steam Electric Station, 5 November 1986.

Site No.	Time	Temperature (F)		Depth in feet																Bottom	
		Air	Surface	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Depth	Temperature
Ambient	1249	36.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0					12.0	47.0
1	1250	36.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0			14.5	47.0
2	1255	36.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.5	47.5	47.5					12.0	47.5
3	1258	36.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.5	47.5	47.5	47.5	47.5	47.5		15.0	47.5
4	1300	36.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0			14.0	47.0
5	1305	36.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0					12.5	47.0
6	1306	36.5	47.0	47.5	47.5	47.5	47.5	47.5	47.5	47.5	47.0	47.5	47.5	47.5	47.5	47.5	47.5			14.0	47.5
7	1314	36.5	47.0	47.0	47.0	47.5	47.5	47.5	47.5	47.5	47.5	47.5	47.5	47.5	47.5	47.5	47.5			14.5	47.5
8	1320	36.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.5	47.5	47.5	47.5	47.5					12.5	47.5
9	1320	36.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0		15.0	47.0
10	1325	35.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0			14.5	47.0
11	1327	35.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0		15.0	47.0
12	1330	35.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0		15.0	47.0
13	1335	35.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	16.0	47.0
14	1335	35.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0							11.0	47.0
15	1340	34.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0			14.0	47.0
16	1342	34.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0						11.0	47.0
17	1345	34.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0									8.5	47.0
18	1346	34.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0						11.5	47.0
19	1351	34.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0					12.5	47.0
20	1355	34.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0						11.5	47.0
Ambient	1400	34.5	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0					12.0	47.0

Table 2

Temperatures (F) recorded at 1-foot intervals from surface to bottom at 21 sites on the Susquehanna River near the discharge diffuser of the Susquehanna Steam Electric Station, 9 January 1987.

Site No.	Time	Temperature (F)		Depth in feet																	Bottom	
		Air	Surface	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Depth	Temperature
Ambient	1517	39.0	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5				14.0	33.5
1	1526	39.0	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5			15.0	33.5
2	1531	37.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5		16.5	33.5
3	1537	37.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5		16.5	33.5
4	1542	39.0	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5		16.5	33.5
5	1547	39.0	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5		16.0	33.5
6	1552	37.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5					13.0	33.5
7	1556	37.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5		16.5	33.5
8	1600	37.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5		16.0	33.5
9	1604	37.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5			15.0	33.5
10	1609	38.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	34.0	33.5	17.0	33.5
11	1614	37.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5										9.0	33.5
12	1618	37.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5		16.5	33.5
13	1622	37.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5		16.0	33.5
14	1628	37.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	34.0	34.0	34.0	34.0	34.0		16.5	34.0
15	1633	38.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	34.0	34.0	34.0		16.5	34.0
16	1638	35.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	34.0	34.0	34.0	34.0	34.0		16.0	34.0
17	1641	35.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5			15.0	33.0
18	1645	35.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	34.0	34.0	34.0	34.0	34.0	34.0		16.5	34.0
19	1650	35.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	34.0	34.0	34.0	34.0		16.0	34.0
20	1653	35.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5			15.0	33.5
21	1659	35.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5				14.0	33.5
Ambient	1710	35.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5				14.0	33.5

Table 3

Temperatures (F) recorded at 1-foot intervals from surface to bottom at 27 sites on the Susquehanna River near the discharge diffuser of the Susquehanna Steam Electric Station, 14 May 1987.

Site No.	Time	Temperature (F)		Depth in feet																	Bottom	
		Air	Surface	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Depth	Temperature
Ambient	1355	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5						12.5	65.5
1	1358	69.0	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5			15.0	65.5
2	1409	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5					13.0	65.5
3	1409	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	66.0	66.0	66.0	66.0	66.0	66.5	66.5	65.5				14.0	66.0
4	1416	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5					13.0	65.5
5	1416	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5		16.0	65.5
6	1420	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5				14.0	65.5
7	1423	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5			15.0	65.5
8	1425	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5				14.0	65.5
9*	1430	—	66.0	66.0	66.0	66.0	66.0	66.0	66.0	65.5	65.5	65.5	65.5	65.5	65.5						12.0	65.5
10	1430	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	66.0	66.0	66.0	66.0				14.0	66.0
11	1435	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	66.0	66.5	66.5	66.5	66.5	66.5	66.5	66.5			15.0	65.5
12**	1439	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5					13.0	65.5
13	1448	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5					13.0	65.5
14	1452	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	66.0	66.0	66.0	66.0	66.0	66.0				14.0	66.0
15	1453	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5				14.0	65.5
16	1501	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	66.0	66.0	66.0	66.0	66.0	66.0	66.0		16.0	66.0
17	1503	77.0	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5						12.0	65.5
18	1504	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	66.0	66.0	65.5	65.5	66.0	66.0			15.0	66.0
19	1511	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5					13.0	65.5
20	1511	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5		16.0	65.5
21	1516	—	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0		16.0	65.0
22	1516	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0		16.0	66.0
23	1520	—	65.5	65.5	65.5	65.5	65.5	65.5	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0			15.0	66.0
24	1523	—	65.5	65.5	65.5	65.5	65.5	65.5													5.0	65.5
25	1524	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	66.0	66.5	66.5	66.5	66.5	66.0	66.0	66.0			15.0	66.0
26	1526	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5					13.0	65.5
27	1531	—	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	66.0	66.0	65.5	65.5	65.5	66.0	65.5			15.0	65.5
Ambient	1535	—	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0					13.0	65.5

* River surface temperature increased from sunlight.

** All temperatures (except ambient) measured after 1439 hours were adjusted for an increase in ambient river temperature by subtracting 0.5 F.

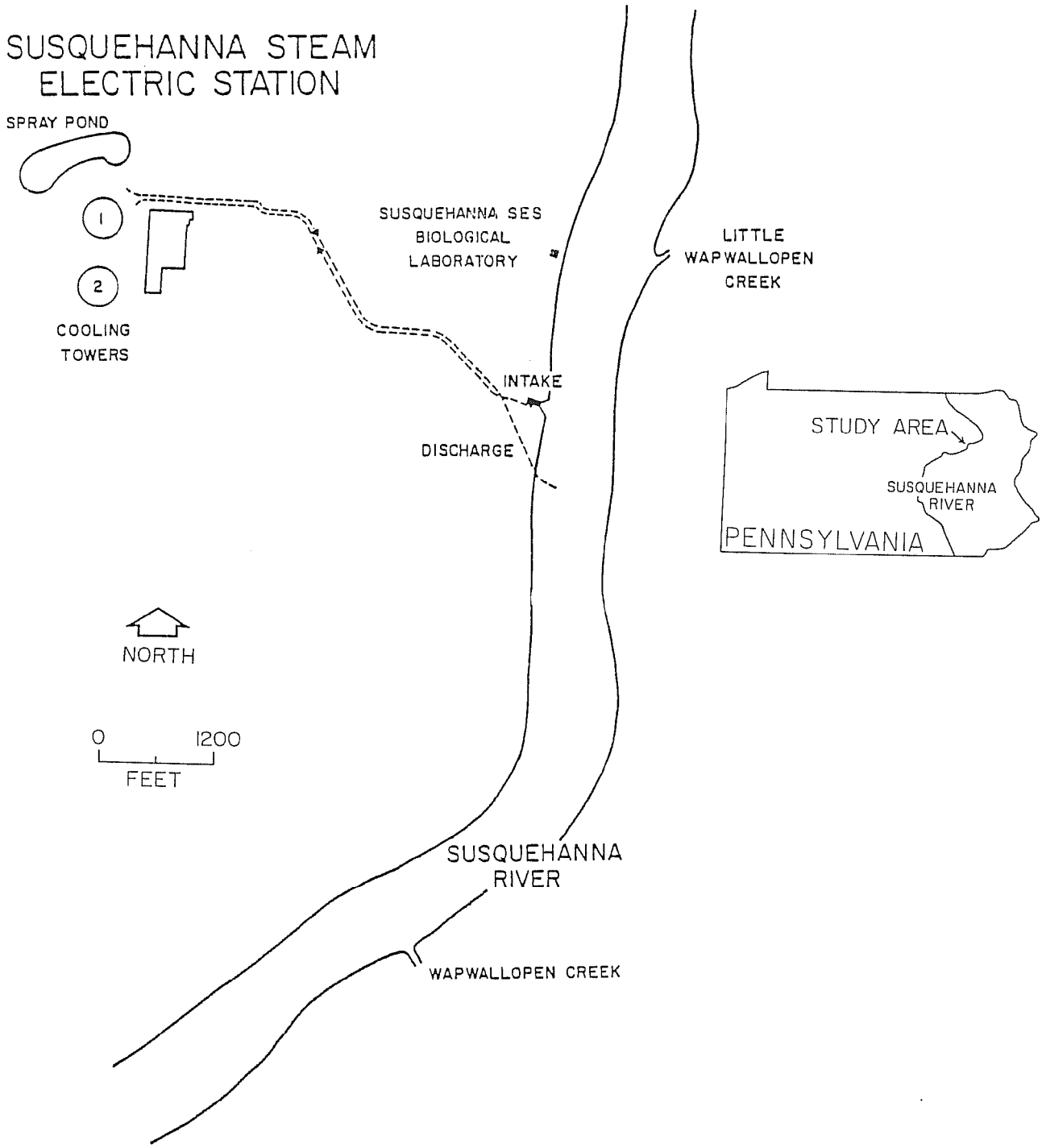

Figure 1

Location of the Susquehanna Steam Electric Station discharge in the Susquehanna River.

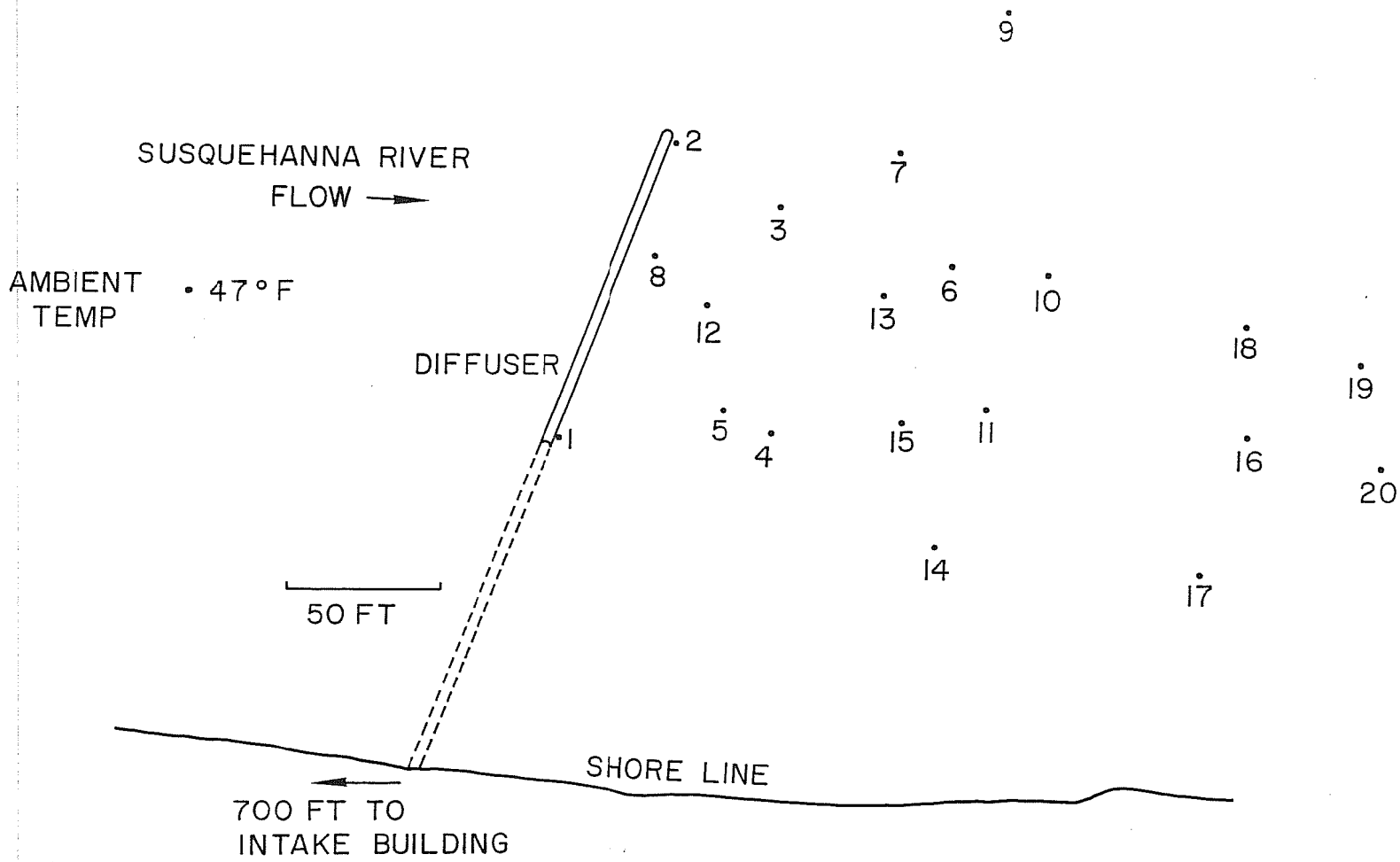

Figure 2

Sites at which water temperatures were recorded at 1-foot intervals from surface to bottom on the Susquehanna River near the discharge diffuser of the Susquehanna Steam Electric Station, 5 November 1986.

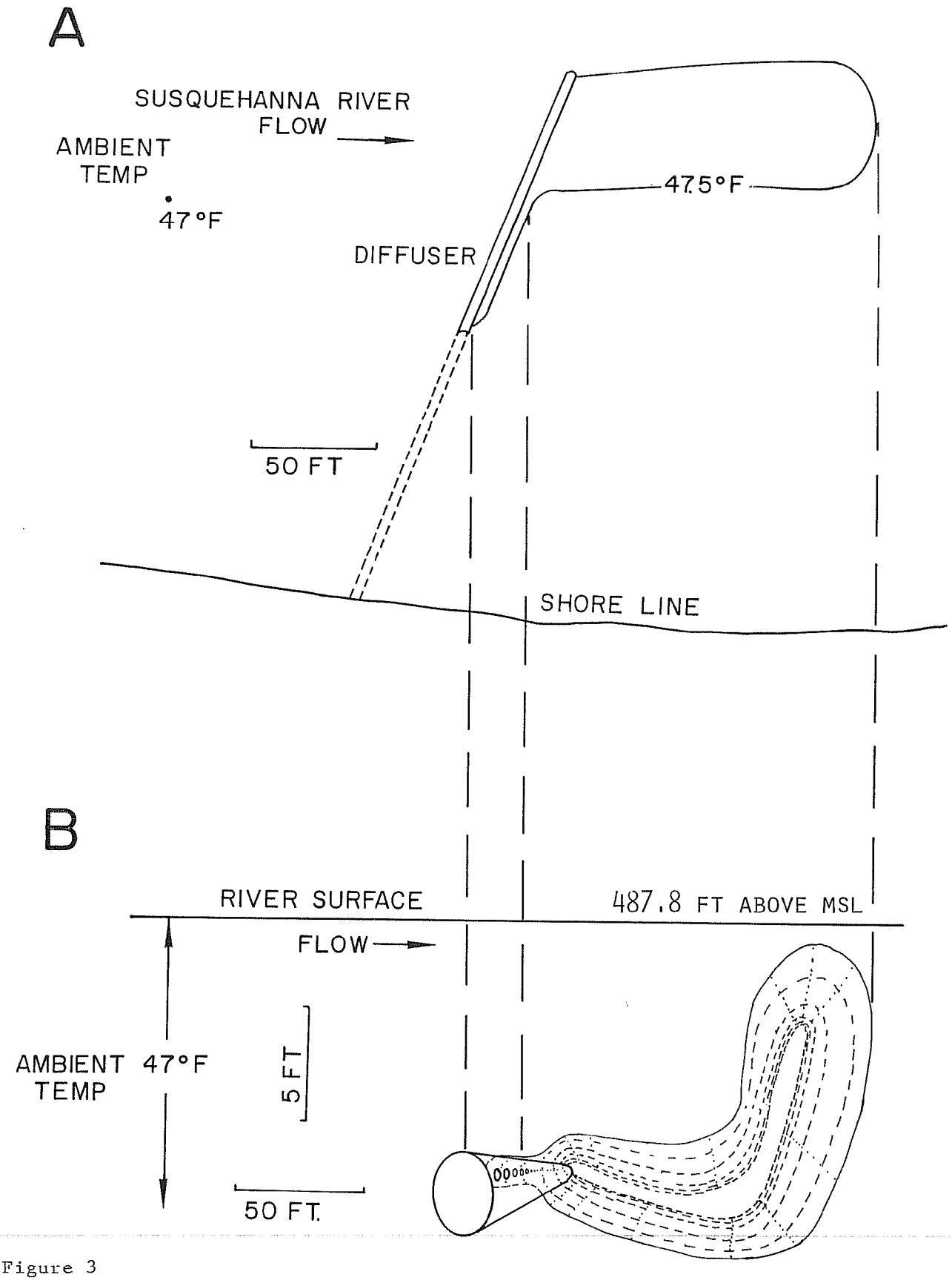

Figure 3

Limits of a thermal plume (0.5 F above ambient water temperature) in the Susquehanna River caused by the release of cooling tower blowdown from the discharge diffuser of the Susquehanna Steam Electric Station, 5 November 1986. (A = planar view, B = three-dimensional view)

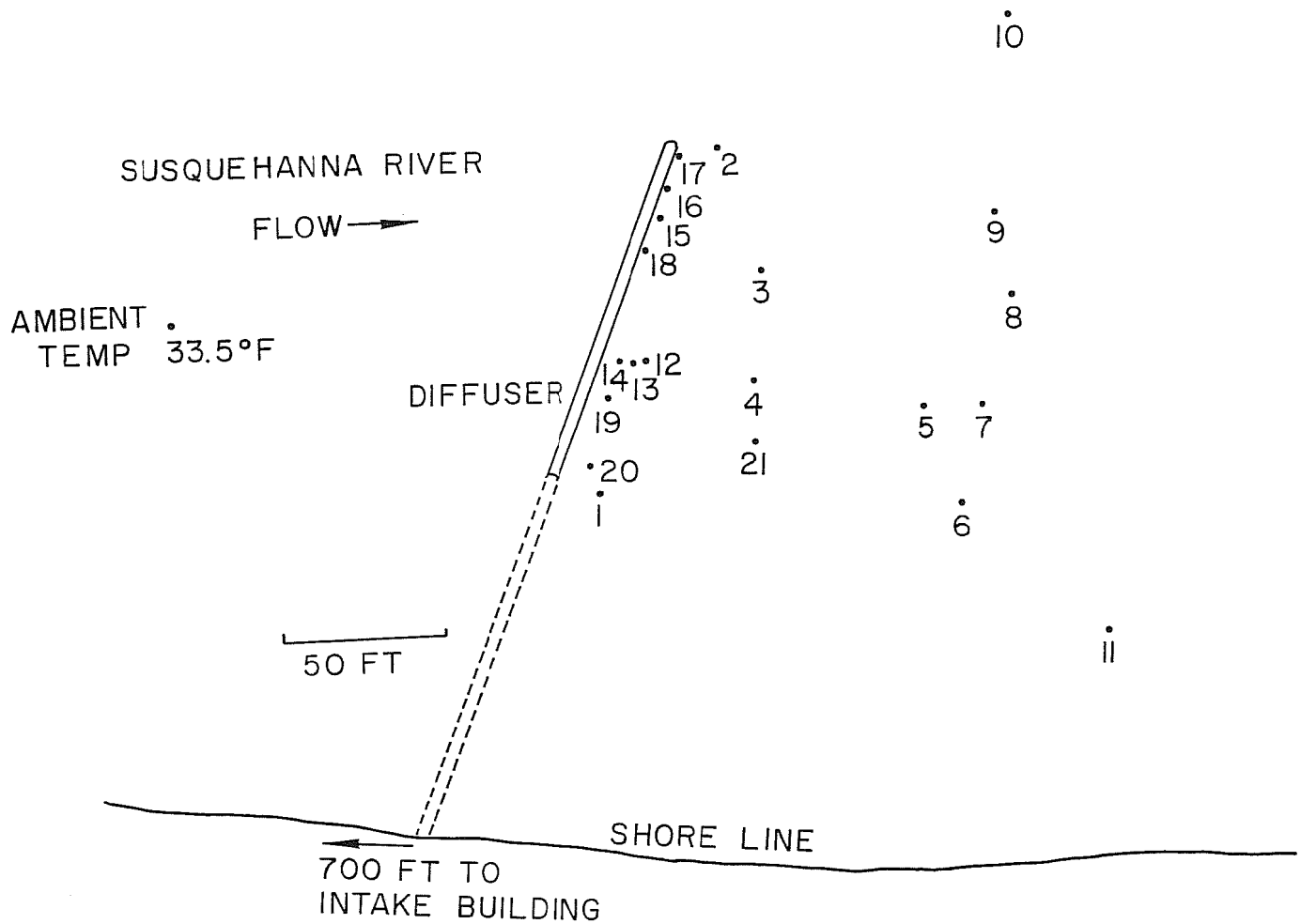

Figure 4

Sites at which water temperatures were recorded at 1-foot intervals from surface to bottom on the Susquehanna River near the discharge diffuser of the Susquehanna Steam Electric Station, 9 January 1987.

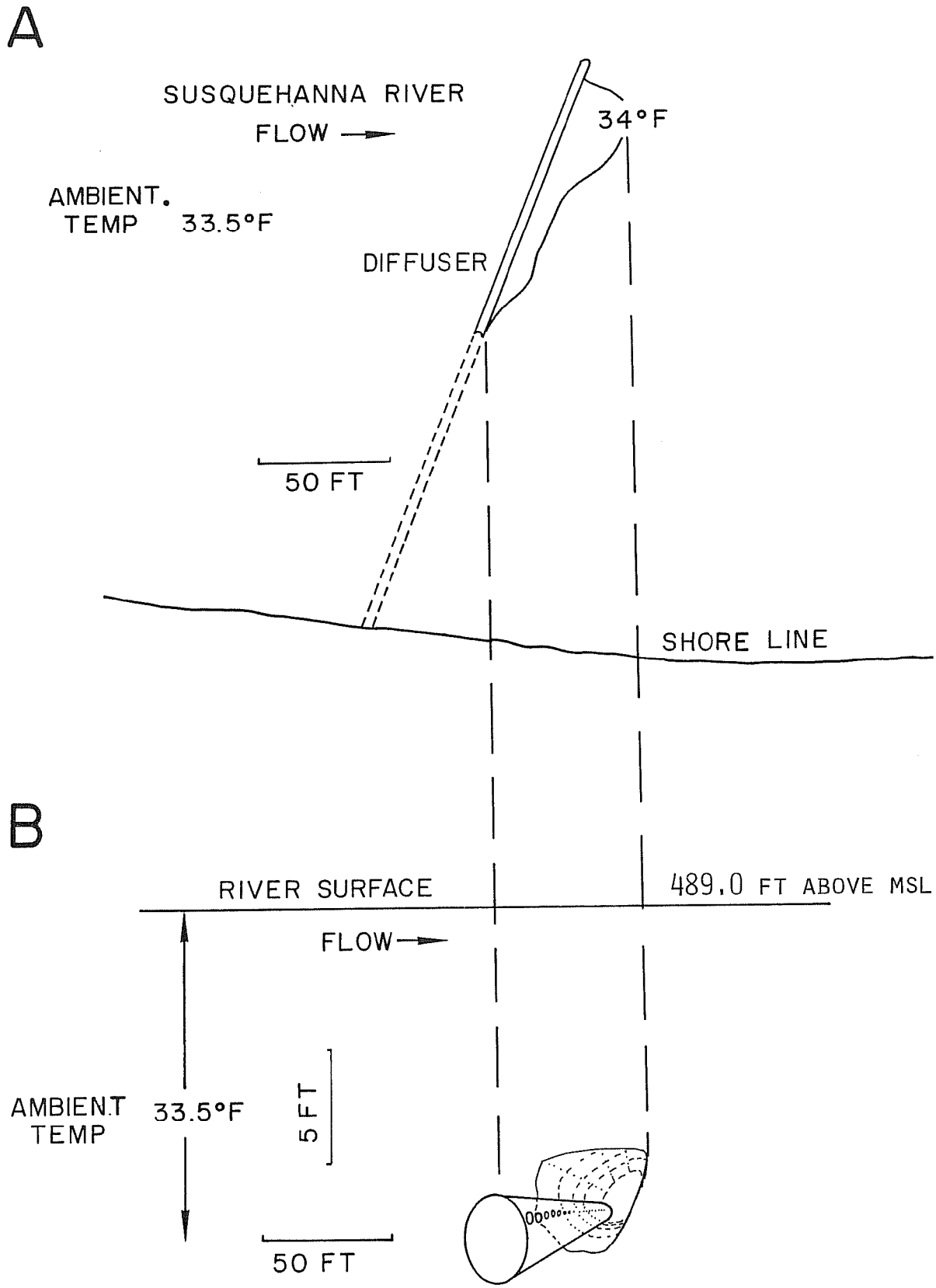

Figure 5

Limits of a thermal plume (0.5 F above ambient water temperature) in the Susquehanna River caused by the release of cooling tower blowdown from the discharge diffuser of the Susquehanna Steam Electric Station, 9 January 1987. (A = planar view, B = three-dimensional view)

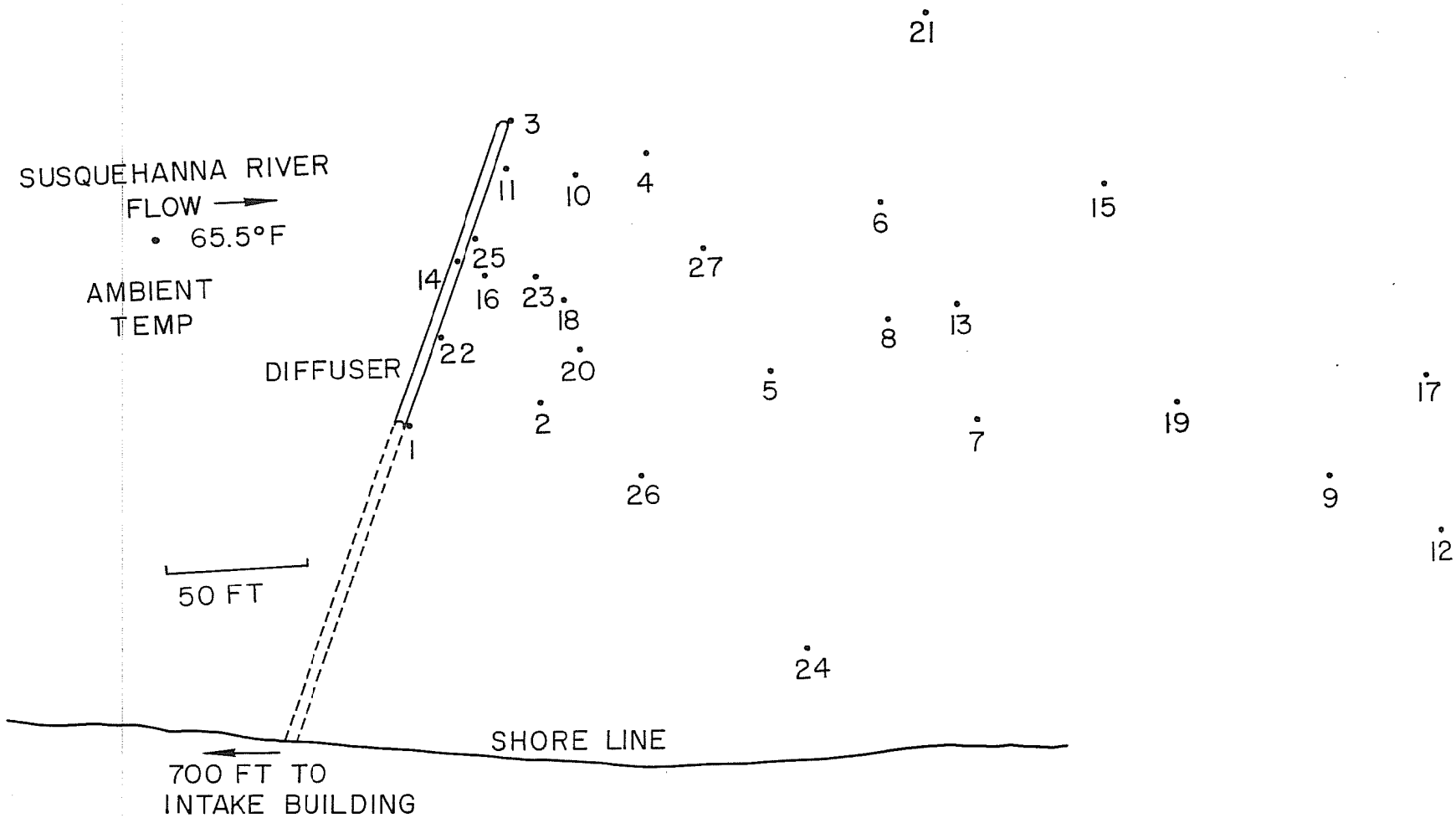

Figure 6

Sites at which water temperatures were recorded at 1-foot intervals from surface to bottom on the Susquehanna River near the discharge diffuser of the Susquehanna Steam Electric Station, 14 May 1987.

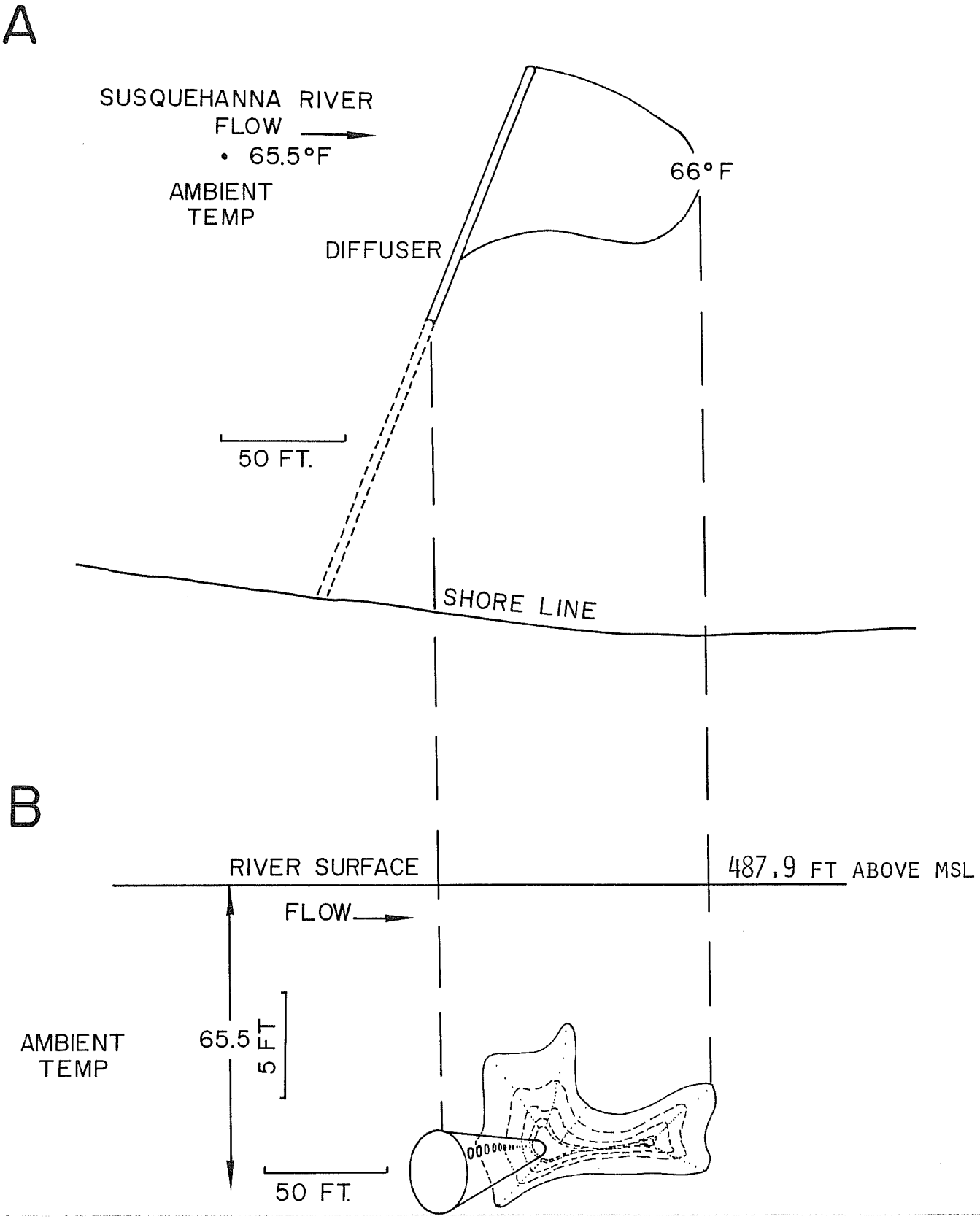

Figure 7

Limits of a thermal plume (0.5 F above ambient water temperature) in the Susquehanna River caused by the release of cooling tower blowdown from the discharge diffuser of the Susquehanna Steam Electric Station, 14 May 1987. (A = planar view, B = three-dimensional view)

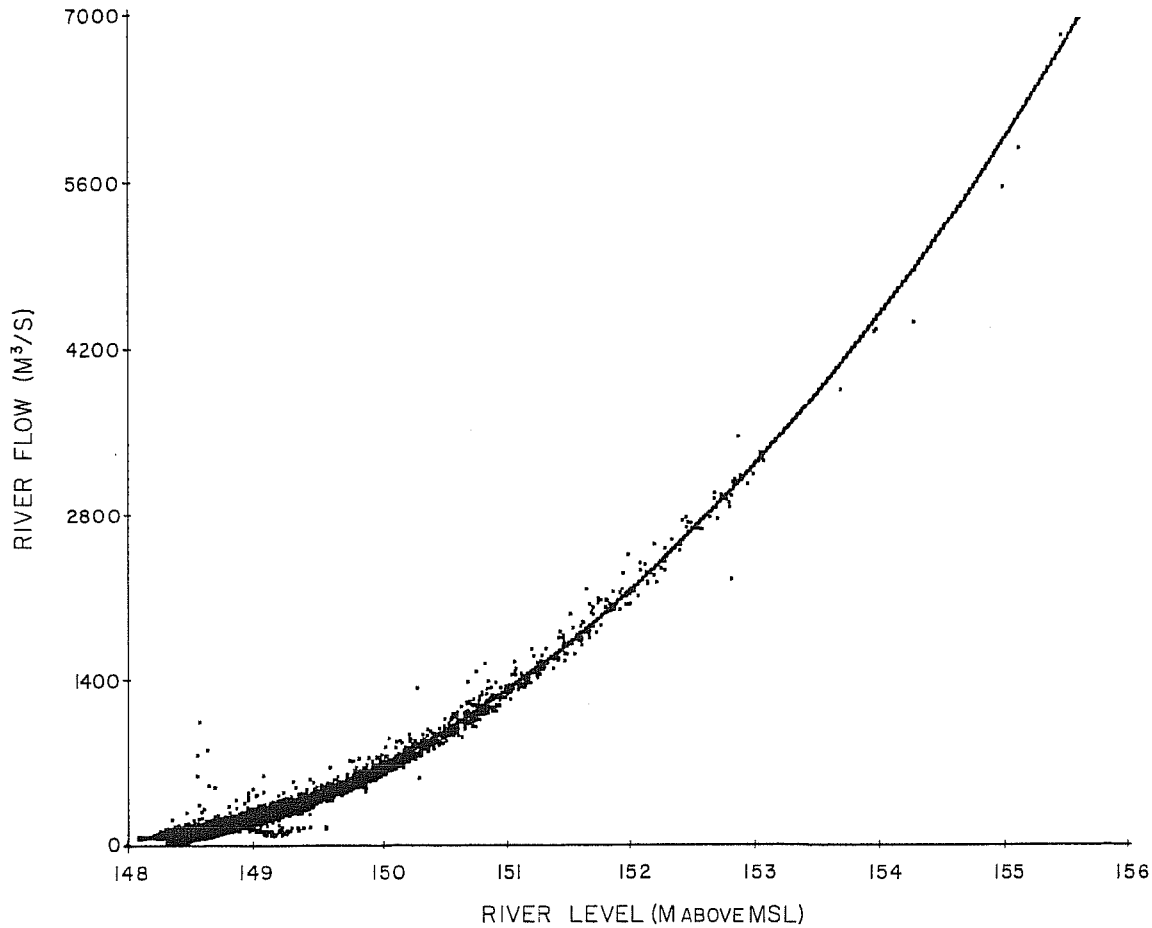

Figure 8

The relationship between flow (m^3/s) and level (m above msl) of the Susquehanna River at the Susquehanna SES Biological Laboratory from July 1973 through November 1980.