H. B. ROBINSON
STEAM ELECTRIC PLANT

316 DEMONSTRATION
SUMMARY

CP&L

Carolina Power & Light Company

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June 30, 1976

Table of Contents

1.0 Conclusions and Recommendation

Conclusions

This 316 Demonstration shows that a balanced, indigenous aquatic community similar to other blackwater communities in the Southeast exists throughout the year in the Robinson Impoundment. As expected, seasonal effects on phytoplankton and benthos related to the thermal effluent were observed in the vicinity of the discharge (Figure 1). However, the entire water column in this area was not affected because of the layering of the heated discharge waters. This seasonal phenomenon had little overall effect upon the indigenous population of fish, shellfish, and wildlife in and on the impoundment and Black Creek below the dam.

Required Action

Having demonstrated in this report that the existing H. B. Robinson Plant thermal effluent has not resulted in appreciable harm to the indigenous population of shellfish, fish, and wildlife, an alternative, less stringent, thermal effluent limitation should be established for this plant under Section 316(a).

Accordingly, it is requested that Permit No. SC 0002925 provide for the continued operation of the H. B. Robinson Steam Electric Plant cooling water system in a once-through mode. Page 3 of 18 of the permit should provide for a maximum heat rejection value of 6.05×10^9 BTU/hr.

No adverse impact (within the meaning of 40CFR402.12) was found to be associated with the present intake structure. Therefore, no intake structure modifications are warranted.

2.0 Background

Legal Authority

The authority for the H. B. Robinson 316(a) Demonstration is provided in the Federal Water Pollution Control Act Amendment of 1972 (the Act) (P.L. 92-500) and in NPDES Permit No. SC 0002925 issued for the Robinson Steam Electric Plant on December 31, 1974. Section 316(a) authorizes establishment of a less stringent thermal limitation than would otherwise be applicable where it is shown that a less stringent standard will provide for the protection and propagation of a balanced, indigenous community of shellfish, fish, and wildlife in and on the waterbody. Implementing regulations are found in 40CFR Part 122 (1974).

Prior to enactment of Public Law 92-500, there were no specific thermal effluent limits applicable to the circulating water system discharges at the H. B. Robinson facility. Thermal limits were, however, established indirectly through federal/state water quality standards that provided for a maximum temperature in the receiving stream and a maximum incremental rise above ambient water temperature, both after opportunity for mixing.

Following enactment of P.L. 92-500, and as required by Section 301 of the Act, the Administrator of the Environmental Protection Agency (EPA) promulgated regulations on October 8, 1974 (40CFR Part 423) that established (among other things) thermal effluent limits for the cooling water systems of the Steam Electric Power Generating Point Source Category. Where more stringent, a point source must also comply with limitations necessary to comply with water quality standards pursuant to Section 301(b)(1)(C) of the Act. An exemption from the overwise applicable limitation is available, however, if the operator can make a successful demonstration under Section 316(a) of the Act. The mechanism for imposing effluent limitations is the National Pollutant Discharge Elimination System (NPDES) Permit. The authority for the NPDES Permit can be found in Section 402 of the Act. On May 14, 1974 CP&L submitted supplemental information to EPA for an NPDES Permit for the H. B. Robinson facility. That submittal requested that less stringent thermal effluents be established pursuant to Section 316(a) of the Act. A final NPDES Permit was issued by the Administrator on December 31, 1974, granting a deferred determination under Section 316(a) and setting June 30, 1976, as the submittal date for the demonstration.

With regard to the otherwise applicable limitations under 40CFR Part 423, the Administrator established certain classes and categories of steam electric generating units. In effect the regulations exempt from thermal effluent limits "old" units placed in service prior to January 1, 1970. This exemption assumes the unit's thermal discharge is in compliance with water quality standards in the receiving stream after opportunity for mixing. H. B. Robinson Unit No. 1 falls within the "old unit" sub-category and and as such is exempt from thermal effluent limits.[1]

Another category established in 40CFR Part 423 is the "generating unit" sub-category. A "generating unit" can be defined as any unit of 500 megawatts or greater placed in service after January 1, 1970. This sub-category encompasses H. B. Robinson Unit No. 2. While this sub-category establishes certain limitations for discharge of heat, it recognizes cooling lakes as acceptable heat dissipation mechanisms providing the owner can show that a cooling lake was in use or under construction as of the effective date of the regulation (40CFR Part 423.13(l3). Since the Robinson Unit No. 2 is served by an existing cooling lake[2] the otherwise applicable thermal limits are those derived from S. C. Water Quality Standards.[3]

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[1] According to EPA interpreation of South Carolina Water Quality Standards, the applicable thermal water quality standards provide that the monthly average temperature, after adequate mixing of heated and normal waters as a result of heated liquids, shall not exceed 90°F nor shall the monthly average water temperature after passing through an adequate zone for mixing be more than 3°F greater than that of water unaffected by the heated discharge.

The Company has estimated that a mixing zone of approximately 350 acres (summer conditions) would accommodate the thermal discharge from Unit No. 1 which could generally be considered a reasonable zone of mixing consistent with the thermal limits.

[2] The term "cooling lake" is defined at 40CFR423.11 as any man-made water impoundment which impedes the flow of a navigable stream and which is used to remove waste heat from heated condenser water prior to recirculating the water to the main condenser.

[3] See supra n.1. According to South Carolina's interpretation, Lake Robinson is an impoundment. As such, water quality standards are only applicable to the dam release. They are 90°F maximum temperature and 5°F rise above ambient. To the extent either or both interpretations are applicable, the data show an alternative standard is required pursuant to Section 316(a) which allows operation of Unit 1 in its present mode and Unit 2 at 2300 MWt capacity.

Scope of the Demonstration

To provide operators of steam electric generating units with guidance in conducting 316(a) demonstration programs, the Administrator published at 40CFR Part 122 three separate and distinct methods for making a biological demonstration. An operator can select any one or a combination of these demonstration plans. Accordingly, the Company prepared a demonstration plan consistent with these regulations and with EPA Region IV's Basic Guide to the Design of 316 Demonstrations. The demonstration plan was submitted to EPA Region IV in December 1974 and was modified on March 17, 1975 to incorporate recommendations made by the agency on March 5, 1975. By letter of July 24, 1975, EPA Region IV acknowledged the adequacy of the study plan. (Refer to Vol. II, Section 1.0 for copy of plan.)

In Volumes II and III of this H. B. Robinson 316(a) demonstration, Carolina Power & Light Company shows that 1) no appreciable harm has resulted from the thermal component of the discharge to the post-impoundment balanced indigenous[4] community of fish and wildlife in and on the Robinson Impoundment and a portion of Black Creek below the impoundment and 2) that in fact an abundant and diverse fishery and wildlife resource (with due consideration of the natural limitations imposed by solar radiation and the peculiar watershed chemistry) exists in and on the water body of the Robinson Impoundment and Black Creek.

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[4]The term "balanced indigenous community" is defined at 40CFR Part 122.1 (i) as "synonymous with the term 'balanced, indigenous population' in the Act and means a biotic community typically characterized by diversity, the capacity to sustain itself through cyclic seasonal changes, presence of necessary food chain species, and non-domination of pollution tolerant species. Such a community may include historically non-native species introduced in connection with a program of wildlife management and species whose presence or abundance results from substantial irreversible environmental modifications. Normally, however, such a community will not include species whose presence or abundance is attributable to the introduction of pollutants that will be eliminated by compliance by all sources with Section 301(b)(2) of the Act, including alternative effluent limitations imposed pursuant to Section 316(a)."

Physical Description

Carolina Power & Light Company's H. B. Robinson Steam Electric Plant consists of two steam electric generating units. Unit No. 1, a 185 MWe coal-fired unit was placed in operation in 1960. Unit No. 2, a 700 MWe (2200 MW thermal) nuclear unit, was placed in operation in 1971. A request has been made to the Nuclear Regulatory Commission (NRC) to increase power for Unit No. 2 to 730 MWe (2300 MW thermal). An NRC Atomic Safety & Licensing Board presently has taken the request under advisement.

For the sole purpose of providing a heat dissipation mechanism for waste heat rejected from the Robinson generating units, an impoundment was constructed on Black Creek in 1959. The total drainage area controlled by the Robinson Impoundment is approximately 44,807 ha (173 sq. mi.). At normal pool evaluation 67.1 m (220 feet) MSL the impoundment has a storage capacity of 41,000 acre-feet and a surface area of approximately 900 ha (2250 acres). Construction of the impoundment was authorized under South Carolina Pollution Control Authority (now Department of Health & Environmental Control) Permit No. 179. Operation is under DHEC Permit No. 307.

Environmental Characteristics of the Impoundment

Black Creek, a tributary of the Pee Dee River Basin, is a typical blackwater stream exhibiting low pH (acidic) and darkly stained water resulting from the leaching of organic material in the swampy drainage. Chemical analyses indicate that pH values between 4.8 - 5.8 can normally be expected in the watershed. Concentrations of nutrients associated with biotic production are low as is typical of blackwater impoundments.

The effects of the naturally occurring low pH and dark color of the water substantially reduce the diversity and productivity of the phytoplankton community. This is evidenced by the presence of acidophilic species (i.e., species tolerant of the acidic conditions). This naturally occurring low phytoplankton productivity is reflected in the higher trophic levels of the food chain.

A second major distinction of blackwater systems in addition to their hemical properties is their solar radiation absorption. Data show that during he summer approximately 60% of the temperature rise of the water discharged rom the Robinson Impoundment is attributable to solar radiation. The darkly tained water absorbs much more heat than "clear" water, just as any dark urface absorbs more heat than a similar, but lighter-colored object.

The Robinson Impoundment is further characterized by habitat variations between the upper impoundment (which is largely unaffected by thermal discharge) and the lower impoundment and discharge areas. The upper impoundment has large quantities of aquatic vegetation and numerous floating and submerged logs which provide fisheries habitat. In contrast, the lower impoundment has large areas of sandy shoreline which are subject to turbulence from wave action, and offers generally less desirable habitat for most aquatic organisms.

3.0 Summary

Plant Operating Data

The intake structures for both H. B. Robinson units are located near the dam on the west shore of Robinson Impoundment. Measured velocities within the Unit 1 intake are less than .46 m/sec (1.5 ft/sec). In Unit 2, velocities generally range between .31 and .92 m/sec (1.0 and 3.0 ft/sec).

The average rise in temperature across the Unit 1 condensers is 13.3°C (24°F). The rise across the Unit 2 condensers is somewhat less, 11.1°C (20°F). The average condenser rise across both units is 11.3°C (20.3°F).

After passage through the condensers, circulating water from both units is routed into a common discharge canal. The discharge canal runs along the west shore of the impoundment terminating at a weir 6.7 km (4.2 miles) north of the plant. Velocities within the canal vary between 0.4 m/sec and 0.7 m/sec (1.3 and 2.5 ft/sec). Circulating water is discharged into the impoundment at the weir. Volume II, Section 2.0 contains detailed plant operating data.

Environmental Data

Temperature

As circulating water is discharged from the discharge canal into the impoundment, warmed water disperses and forms a surface layer over cooler bottom waters entering the discharge area from the upper impoundment and Black Creek drainage area. Normal circulation patterns are southward from the discharge to the dam and the plant.

Seasonal variation of surface and vertical temperature patterns in the impoundment was noted. During early fall, winter, and late spring waters were well mixed in the lower impoundment. Generally uniform temperatures were recorded for each water column, especially at the deeper southernmost transects during winter periods. During spring, mixing occurred in the lower impoundment after which a temperature gradient was established and maintained until fall when mixing reoccurred. However, during summer, thermal stratification was established at the deeper stations.

In the mid-impoundment area near the discharge, heated discharge waters layered over significantly cooler bottom water. This phenomenon was observed during all seasons of the year. (Vol. II, Figures 3.3.3 through 3.3.11 attached).

Maximum temperatures were recorded during July and August when discharge temperatures generally remained above 40°C (104°F) but below 43°C (109°F). Modeled temperatures as well as observed temperatures during summer indicated that surface temperatures at the dam were warmed by about 2°C (3°F-4°F).

Water Chemistry

The acid pH of the water of Robinson Impoundment and Black Creek is characteristic of the drainages of the coastal areas of this region. The considerable quantities of humic materials produce both the color and the acidic nature of these waters. Historically, such waters have always been recognized as being of low biological activity.

There was no overall pattern of change in the water quality of Black Creek as it passed through the impoundment that could be attributed to the operation of the impoundment with the exception of copper. (Vol. II, Section 3.4). Copper levels within the impoundment are in the concentration range which could be algalstatic. We are continuing to monitor copper concentrations.

Dissolved Oxygen

Dissolved oxygen patterns and concentrations were similar to other man-made impoundments of this type. Concentrations of dissolved oxygen were generally uniform throughout the water column at all stations from mid-fall to mid-spring. From late spring to early fall, D.O. concentrations below 4 mg/l were recorded at or near the bottom of the deeper impoundment stations, with temporary dissolved oxygen stratification occurring during summer. (Vol. III, CP&L Exhibit 2.5.)

Fisheries

Fisheries studies at the Robinson Impoundment began in 1972 and 1973 and were reviewed and intensified to strengthen the studies and meet regulatory agency requirements. These studies were designed to study all major aspects of fish distribution, growth, feeding, and reproduction, in order to determine if any of these were affected by the plant's operation.

Species composition and distribution studies showed that thirteen of the thirty-one species collected in the impoundment were centrarchids (sunfish), indicating the importance of that group. (Vol. II, Table 4.2.1 attached.) The species list is similar to other area lakes exhibiting similar environmental characteristics (low pH, dark water) (Vol. II, Table 4.2.2 attached).

The Robinson Impoundment fisheries do not appear to be significantly reduced by plant operations except in the immediate discharge area during summer. Fish distributions appear to be primarily affected by habitat. Numerically, little difference was evident in total gill net catches from Stations E-3, E-1, C-3, C-1, and A-1 (Figure 1), but these catches were appreciably lower than those in the upper impoundment, particularly G-3. Bluegill and chain pickerel were more abundant in the lower impoundment, while suckers and golden shiners were more abundant in the discharge and upper impoundment. (Vol. II, Section 4.2.3, Gill Netting).

Electrofishing samples showed generally increased diversity from the lower impoundment to the upper impoundment, with temporal and spatial variations. Transect A showed highest total catches, while the discharge and upper impoundment areas showed no apparent differences. Largemouth bass were more abundant at E-3, E-1, and A-1, while warmouth were more abundant at A-1, G-3, and A-3. (Vol. II, Section 4.2.3, Electrofishing.)

Standing crop estimates ranged from 29.3 kg/ha (26.0 lbs/acre) in the upper impoundment in 1975 to 139.8 kg/ha (124.0 lbs/acre) in the lower impoundment during 1975. During both 1974 and 1975, greatest numbers of fishes were collected from the mid-impoundment. No species was conspicuous by its presence or absence. These data are similar to other lakes in the region with comparable environmental characteristics. Although surface temperatures in some areas of Robinson Impoundment approached thermal maxima for many species, standing crop data show fish are present in good numbers, possibly indicating utilization of temperature stratified or refuge areas. (Vol. II, Section 4.3.3.)

Food habits analysis for the bluegill have indicated that planktivory is an important feeding strategy of bluegills in the lower impoundment and that this feeding strategy probably reflects the optimal feeding conditions under the existing habitat conditions (i.e., limited littoral habitat). In the upper impoundment, the diet of bluegills was more diverse, had a greater evenness in distribution of major food items, and included a greater proportion of large-bodied benthic invertebrates. This feeding behavior is typical of that described in the literature and no stresses were apparent from either low productivity or heat load. In the discharge area, the feeding conditions during he summer of 1975 were the poorest encountered in the impoundment and benthos bundances and species diversity were very low creating an unstable food supply. his lack of stability of dominant food items indicated a food stress on blue- .ill population in the discharge area, although it apparently had little overall mpact on growth the reproduction of bluegills in the impoundment. Food habits of largemouth bass, warmouth, and chain pickerel were similar to literature lescriptions and a comparison of food selectivity with availability in the habitat suggest that food was not a limiting factor for growth and reproduction. (Vol. II, Section 4.4.3.)

Age-growth and length-weight studies showed no obvious differences throughout the impoundment although some variations did exist. Growth rates were low but similar to other blackwater lakes in the region. Length-weight analysis did not indicate poor condition of fishes in the discharge vicinity. (Vol. II, Section 4.5.3.)

Fecundity estimates, indicative of potential productive effort, were similar to literature values for largemouth bass and warmouth. Bluegill fecundity was lower than literature values as was mature egg diameter. The causative environmental and/or biological determinants for these findings were not apparent from the data. (Vol. II, Section 4.2.2.)

Examination of data pertinent to a 316(b) demonstration showed that entrainment of larval fish through the H. B. Robinson Unit 2 circulating water system occurred during all months except January but no fish eggs were collected in any of the samples. Of the fish collected, 93.8% were percids. Catostomids were only collected during May (.3% of the total) while centrarchids (2.6%) were collected in June, July, and October. A small number of specimens (3.3%) collected during June and October could not be identified to the family level. Of these taxa, and others found in the impoundment, none are known to prefer pelagic areas such as those in the vicinity of the intake structure for spawning. Percids, however, are thought to move into the pelagic areas of the impoundment soon after hatching as evidenced by their abundance in ichthyo- plankton tow samples from the lower impoundment and discharge areas. The pre- sence of larval percids during 11 months of the year, their apparent numerical abundance in the lower and middle impoundment areas (Vol. II, Section 4.2, Section 4.3), and their continued presence and abundance after 4 years of plant operation, strongly suggest no appreciable harm has been done to percid populations and therefore the effects of ichthyoplantion entrainment on the fish population of Robinson Impoundment are negligible.

Fish impingement on the Unit 1 intake screens was negligible averaging less than 0.5 kg of fish per day during 1974 and 1975. Rates for Unit 2 were higher averaging 5.8 kg per day (12.7 lbs per day) in 1974 and 4.8 kg per day (10.6 lbs per day) in 1975. Of these, bluegills made up 98% (74% of the biomass) and 95% (75% of the biomass) of the catch during 1974 and 1975. Maximum impingement on Unit 2 occurred during late summer of both years. The majority of fish impinged were less than 115 mm in length with the larger average sizes collected during the late winter and spring months.

In evaluating the importance of impingement, the species and numbers of fish present in the vicinity of the intake must be considered (Vol. 2, Sections 4.2 and 4.3). The majority of fish impinged were small bluegills which were also very abundant in the area. The abundance data, particularly after four years of plant operation, suggest that impingement has not done appreciable harm to the bluegill population in this area of the impoundment.

Plankton

The study of the plankton community of the Robinson Impoundment began in May, 1973, and continued, with modifications, through December, 1975. Plankton community dynamics were described by studies of standing crop (numbers, biomass, and species diversity), chlorophyll concentrations, and primary productivity.

Standing crop data indicated similar populations by abundance and population composition in the lower impoundment (A) and the discharge area (E), (Vol. II, Section 5.3, Standing Crop), whereas the upper impoundment population was generally much smaller by number and biomass. The same taxa and major groups were primarily important at all three stations. Chlorophyta, or green algae, was the dominant group throughout the year, with small coccoid green algae and desmids being most abundant within this group. Diversity was low at all three stations but was comparable to other water bodies of similar water quality.

The zooplankton community was dominated by a very few taxa of Cladocera and Copepoda. Eubosmina sp. and Cyclops spp. were dominant in the fall, while Diaphanosoma sp. and Diaptomus sp. were dominant in the spring. Although the zooplankton population during August was greatly reduced at the discharge and was reduced in the lower impoundment, the population composition and abundance returned to previous levels in September.

Chlorophyll data were comparable with quarterly estimates of primary productivity and standing crop and offer a good estimate of phytoplankton population dynamics. (Vol. II, Figures 5.3.1 and 5.3.2 attached). Comparison of monthly chlorophyll concentrations indicated that the same "population" existed in the lower impoundment and the discharge. Erratic fluctuations and the absence of a seasonal pattern in chlorophyll concentrations in the upper impoundment suggests the presence of a population originating in the stream.

The phytoplankton community appears to be adapted to the regime of low alkalinity, nutrient fluctuations, and the range of temperatures observed over the sampling period. At temperatures exceeding 32°C for long periods, a population stress was indicated by the reduction of primary productivity in the discharge area (E-3) (Vol. II, Section 5.3, Primary Productivity). This was reflected in community production efficiency and energy flow in this area during the summer. However, since the population composition and total abundance were not altered as a result of this stress, it can be concluded that the population is stable and can recover from periodic stresses when conditions are more favorable.

Overall, phytoplankton standing crop and primary productivity appeared to be enhanced in the lower impoundment and discharge area when compared with the upper impoundment. Primary production of the Robinson Impoundment, while moderately low, compared well with rates for similar water bodies in the area. (Vol. II, Table 4.3.3 attached.)

Benthos

The numerically important benthic taxa collected during the study were Chironomidae (41% of the total), Oligochaeta (33%) and Culicidae (12%). These three taxa totaled 86% of the organisms collected. Within the remaining 14%, two additional taxa, Trichoptera and Ephemeroptera were examined because of their importance as fish food items. The remaining taxa were not collected in sufficient numbers to merit further consideration.

Within the numerically important taxa, spatial and temporal distributions were determined for the most frequently collected genera. (Vol. II, Tables 6.3.2 - 6.3.5 and Figures 6.3.1 - 6.3.8).

Diversity indices were calculated to obtain information on benthic community structure and stability (Vol. II, Table 6.3.6 attached).

Organism abundance and diversity appeared to be relatively consistent throughout the year at all parts of the impoundment except the discharge area. The abundance and diversity at the discharge were similar to the other sampling areas of the impoundment from November through May, but were depressed during summer months which was reflected in the comparison of the annual mean abundances of the discharge area with other locations. Data suggest that this depression of diversity and abundance at the discharge is the result of the thermal effluent during the summer months.

Aquatic Vegetation

A complex set of interacting factors combine to determine the distribution of aquatic vegetation. Water chemistry, substrate, turbulence, light penetration, and temperature were all found to influence distribution of aquatic vegetation in Robinson Impoundment. (Vol. II, Section 7.3.1). It can be generalized from the literature reviewed that detrimental temperature effects may become apparent near 35°C (95°F). However, temperatures and their effects vary among species. Except in the immediate area of the discharge, turbulence, substrate, and physiographic and man-made features are the primary reasons for reduced aquatic vegetation in unprotected areas of the impoundment.

No apparent differences in the overall species distribution (Vol. II, Figures 7.2.1 - 7.2.4 attached) could be discerned from the dam to the SR 346 bridge, except those caused by substrate and turbulence. Areas in which the thermal effluent restricts the growth of aquatic plants occur in the protected coves on the eastern shore opposite the discharge canal and in the coves directly north of the canal. These areas provide necessary habitat for potential colonization of aquatic plants. Wind caused turbulence in these areas is moderate; the substrate contains some silt and organic material, and the bottom slopes gradually away from the shores, providing an expanse of shallow water.

Above the SR 346 bridge (Vol. II, Figure 7.2.4 attached), an abrupt change in vegetation is apparent. Substrate and reduced wave action increase the suitability of this area for colonization by macrophytes. Except when strong southerly winds force heated water under the bridge, very little, if any, thermal addition is made to this area by the plant discharge. There are no identifiable effects of the thermal effluent from the Robinson Plant in this area.

In considering the entire impoundment, the limited areas which are thermally influenced from the standpoint of aquatic macrophytes do not pose a threat to the protection of a balanced and indigenous community of shellfish, fish, and wildlife in and around the impoundment.

Terrestrial Vertebrates

For the four classes of vertebrates (amphibians, reptiles, birds, mammals) examined during the study, habitat preference was found to be the most important factor determining distribution of these animals within the study area.

Twenty-two species of amphibians (Vol. II, Table 8.2.1 attached) were identified within the study area. Needs common to all individuals of those species while at Robinson Impoundment or Black Creek included water temperatures within tolerable ranges, cover, food, and breeding sites. The expected and observed habitat preferences and requirements, not the elevated temperatures, were considered primarily responsible for the restriction of most of the amphibian species to shallow, more heavily vegetated margins of the impoundment. Limitation of aquatic vegetation by the heated discharge (Vo. II, Section 7.0) reduced the amount of suitable habitat available for amphibians in the immediate area of the discharge.

The combined thermal impact on the reproduction, development, and growth of the amphibian species at Robinson Impoundment was not considered a signficant threat to the continued existence of those species or population balances.

Ten species of aquatic and semi-aquatic reptiles (Vol. II, Table 8.3.1 attached) were found to occur within the study area. These species depended on the aquatic ecosystem for such factors as water temperature within the tolerable ranges, appropriate cover, and adequate food supply.

In the summer, thermal exclusion areas in the vicinity of the discharge reduced the distribution of some reptilian species. For those species which did occur in the thermally affected area, cooler refuge areas existed within or adjacent to the exclusion areas and provided a suitable habitat where displaced reptiles could survive critical periods.

A reduction of the distribution of reptilian species in the area of the discharge may have resulted from the seasonal limitation of aquatic macrophyte and benthic production. (Vol. II, Section 6.0 and Section 7.0).

The Robinson Impoundment provides an attractive habitat for a wide variety of aquatic avifuana (Vol. II, Table 8.4.1 attached). Comparisons of the species composition and relative abundance of avifauna present at Robinson Impoundment with those recorded at the Sandhills National Wildlife Refuge, the EPA Savannah River Plant, and other study areas in the southeast, indicate little or no difference.

Within the impoundment, the availability of suitable habitat determined the distribution of the species. Habitat for a given group did not differ in its attractiveness between heated and unheated portions of the impoundment in any way that could be attributed to heat load.

Within habitat types, the effects of the thermal effluent on aquatic avifauna are indirect. Each group of waterbirds utilizes one or more components of the aquatic ecosystem as a food source. Impact upon these components by the heated effluent would result in changes in numbers and distribution in the higher trophic levels occupied by aquatic birds. Data presented in Volume II, Sections 4.0, 6.0, and 7.0 indicate that these lower trophic levels were not impacted to the extent that the avifauna utilizing as a food source were affected.

Fifteen species of mammals (Vol. II, Table 8.5 attached) were observed at Robinson Impoundment and Black Creek during the study period. Five of those species were determined to interact with the aquatic ecosystem to a significant extent.

The ability of mammals to thermoregulate precludes any direct effect of the heated effluent upon species residing in the water. Availability of suitable habitat was the factor determined to have exercised the greatest influence on mammal distributions at the Robinson Impoundment and along Black Creek.

The thermal impact on the terrestrial vertebrates was not considered great enough to threaten the continued existence or maintenance of the balanced indigenous community found to occur at Robinson Impoundment.

4.0 Reference Tables and Figures

(Table and Figure Numbers Correspond to those Used in Volume II)

Table 4.2.1 Common and scientific names of fishes collected from H. B. Robinson Impoundment during 1974 and 1975

Bowfin	Amia calva
Eastern mudminnow	Umbra pygmaea
Redfin pickerel	Esox americanus
Chain pickerel	Esox niger
Golden shiner	Notemigonus chrysoleucas
Dusky shiner	Notropis cummingsae
Creek chubsucker	Erimyzon oblongus
Lake chubsucker	Erimyzon sucetta
Spotted sucker	Minytrema melanops
White catfish	Ictalurus catus
Yellow bullhead	Ictalurus natalis
Flat bullhead	Ictalurus platycephalus
Swampfish	Chologaster cornuta
Pirate perch	Aphredoderus sayanus
Lined topminnow	Fundulus lineolatus
Mosquitofish	Gambusia affinis
Mud sunfish	Acantharchus pomotis
Flier	Centrarchus macropterus
Banded Pigmy sunfish	Elassoma zonatum
Blackbanded sunfish	Ennaecanthus chaetodon
Bluespotted sunfish	Enneacanthus gloriosus
Redbreast sunfish	Lepomis auritus
Pumpkinseed	Lepomis gibbosus
Warmouth	Lepomis gulosus
Bluegill	Lepomis macrochirus
Dollar sunfish	Lepomis marginatus
Largemouth bass	Micropterus salmoides
White crappie	Pomoxis annularis
Black crappie	Pomoxis nigromaculatus
Sunfish hybrid	Lepomis sp.
Swamp darter	Etheostoma fusiforme
Sawcheek darter	Etheostoma serriferum

Table 4.2.2 Fish species composition of H. B. Robinson Impoundment and other similar bodies of water in North and South Carolina

Common Name	Robinson Impoundment 2250 a Present Study	Singletary Lake 572 a (Louder, 1961)	Lake Waccamaw 8938 a (Louder, 1961)	Par Pond 3000 a (Clugston, 1973)	Alligator Lake 5600 a (Crowell, 1966)	Great Lake 2992 a (Bayless, 1966)	Catfish Lake 921 a (Bayless, 1966)
Longnose gar			x		x	x	
Bowfin	x		x		x		
American eel	x*		x	x	x		
Blueback herring				x			
Gizzard shad			x	x			
Eastern mudminnow	x	x					
Redfin pickerel	x	x	x	x			
Chain pickerel	x	x	x	x			
Carp			x				
Golden shiner	x		x	x	x	x	x
Ironcolor shiner		x	x				
Dusky shiner	x						
Coastal shiner			x	x			
Creek chubsucker	x	x	x				
Lake chubsucker	x	x	x	x			
Spotted sucker	x			x			
White catfish	x		x		x		
Yellow bullhead	x	x	x	x	x	x	x
Brown bullhead				x	x		
Flat bullhead	x		x	x			
Channel catfish				x			
Tadpole madtom	x*	x	x		x		
Margined madtom	x*						
Swampfish	x						
Pirate perch	x	x	x	x			
Lined topminnow	x						
Waccamaw killifish			x				
Mosquitofish	x	x	x	x		x	
Brook silverside				x			
Waccamaw silverside			x				
White perch			x				
Mud sunfish	x		x				
Flier	x	x	x		x		
Banded pigmy sunfish	x		x	x			
Blackbanded sunfish	x						
Bluespotted sunfish	x		x				x
Banded sunfish			x			x	
Redbreast sunfish	x		x	x			
Pumpkinseed	x		x				
Warmouth	x	x	x	x		x	x
Bluegill	x	x	x	x	x		
Dollar sunfish	x			x			
Redear sunfish				x			
Spotted sunfish			x	x			
White crappie	x				x		
Black crappie	x				x		
Largemouth bass	x	x	x	x			
Swamp darter	x	x	x	x			
Tessellated darter	x*						
Waccamaw darter			x				
Sawcheek darter	x						
Yellow perch		x	x	x	x	x	x
Piedmont darter	x*						
*Black Creek only							
Total Collected	36	16	35	25	13	7	5

Table 5.3.8 Comparison of Robinson Impoundment annual average primary productivity with reported literature values

Water body (type)	Productivity $mgC/m^2/day$	Rank	Author(s)
*Sylvan, Ind.	1564	1	Wetzel, 1966
*Fredriksburg, Denmark	1030	2	Nygaard, 1955
*Fureso, Denmark	750	3	Jonassen & Mathiesen, 1959
Little Crooked Lake, Ind.	608	4	Wetzel, 1969
*Clear Lake, Calif.	438	5	Goldman & Wetzel (1963)
*Walters, Ind.	437	6	Wetzel, 1966
Crooked Lake, Ind.	414	7	Wetzel, 1969
*Par Pond, S. C. (reactor-cooling reservoir)	396	8	Tilly, 1973
Robinson Impoundment (reactor-cooling impoundment)	385	9	Miller
*Clear Pond, S. C. (Carolina bay)	285	10	Tilly, 1973
*Clark Hill, S. C. (reservoir)	240	11	Tilly, 1973
*Naknek, Alaska	173	12	Goldman, 1960
*Brooks, Alaska	158	13	Goldman, 1960
*Big Snooks, S. C.	102	14	Tilly, 1973

*from Tilly (1973a)

Table 6.3.6 Diversity estimates (d) of benthos collected in Robinson Impoundment, January - December, 1975

	STATIONS											
	A-1	A-3	C-1	C-3	D-1	D-3	E-1	E-3	F	F-S	G	G-S
Jan.	1.99	0.73	1.49	1.98	1.98	2.06	2.33	1.58	2.54	2.19	3.16	2.71
Feb.	2.22	0.72	2.13	2.23	1.72	2.13	1.22	1.79	3.07	2.72	2.88	3.78
Mar.	2.19	1.87	2.86	2.01	1.73	1.97	1.78	2.22	2.01	3.22	2.56	3.92
Apr.	2.82	2.10	3.11	2.61	1.73	2.18	1.20	2.19	2.30	2.88	3.10	3.91
May	2.98	1.49	2.56	1.61	2.27	2.95	2.35	2.62	2.99	3.03	2.62	3.62
Jun.	0.83	2.10	3.18	1.51	0.73	2.89	2.69	2.47	2.34	3.10	2.15	2.79
Jul.	3.04	1.06	2.10	0.64	1.45	2.40	2.77	1.00	2.91	3.19	3.15	3.56
Aug.	2.17	1.53	2.52	0.87	1.18	2.99	0.35	1.39	2.32	3.30	2.52	2.98
Sep.	2.01	1.49	1.73	0.44	1.78	2.23	0.0	0.47	2.25	1.90	1.45	2.71
Oct.	2.89	1.48	1.41	1.30	0.74	1.55	0.0	0.82	2.56	1.55	2.70	2.73
Nov.	1.70	1.20	1.84	1.74	1.09	1.88	1.70	2.70	2.70	1.91	2.45	3.90
Dec.	1.72	1.44	2.81	2.02	2.21	2.62	2.05	2.28	2.91	2.32	1.99	4.21

Table 8.2.1 Amphibian species collected and/or observed at Robinson Impoundment and Black Creek, August 1974 through May 1976. (Nomenclature follows Conant, 1975)

Scientific Name	Common Name	Impoundment	Black Creek
Siren intermedia intermedia	Eastern lesser siren	X	X
Necturus punctatus	Dwarf waterdog	X	X
Amphiuma means	Two-toed amphiuma		X
Desmognathus fuscus	Dusky salamander	X	
Stereochilus marginatus	Many-lined salamander		X
Pseudotriton montanus	Mud salamander	X	X
Pseudotriton ruber	Red salamander	X	
Eurycea bislineata	Southern two-lined salamander	X	X
Eurycea quadridigitata	Dwarf salamander		X
Bufo americanus	American toad	X	
Bufo terrestris	Southern toad	X	X
Bufo woodhousei fowleri	Fowler's toad	X	
Acris gryllus gryllus	Southern cricket frog	X	X
Acris crepitans crepitans	Northern cricket frog	X	
Hyla crucifer	Spring peeper	X	X
Hyla cinerea	Green treefrog	X	X
Hyla squirrella	Squirrel treefrog	X	
Limnaoedus ocularis	Little grass frog	X	
Rana catesbeiana	Bullfrog	X	X
Rana virgatipes	Carpenter frog	X	X
Rana clamitans	Bronze frog	X	X
Rana utricularia	Southern leopard frog	X	X

Table 8.3.1 Reptiles collected and/or observed at Robinson Impoundment and Black Creek, August 1974 through May 1976 (Nomenclature follows Conant, 1975)

Scientific Name	Common Name
Aquatic and Semi-aquatic Species	
Chelydra serpentina	Snapping turtle
Sternotherus odoratus	Stinkpot
Clemmys guttata	Spotted turtle
Chrysemys scripta scripta	Yellow-bellied turtle
Chrysemys concinna concinna	River cooter
Chrysemys rubriventris	Red-bellied turtle
Deirochelys reticularia reticularia	Eastern chicken turtle
Natrix fasciata fasciata	Banded water snake
Natrix taxispilota	Brown water snake
Agkistrodon piscivorus piscivorus	Eastern cottonmouth
Terrestrial Species	
Terrapene carolina carolina	Eastern box turtle
Anolis carolinensis carolinensis	Green anole
Cnemidophorus sexlineatus sexlineatus	Six-lined racerunner
Eumeces fasciatus	Five-lined skink
Heterodon platyrhinos	Eastern hognose snake
Coluber constrictor	Black racer
Opheodrys aestivus	Rough green snake
Elaphe obsoleta obsoleta	Black rat snake
Lampropeltis getulus getulus	Eastern kingsnake
Leiolopisma laterale	Ground skink

Table 8.4.1 Aquatic avifauna species by category observed at Robinson Impoundment, August 1974 through February 1976

Species	Species
Grebes	Red-necked grebe
	Horned grebe
	Pied-billed grebe
Surface-Feeding Ducks	Mallard
	Black duck
	Gadwall
	American wigeon
	Blue-winged teal
	Green-winged teal
	Wood duck
Diving Ducks	Redhead
	Ring-necked duck
	Lesser scaup
	Old squaw
	Bufflehead
	Ruddy duck
	Hooded merganser
	Red breasted merganser
	Common merganser
Herons and Bitterns	Great blue heron
	Green heron
	Little blue heron
	Great egret
	Snowy egret
	Yellow-crowned night heron
	Least bittern
	American bittern
Rails	King rail
	American coot
Shorebirds	Spotted sandpiper
	Killdeer
	Silitary sandpiper
	Northern phalarope
	Common snipe

Table 8.4.1 (continued) Page 2

Category	Species
Gulls and Terns	Herring gull
	Ring-billed gull
	Bonapartes gull
	Common tern
	Black tern
Miscellaneous	Common loon
	Canada goose
	Whistling swan
	Double crested cormorant
	Belted kingfisher

Table 8.5.1 Mammal species observed at Robinson Impoundment and Black Creek, August 1974 through February 1976

Opossum (Didelphis marsupialis)

Starnose mole (Condylura cristata)

Eastern cottontail (Sylvilagus floridanus)

Gray squirrel (Sciurus carolinensis)

Beaver (Castor canadensis)

Cotton rat (Sigmodon hispidus)

Muskrat (Ondatra zibethica)

Norway rat (Rattus norvegicus)

Red fox (Vulpes fulva)

Grey fox (Urocyon cinereoargentus)

Raccoon (Procyon lotor)

Mink (Mustela vison)

Striped Skunk (Mephitis mephitis)

Otter (Lutra canadensis)

Whitetail deer (Odocoileus virginianus)

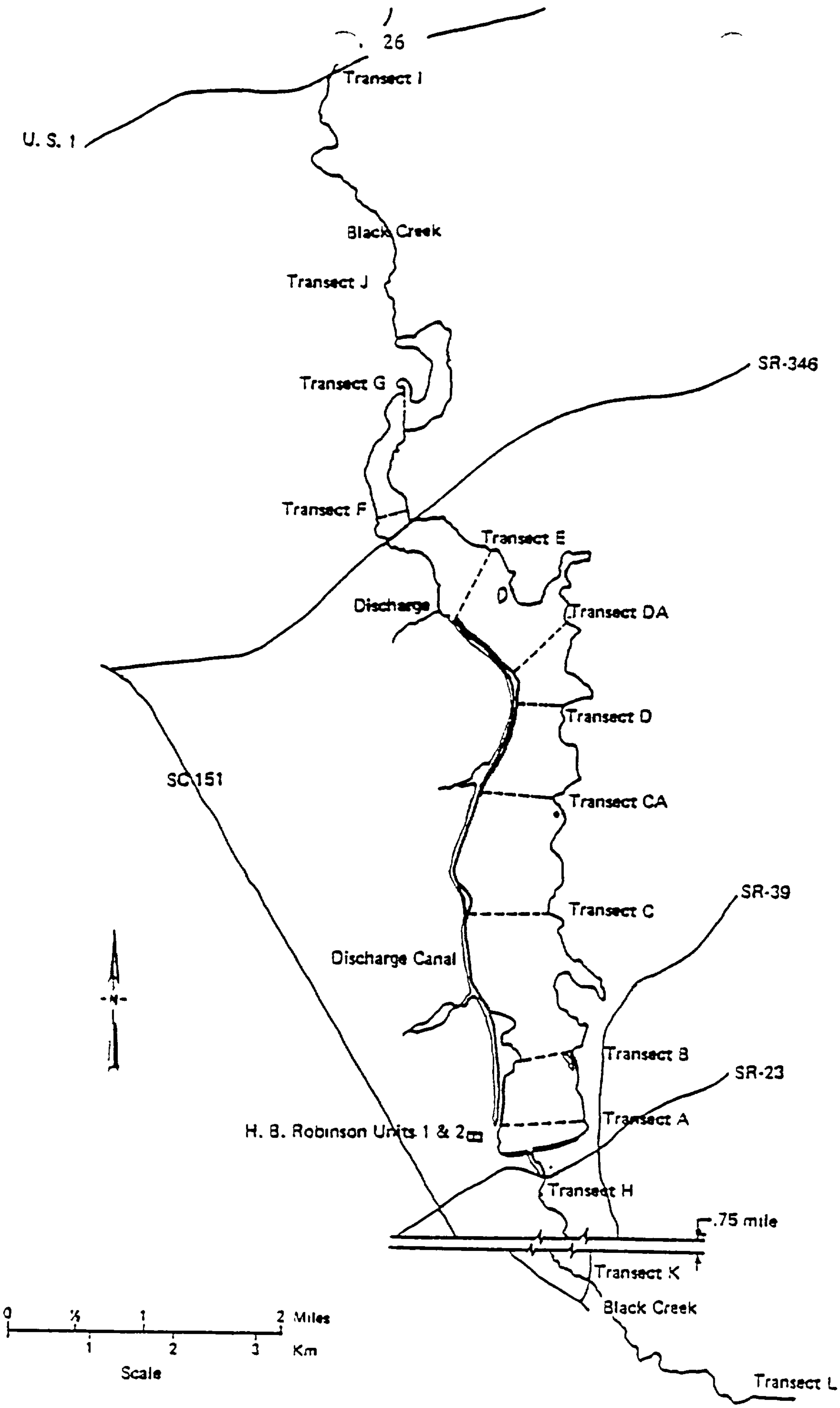


Figure 1. Robinson Impoundment and Black Creek sampling transects.

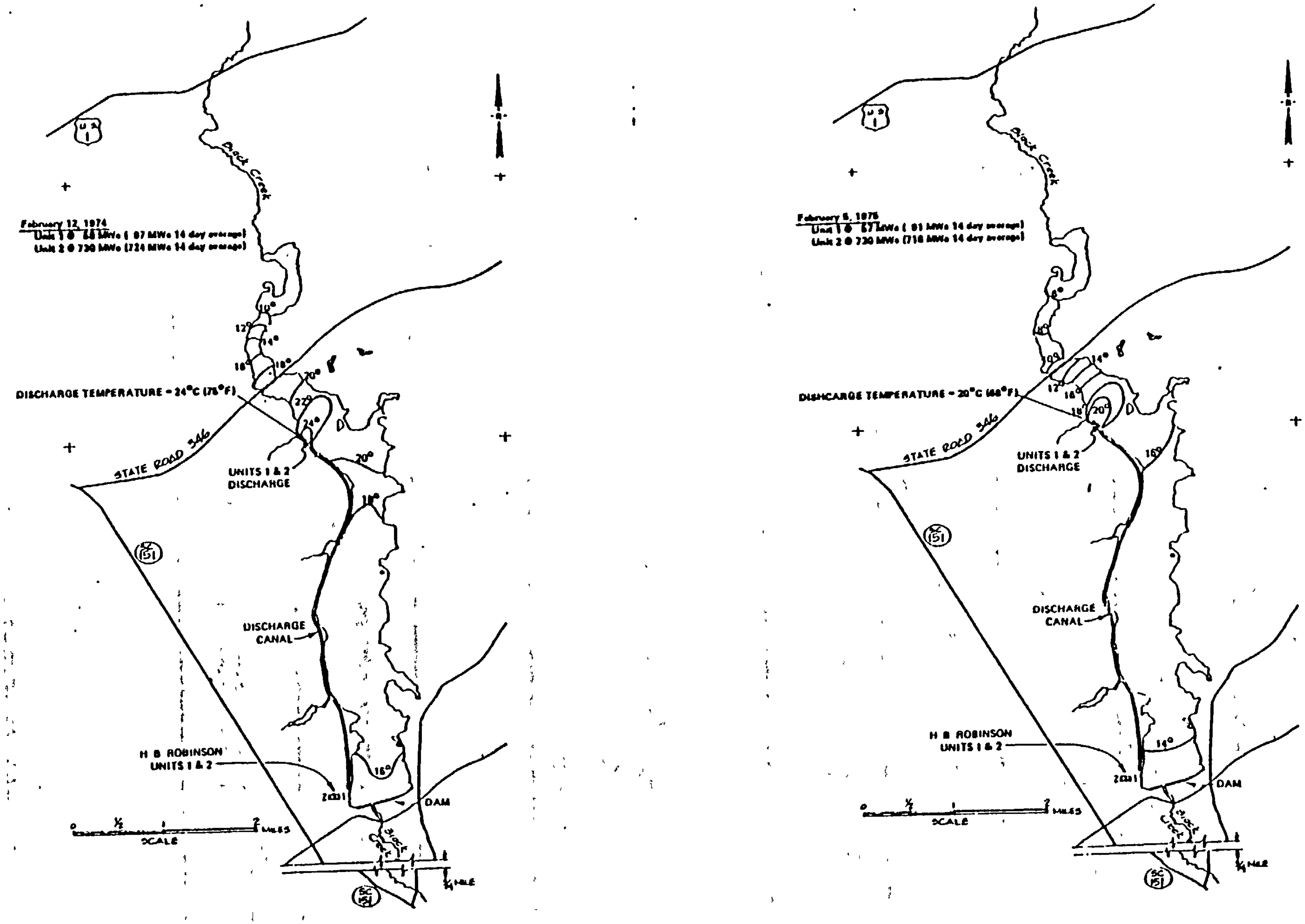


Figure 3.3.3 Robinson Impoundment 2°C surface isotherms, winter conditions: February 12, 1974 and February 5, 1975

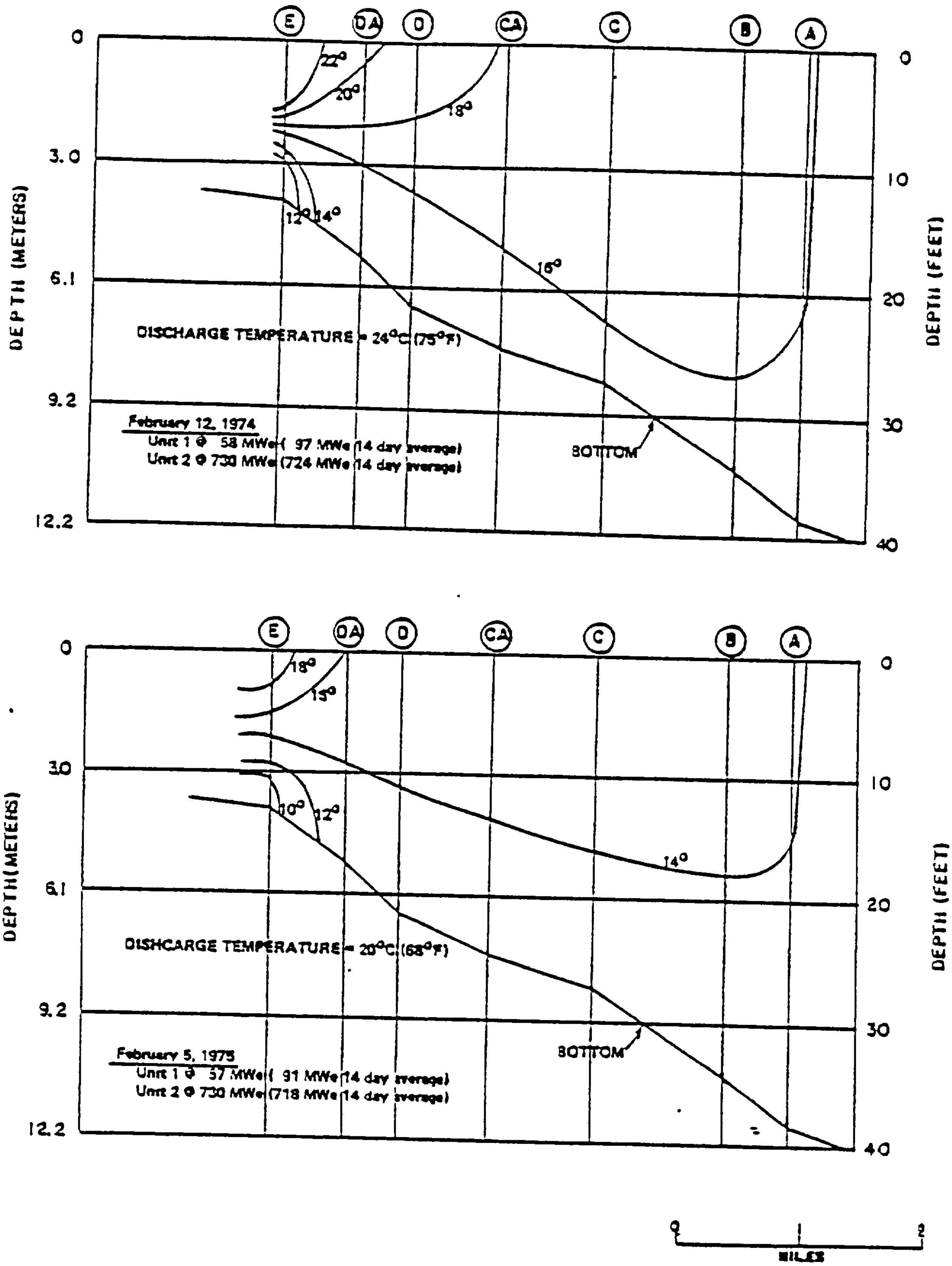


Figure 3.3.4 Robinson Impoundment 2°C vertical isotherms (north to south), winter conditions: February 12, 1974 and February 5, 1975 (indicating deepest station at each transect)

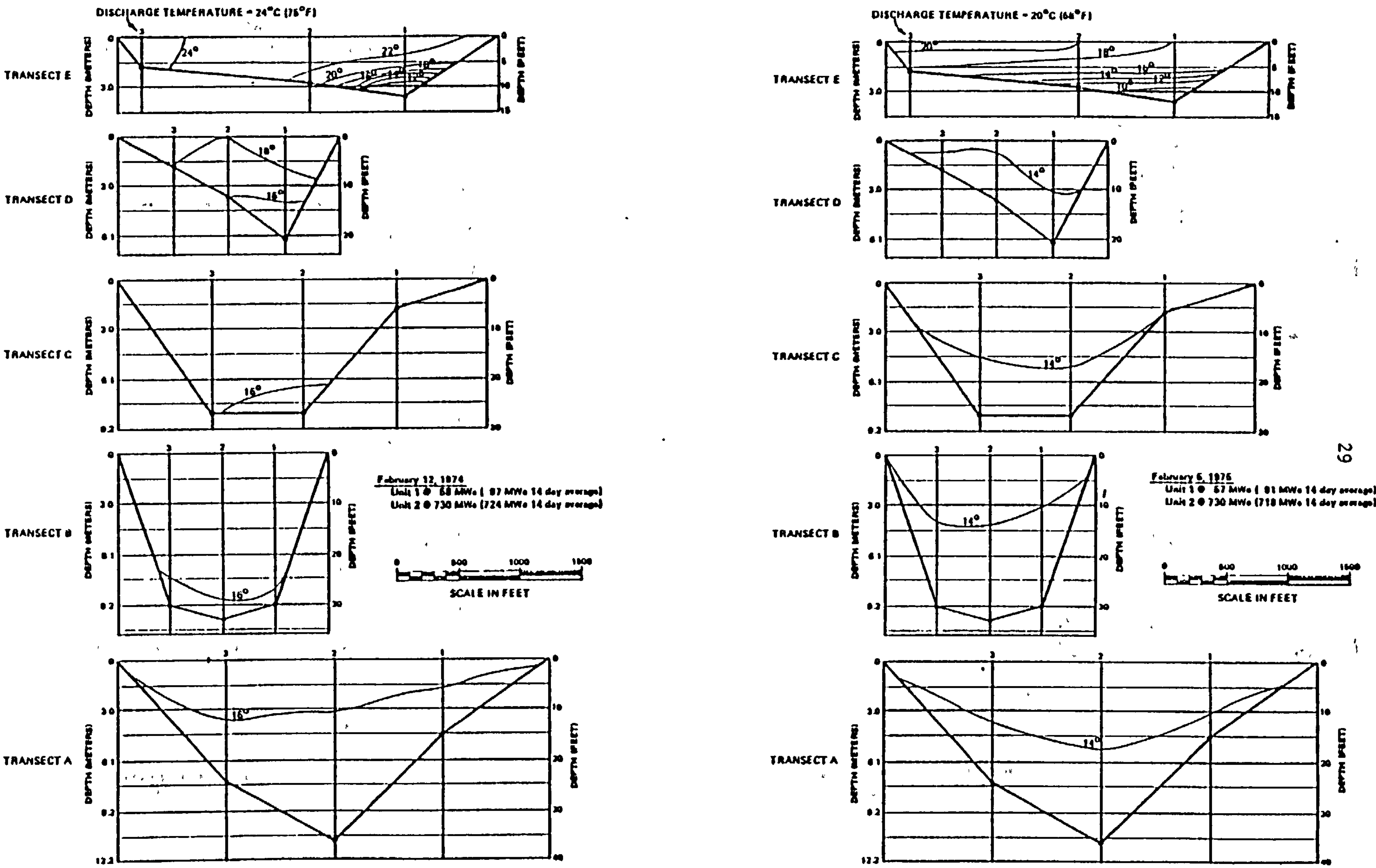


Figure 3.3.5 Robinson Impoundment 2°C vertical isotherms (east to west), winter conditions: February 12, 1974 and February 5, 1975

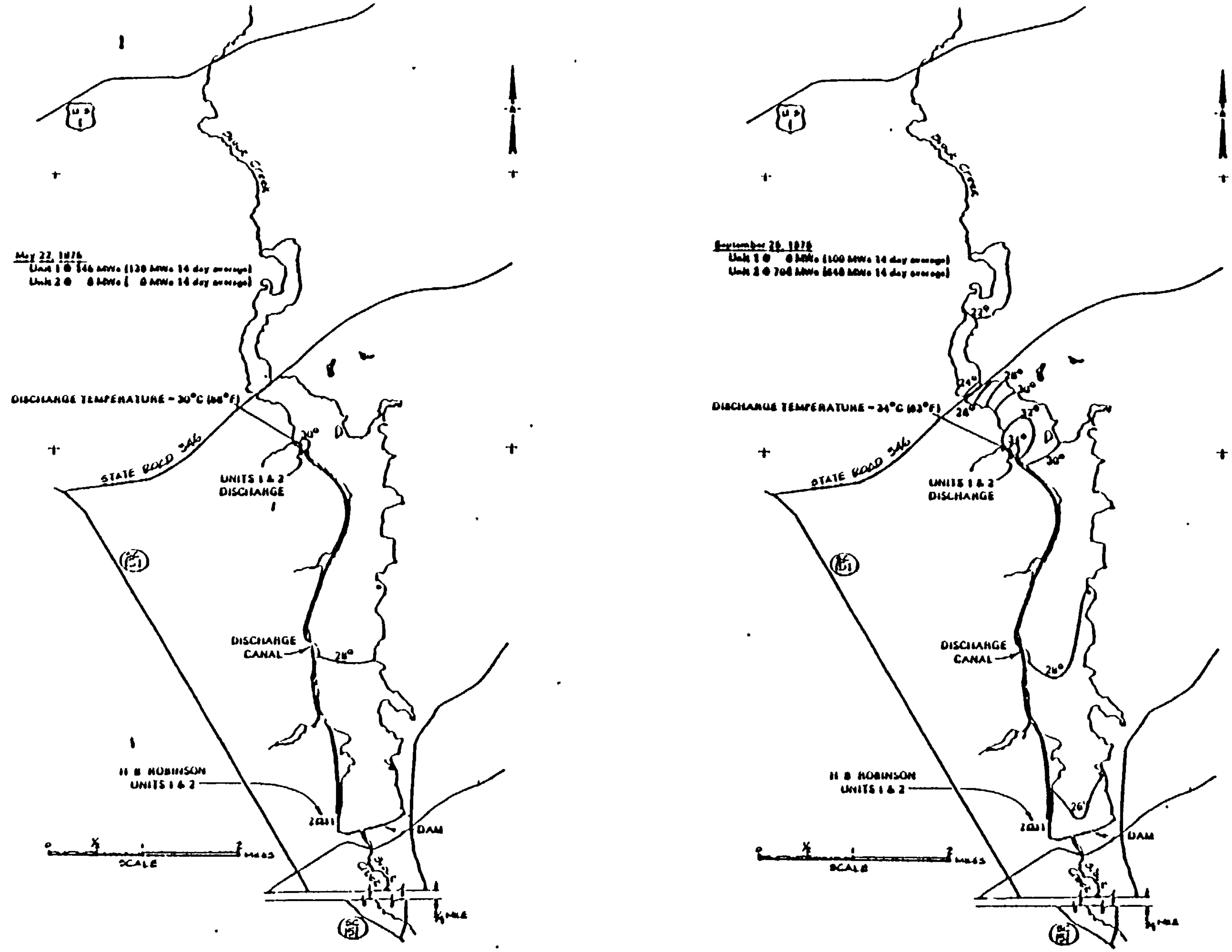


Figure 3.3.6 Robinson Impoundment 2°C surface isotherms, spring and fall mixing conditions: May 22, 1975 and September 25, 1975

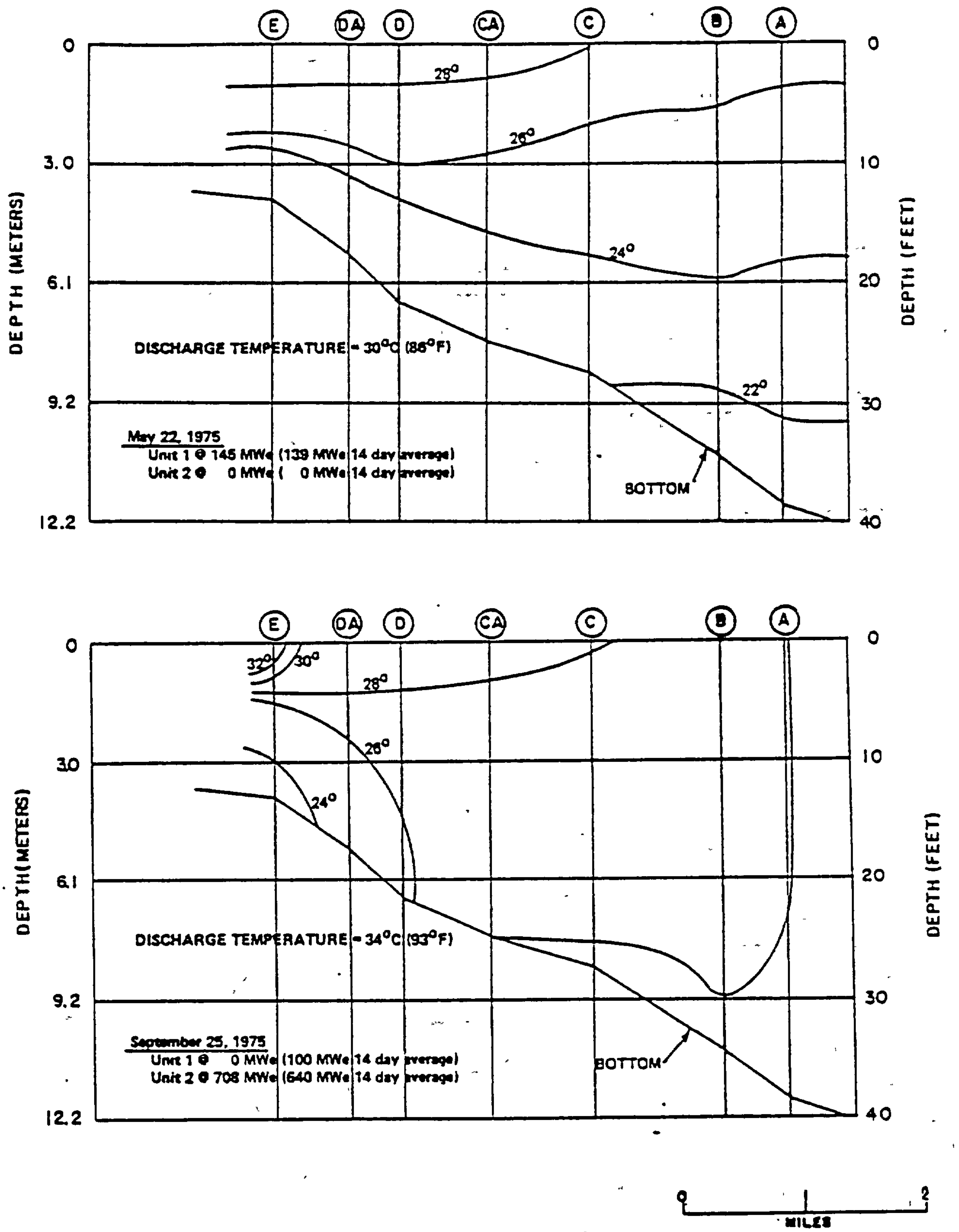


Figure 3.3.7 Robinson Impoundment 2°C vertical isotherms (north to south), sprinr and fall mixing conditions: May 22, 1975 and September 25, 1975 (indicating deepest station at each transect)

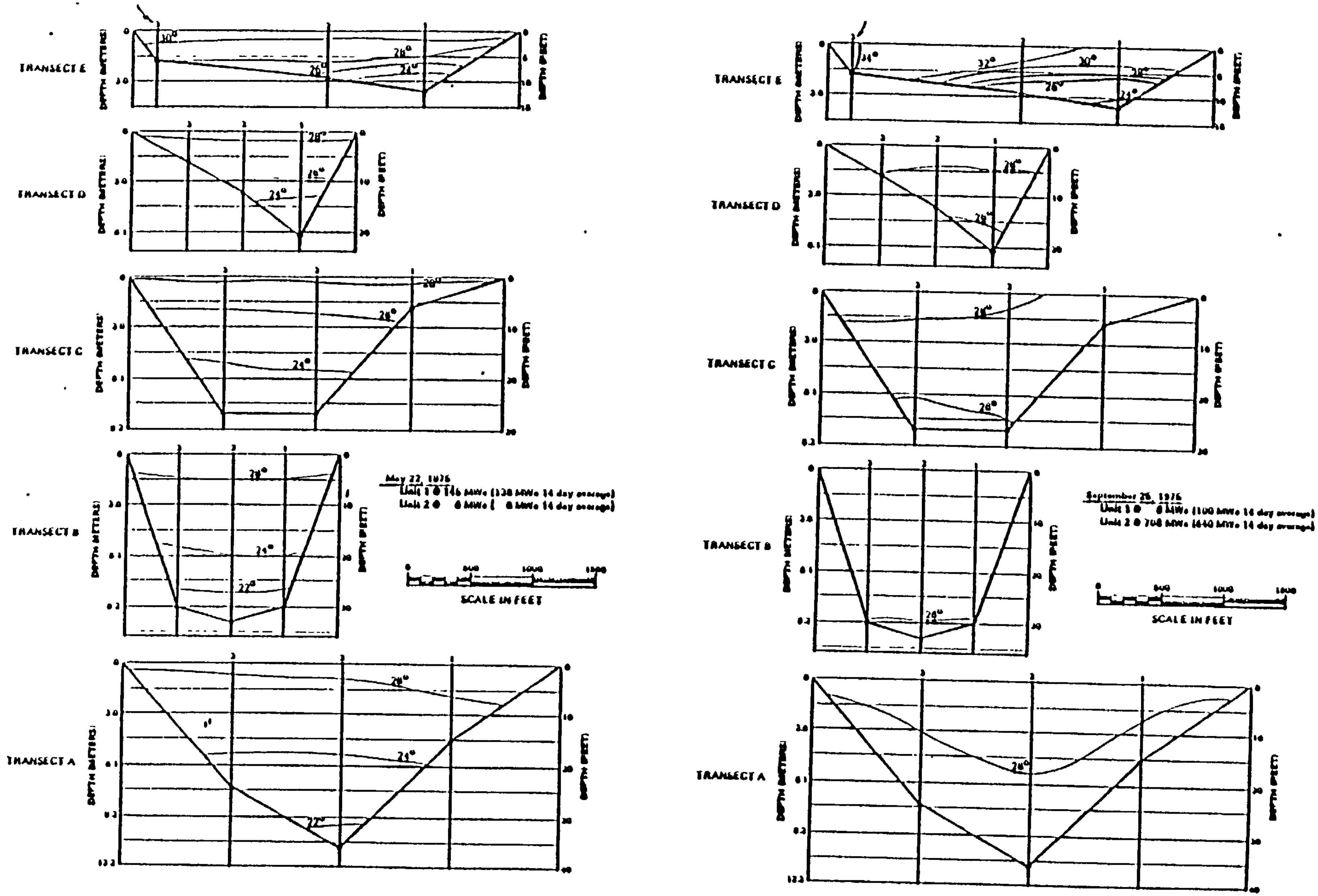
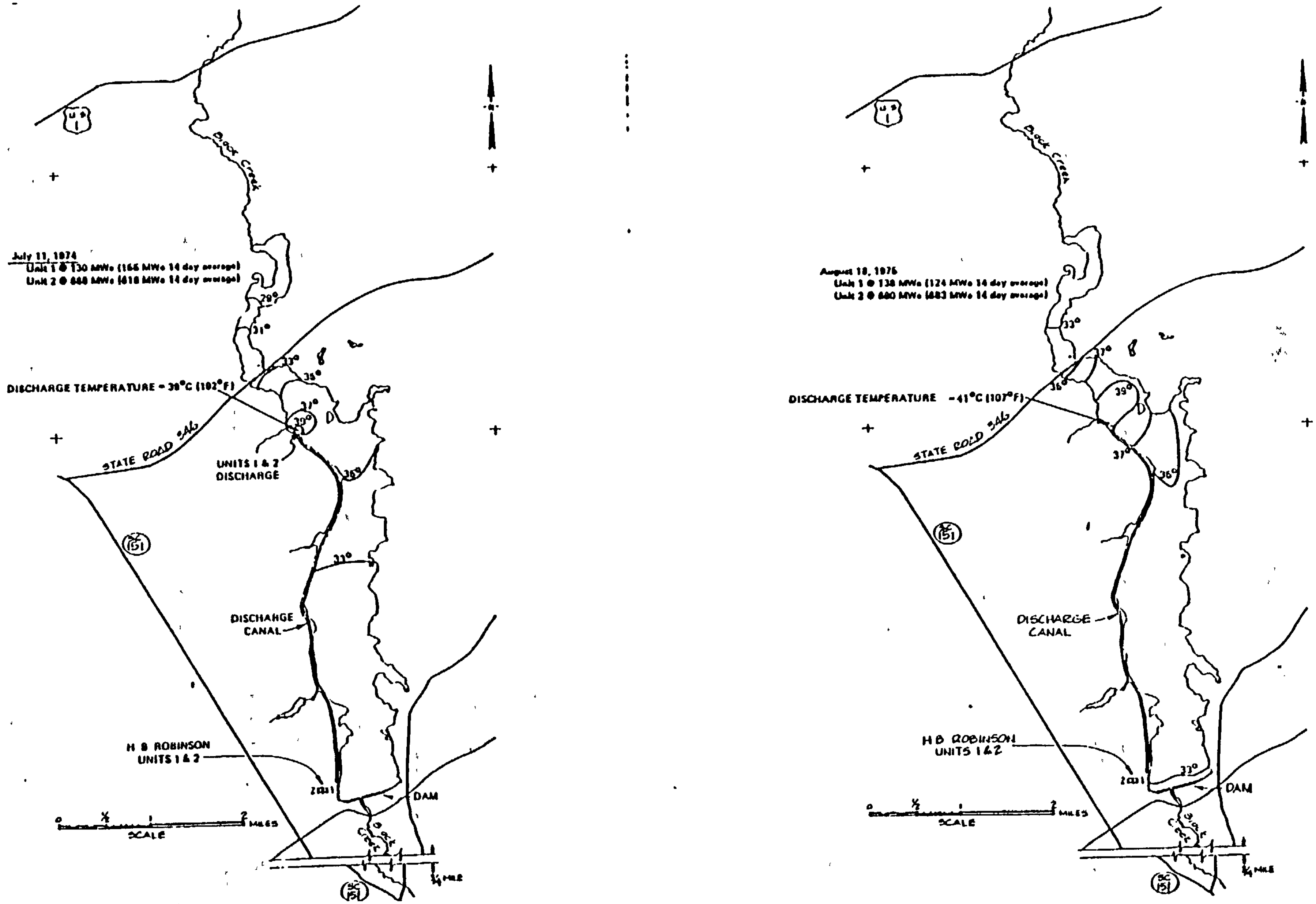


Figure 3.3.8 Robinson Impoundment 2°C vertical isotherms (east to west), spring and fall mixing conditions: May 22, 1975 and September 25, 1975



Figures 3.3.9 Robinson Impoundment 2°C surface isotherms, summer conditions: July 11, 1974 and August 18, 1975

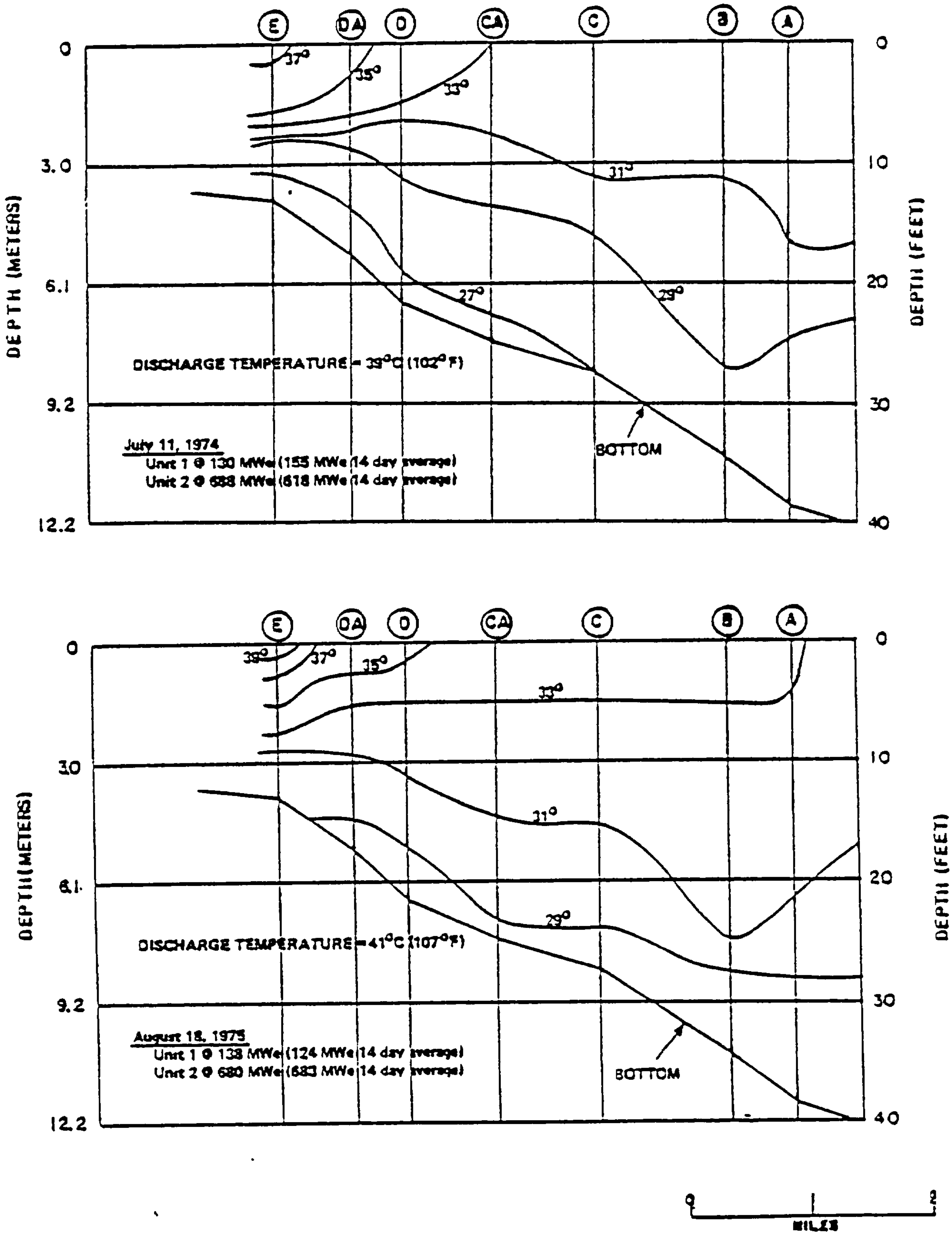


Figure 3.3.10 Robinson Impoundment 2°C vertical isotherms (north to south), summer conditions: July 11, 1974 and August 18, 1975 (indicating deepest station at each transect)

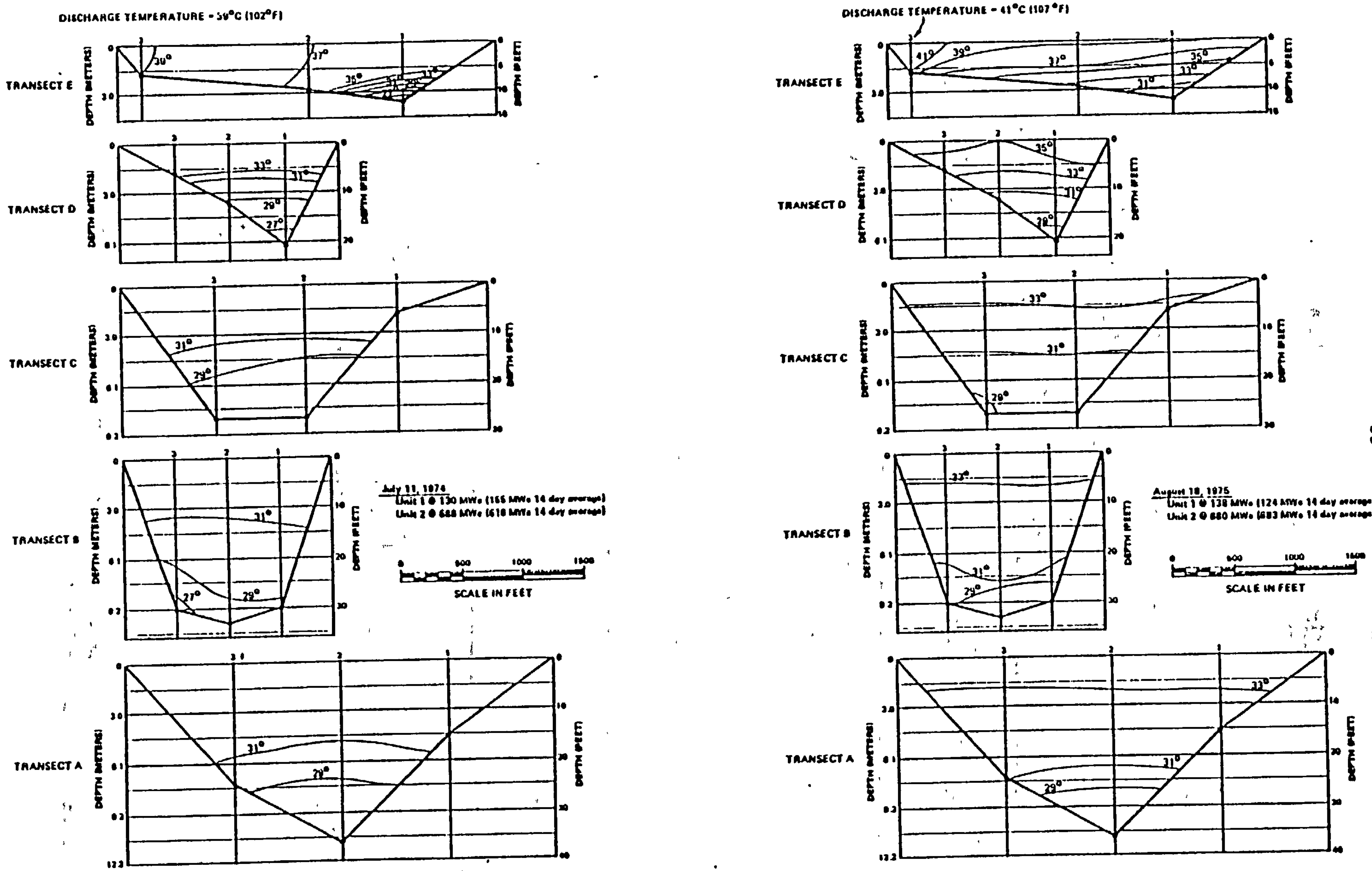


Figure 3.3.11 Robinson Impoundment 2°C vertical isotherms (east to west), summer conditions: July 11, 1974 and August 18, 1975

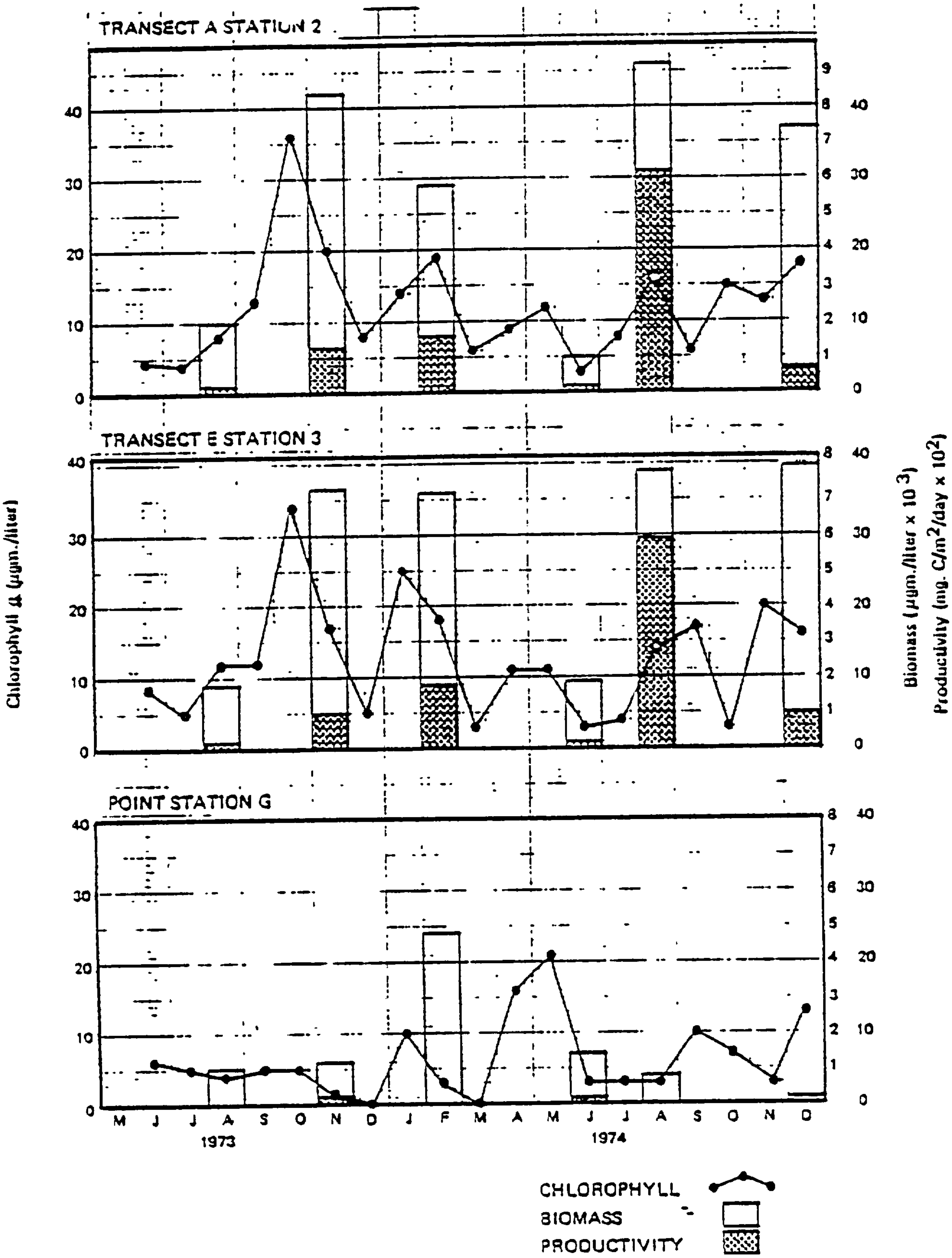


Figure 5.3.1 Chlorophyll, biomass, and primary productivity by month and quarter: Robinson Impoundment, May 1973 - December 1974

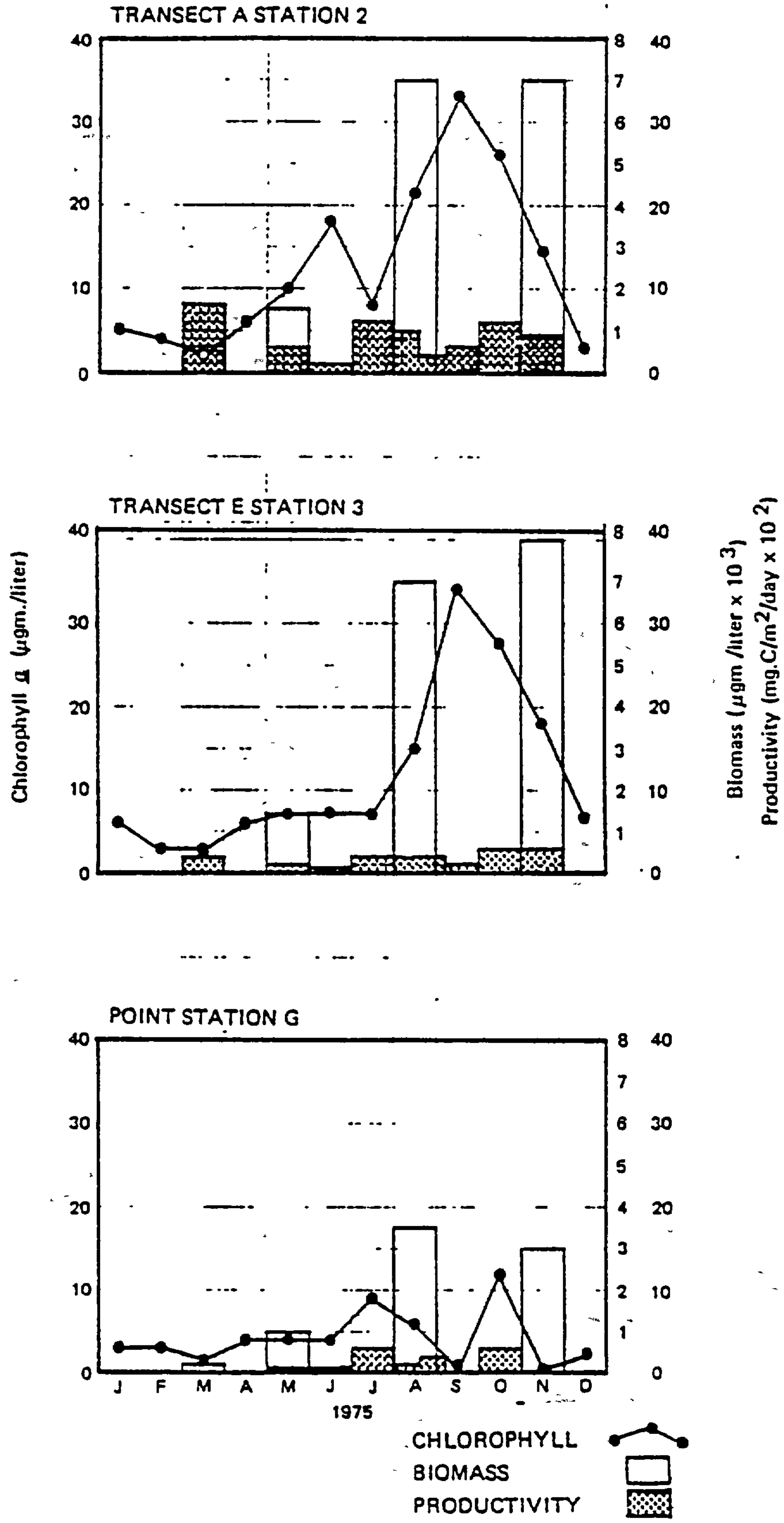


Figure 5.3.2 Chlorophyll, biomass, and primary productivity by month and quarter: Robinson Impoundment, January to December 1975

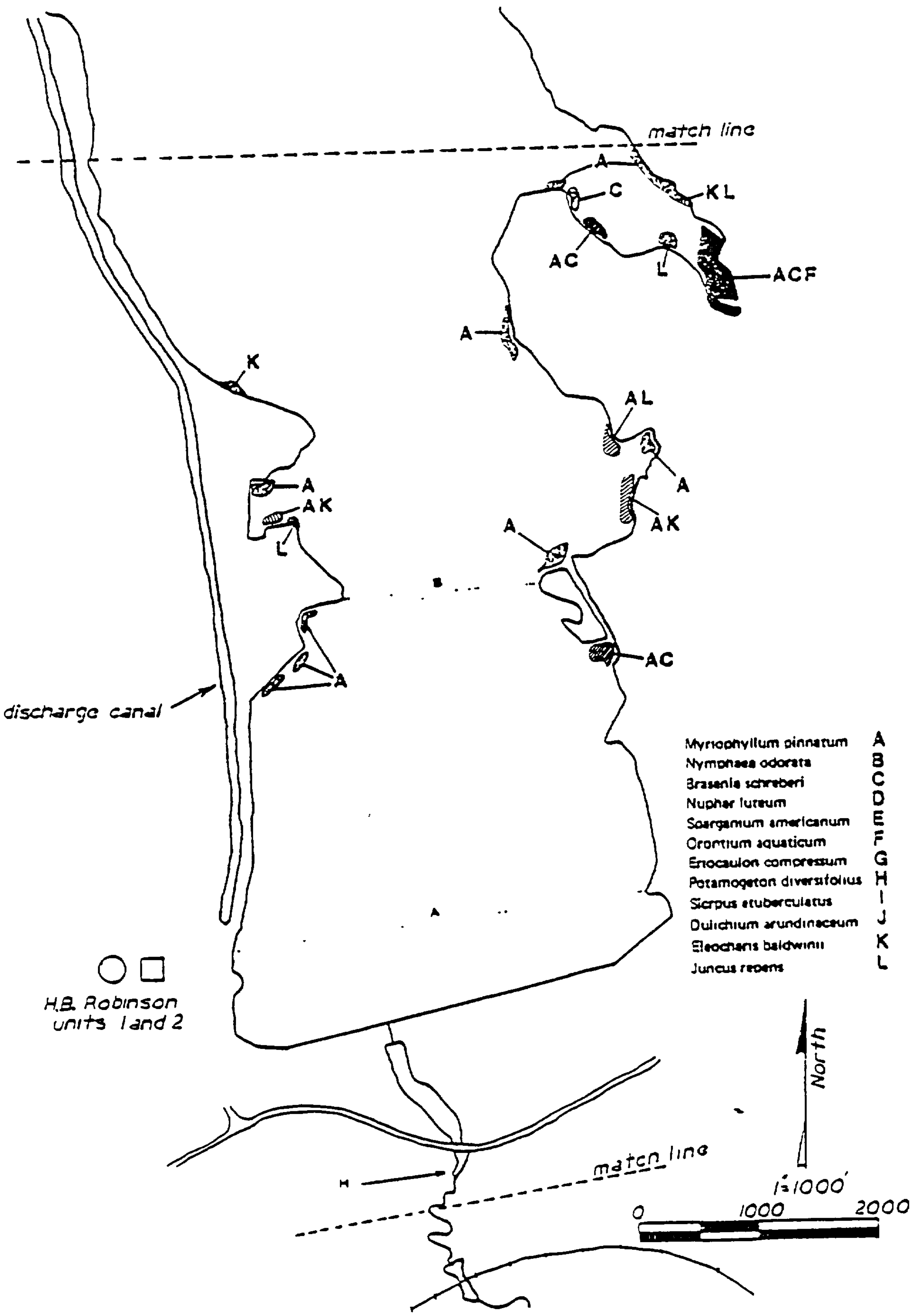


Figure 7.2.1 Vegetational distributions

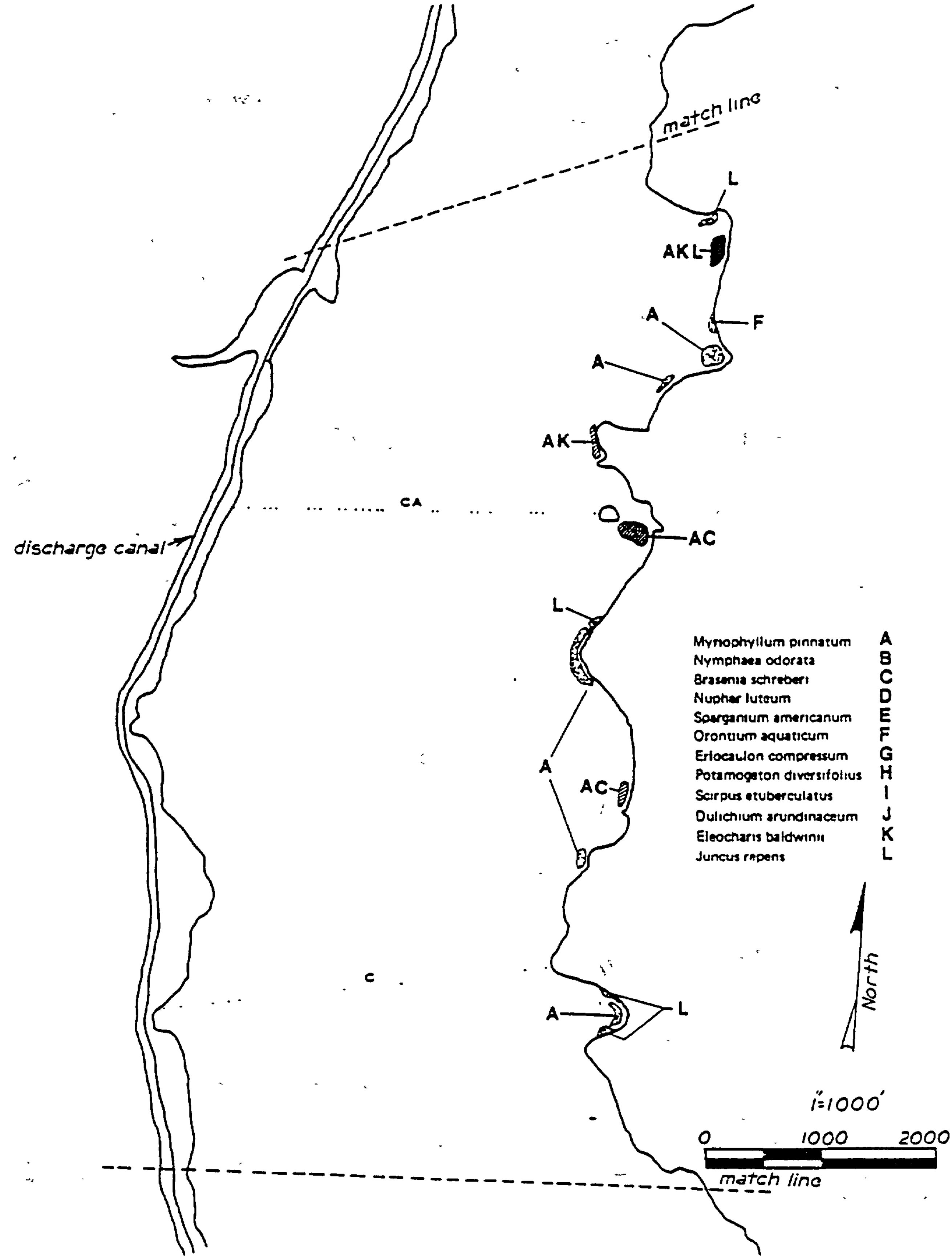
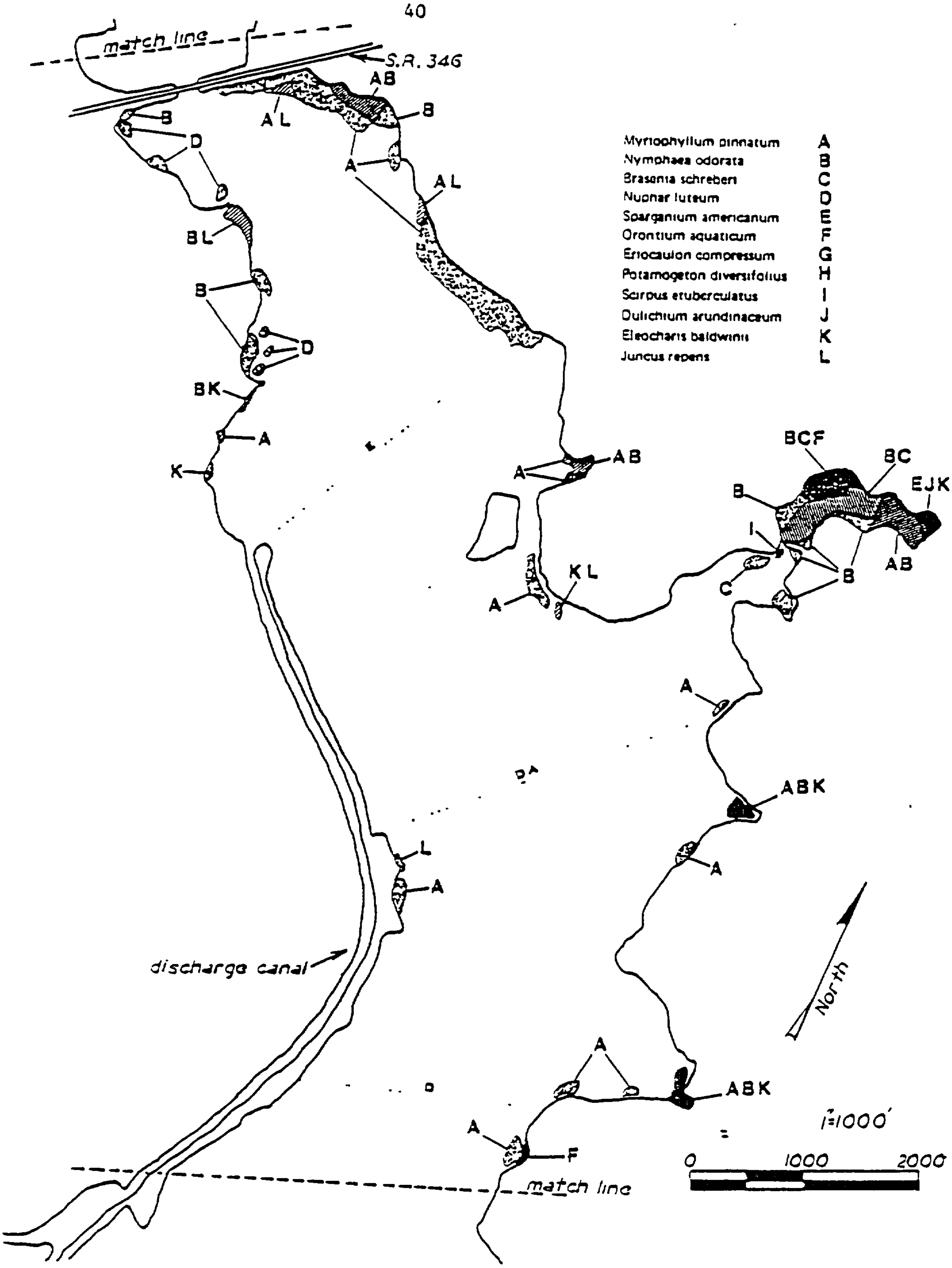


Figure 7.2.2 Vegetational distributions



gure 7.2.3 Vegetational distributions

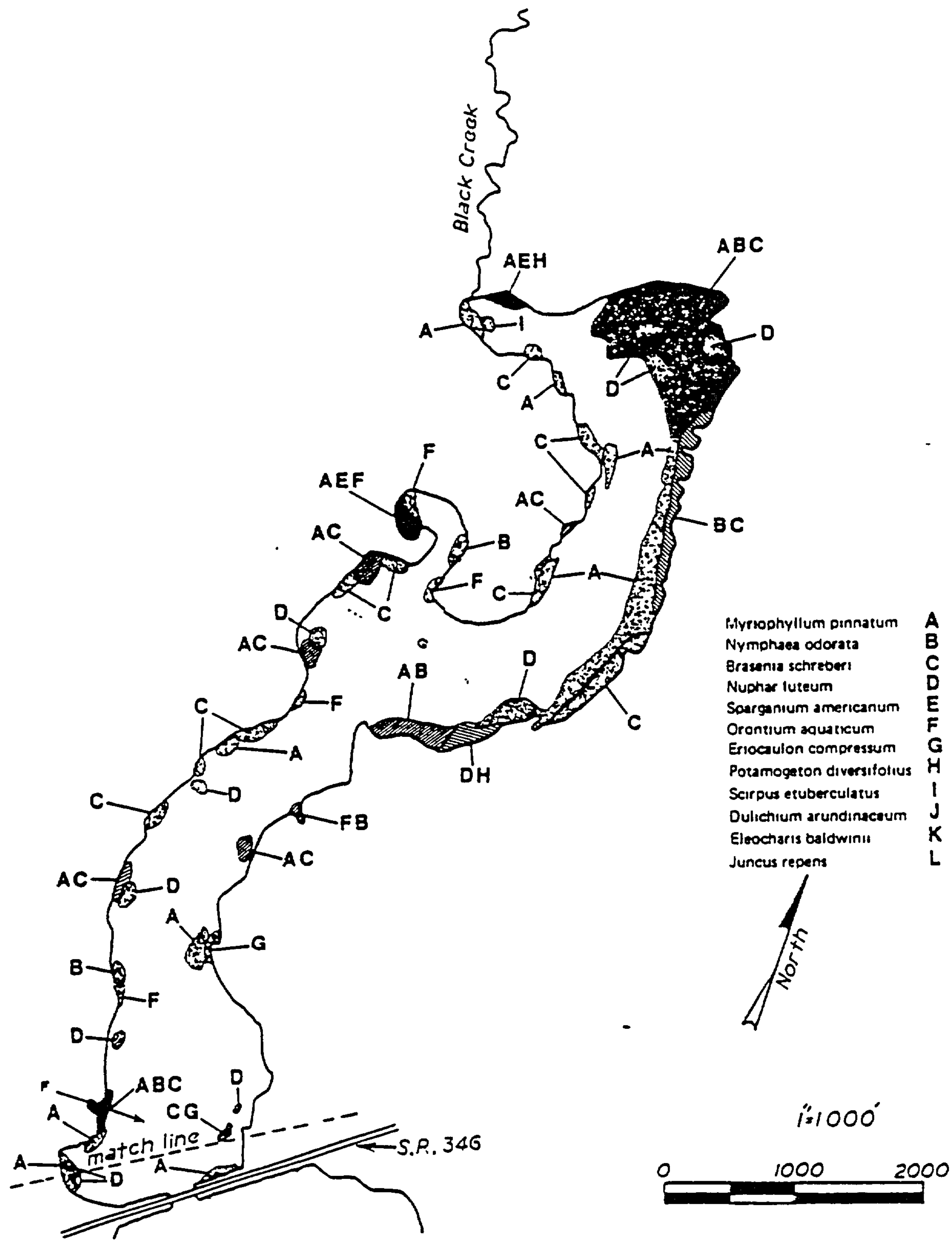


Figure 7.2.4 Vegetational distributions