NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS

FERMI 2 POWER PLANT
REMOTE SENSING
AND VEGETATION GROUND TRUTH PROGRAM
1992 FINAL REPORT

Prepared for

DETROIT EDISON COMPANY
2000 Second Avenue
Detroit, Michigan

Prepared by

NORMANDEAU ASSOCIATES INC.
25 Nashua Road
Bedford, New Hampshire

R-13328.00

April 1993

FOREWORD

This report summarizes the methods and results of the 1992 remote-sensing and vegetation ground-truth exercise conducted by Normandeau Associates Inc. (NAI) within the prescribed survey area in the vicinity of the Fermi 2 power plant, Enrico Fermi Energy Center, Monroe County, Michigan. Four pre-operational reports were prepared as part of this program, the first three by the Ecological Services Group of Texas Instruments Incorporated, the last by NAI. These reports are cited as TI 1978, TI 1979, TI 1980 and NAI 1983, respectively. Their findings were described and discussed in a report (NAI 1984) that served as a pre-operational baseline summary of all work done up to that point. Following commencement of limited plant operation in November 1985, the first study to look for operational impacts on surrounding vegetation was conducted by NAI in 1987 and described in a report cited as NAI 1987. Its successor, NAI 1988, covered the first growing season during which the plant was licensed to operate at full capacity. Two years later, the study was repeated (NAI 1990). The present report describes the findings from 1992.

TABLE OF CONTENTS

LIST OF FIGURES

PAGE

LIST OF TABLES

SUMMARY

Color infrared aerial photographs were used in 1992 to delineate cover types, vegetation stress patterns, and crop land-use in the 39-square-mile Fermi 2 Survey Area. Soil samples were collected and analyzed from areas expected to receive a wide range of cooling-tower salt deposition. These analyses provided the fourth opportunity since the plant began operation to evaluate the effect of cooling-tower salt drift on soils, and to evaluate vegetation stress that could be attributable to plant operation.

Results confirmed one trend in cover type change noted in previous reports. Although land-use patterns generally resemble those described in the previous NAI reports, active cropland continued its decade-long decline accompanied by a further increase in residential/commercial development. Areas of stressed natural vegetation were the least extensive on record, owing chiefly to adequate summer rainfall and moderate summer temperature. However, if Lake Erie's water level continues its current rate of rise during 1993 and 1994, or too abruptly falls again, lakeshore vegetation may exhibit renewed signs of stress in two years' time.

The total area of apparent vegetation stress was 93 acres, three times lower than that estimated for 1990. Most of the stress resulted from (1) localized soil waterlogging where drainage was impeded or otherwise altered, especially as a result of lake-level fluctuations; and (2) early-successional competition among young woody species and populations.

Although the coolest growing season on record slowed and impaired crop fruiting, vegetative growth flourished. Insect infestations were well below pest proportions. No correlation could be detected between vegetation stress and the predicted pattern of salt-drift deposition.

About 13,000 acres of croplands were mapped. As usual, the major crops in descending order of acreage were: soybeans; hay, pasture and fallow; corn; and recent tillage

Soil sampling indicated no significant changes from the 1990 data. Values for chloride reversed the previous decade's rise and remained well within acceptable limits. The pH and conductivity of the samples were consistent with good fertility and low ionic stress. None of the data for the six soil parameters correlated positively or negatively with the three zones of predicted salt deposition intensity.

1.0 INTRODUCTION

1.1 PROGRAM HISTORY AND OBJECTIVE

From 1978 to 1980 the condition of natural vegetation was annually surveyed within a five-mile radius of the Fermi 2 cooling towers. Maps of vegetation cover types were prepared, including delineation of all areas under apparent stress. Where possible, causes of stress were identified. This baseline study was resumed in 1983, when two new objectives were added: a crop cover-type survey and soils analysis. Taken together, all of these data provided the background information against which to measure the effects of dissolved-solids deposition resulting from plant operation (NAI 1984).

Following commencement of limited plant operation in 1985, a repeat was made in 1987 of the 1983 survey. This survey afforded the first opportunity to observe changes in selected parameters that were possibly attributable to plant operation. In January 1988, the Fermi 2 plant completed its commercial test run (100 hours at maximum power) and became licensed to commence routine operation. The plant operated at 62% capacity during 1988 (Terrasi 1989). The 1988 survey thus was in a position to record stress effects on vegetation at a potentially higher level than previously would have been possible. The findings of the 1988 survey were negative, however (NAI 1988). During 1990, the plant operated at 86% capacity up to the time the survey was conducted (Terrasi 1991), making this the best opportunity yet to detect correlations between cooling-tower emission and injury to natural vegetation. Again, however, the findings were negative (NAI 1990). During 1992, the plant's electrical performance approximated 96.7% of capacity through August, improving yet again the opportunity to detect correlations (Lehmann 1993).

2.0 METHOD

Aerial color infrared photography provided the data base for delineating vegetation cover type, vegetation stress, and crop type. Interpretation of the photographs was checked in the field, and necessary adjustments were made to the original base map. Soil samples were collected at the same time.

2.1 AERIAL CIR PHOTOGRAPHY

Aerial color infrared (CIR) photographs used in this survey of the 39-square-mile study area (5-mile radius) surrounding the Fermi 2 Power Plant were taken 12 August 1992 between 10:45 and 11:30 hours and again 19 September 1992 between 10:45 and 11:15 hours. Cloudy weather forced the postponement of final photography (Flight Lines 7, 6 and part of 5, those farthest from the plant) until the later date. Specifications included a 30-percent side overlap and a 60-percent forward overlap to provide optimum stereoscopic viewing resolution. Seven flight lines were required to cover the designated study area at the desired degree of overlap (Figure 2-1). Kodak 2443 Color Infrared Ektachrome film was used to take the photographs, which were processed as positive transparencies from a 9-inch roll. The photographs were taken with a Zeiss Camera, with 6-inch focal length lens from a local altitude of 5,000 feet, assuring a working scale of 1:10,000 (1 inch = 833 feet).

Additional CIR photographs were taken of the immediate power plant area at an altitude of 8,000 feet, as a special record of the operational zone.

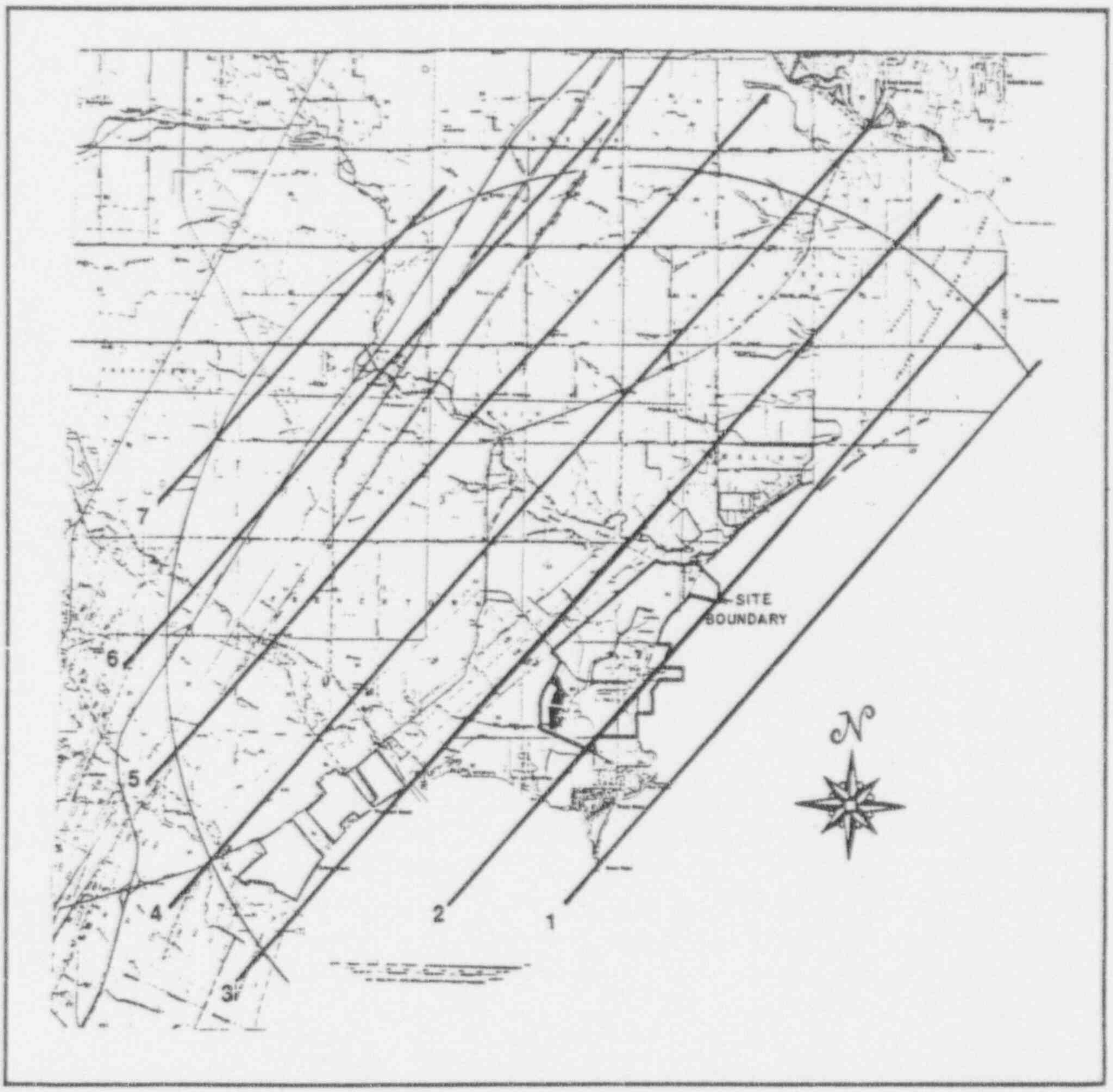


Figure 2-1. Fermi 2 site, survey area, and flight line map of color infrared photograph coverage, 12 August 1992.

2.2 VEGETATION COVER TYPE MAPPING

Each Ektachrome transparency was separated from the others on the roll, placed in a protective acetate sleeve, and labelled with flight line and exposure number. A mirror stereoscope was used, as described in the 1978 report (TI 1978), to establish each type boundary. Land use and vegetation cover types were as defined in the same report. The 1992 cover type map and base map were prepared from optically reduced and corrected composites of the 1992 CIR photographs, using the methods described previously (TI 1978). Areas of each cover type were measured by dot count method or digital planimeter from the 1:24,000 scale map (1 inch = 2,000 feet; 1 square inch = 91.82736 acres).

2.3 VEGETATION STRESS

Areas lacking spectral reflectance on the CIR photographs were interpreted as potentially containing vegetation stressed by morphological and/or physiological injuries (e.g., defoliation, limb breakage, disruption of photosynthesis). Both types of injuries reduce spectral reflectance from an individual plant, producing differences in the color of images on infrared photographs. With injury, the reddish photographic appearance, characteristic of healthy vegetation, grades to pink, mauve, red-brown, white and yellow as infrared reflectance is progressively lost.

The precise levels of spectral reflectance from a plant, however, are also influenced by a complex of other factors unrelated to the degree or type of injury. These factors include age of both the plant and the foliage, season, and leaf type. For example, species with compound leaves will produce less spectral reflectance than simple-leaved species, thus appearing a shade of color different from that of the adjacent vegetation. The leaves of some species (e.g., cottonwood) may naturally change color earlier than other species, producing differences in spectral reflectance that are not necessarily a result of injury. In addition, many herbaceous species naturally complete their

life cycle within one or two years and die soon after flowering. Consequently, color differences among herbs may simply represent differences in life-cycle length and not areas of stressed vegetation.

In order to accurately determine areas of stressed vegetation, several steps were followed. Areas with more than 50 percent of the plants showing reduced spectral reflectance were delineated by the photointerpreter as potential areas of stress. These areas were delineated on the even-numbered acetate sleeves with a fine-tipped drafting pen. Areas so delineated were checked during ground truthing to determine: (1) the species affected, (2) if the reduction in spectral reflectance represented a species-specific infrared photograph signature instead of stressed vegetation, and (3) the most probable causal agent(s) if the vegetation was indeed stressed. Only areas exhibiting current stress symptoms were identified as stress areas. Areas of dead vegetation, but with healthy regrowth or regeneration were assumed to represent areas recovering from previous injuries.

To further document vegetation stress, color photographs were taken of typical examples of stressed species and of conspicuous causal agents (e.g., fluctuating lake level). Color photographs were also taken to document species-specific spectral reflectance signatures that were tentatively identified as indicative of potential vegetation stress but later found to represent natural differences in life history or leaf characteristics. Where identification of plants proved difficult, specimens were collected using methods previously described (TI 1980).

Stressed areas delineated in the ground-truthed aerial photographs were optically transferred to the cover type map, and the affected areas measured by the dot-count method.

2.4 CROP TYPE MAPPING

The CIR photographs were also used to delineate crop types in the survey area. Within 30 days of the first overflight, approximately 30% of the land supporting crops was field-checked. Aerial photographs cannot be used to differentiate among crops of the same morphology, such as various grains, hay, and other narrow-leaved members of the grass family (Gramineae). Consequently, cover-type categories were used which represented the greatest degree of differentiation practical for the study area. The change in cover-typing implemented in the 1987 survey was continued in 1992. This change reflects the federal government's Set-Aside Program, effective from 1985 with the passage of the farm bill of that year. Since then, up to 5% of each farmer's crop acreage has lain fallow each year, as a means of controlling surplus production. In many cases it proved difficult to distinguish between a late-season field in which a small crop species like alfalfa was being overgrown with robust weeds, and a fallow field grown up to a mixture of about equal parts corn, hay, soy and pioneer weed species. On the assumption that much of this heterogeneous growth represented potential fodder or green manure, it was collectively assigned to the crop type redesignated as "Hay, other grass crops, pasture and fallow." All plots greater than five acres and many of the smaller plots were delineated on the odd-numbered aerial photographs and assigned to type. These areas were then optically transferred to the same base map used for cover types, at a 1 inch = 2,000 feet scale (1:24,000). Acreage of each plot was determined by dot counting (for plots less than 25 acres) and by digital planimeter (for larger plots). The two methods were cross-checked and calibrated against areas of known acreage for accuracy and precision. Errors in the dot counts were found not to exceed five acres; errors in the digital planimeter were less than five acres for small parcels and less than 1% for larger plots.

2.5 SOIL SAMPLING AND ANALYSIS

Soil samples were taken from the same stations as in 1983, 1987, 1988 and 1990 (see Figure 2-2). The same methods for sampling and analysis were used (NAI 1983). As before, two locations were sampled in each of the three zones of predicted impact: .01-.1 pounds of dissolved solids per acre per year, .1-.5 lb/ac/yr, and greater than .5 lb/ac/yr. Dissolved solids from cooling-tower emissions could be expected to accumulate here, if anywhere, in concentrations roughly proportional to this theoretical zonation.

2.6 PROGRAM SCHEDULE

The completion dates for each major task of the 1992 program were:

Aerial CIR Photography	19 September 1992
Photointerpretation	2 February 1993
Ground Truth and Soil Sampling	11 September 1992
Analysis of Soils	4 January 1993
Reports	
Draft	April 1993
Final	April 1993

Aerial CIR photography was interrupted and its completion delayed owing to recurrent mid-day cloud development over the study area. On receipt, the photographs were given a partial cover typing and crop typing and full vegetation stress appraisal prior to ground-truthing on site. The ground-truthing took three days. It included verification of cover and crop typing and vegetation stress delineations; soil sampling; and further photographic documentation by hand camera. Photointerpretation was then completed in the office. Analysis of the soil samples was completed in early January.

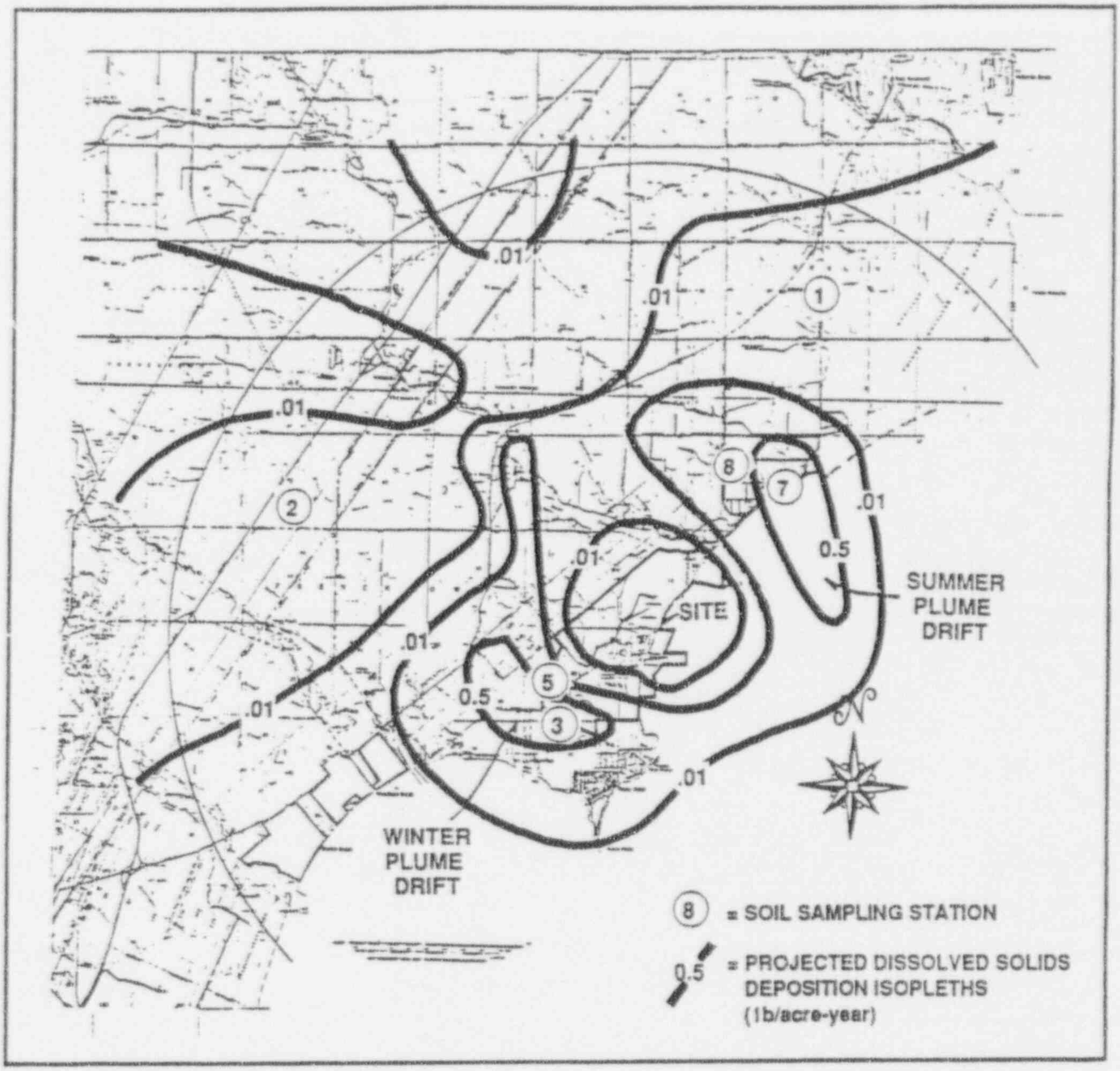


Figure 2-2. Fermi 2 site, projected dissolved solids deposition isopleths, and soil sampling stations.

3.0 RESULTS AND DISCUSSION

3.1 COVER TYPE AND LAND USE

Results of the 1992 cover-type survey are recorded in Figure 3-1 (see the folded 1:24,000-scale map in the back pocket) and Table 3-1. The total area estimate varied from that of 1990 by just 89 acres, or .3 percent, the same proportion of deviation as from the four-year mean of records beginning with 1983, when the study area limits first stabilized.

The subtotals for Deciduous Forest, Wetlands and Inactive Land all decline from their respective estimates for 1990, but by less than 100 acres apiece, or 5%, 6% and 6% respectively. On the other hand, the Water cover type appears to have reclaimed some of the area it attained in the decade prior to 1990. As Figure 3-2 shows, the mean Lake Erie water level has been rising anew, by more than one foot, during the past two years. Perhaps the consequent shoreline encroachment accounts for some of the overall decline noted in the herbaceous wetland. Logically, one would predict a shift in favor of more Deep Marsh at the expense of Shallow Marsh. In fact, the opposite tendency appears in the record. The explanation may be that most of the Water cover type measured in this study lies within the causeways, dikes and sluice gates of the Pointe Mouillee State Game Area. Since 1992 the Lead Unit of this area has alternately impounded and released the outflow to Lake Erie of several creeks (Ainslie 1993). The attendant water-level fluctuations aim to encourage the periodic establishment of emergents rather than submergent or floating macrophytes, which prefer relatively stable water levels. In effect, the impounded water either stands low to expose a maximum area of mudflat for germination of pioneer seedling emergents during the late summer and fall, or it stands high but not long enough for most non-emergent Deep Marsh plants to thrive. In aerial photographs, the distinction between vegetated wetland and open water is thus enhanced, reducing the area of Deep Marsh and expanding that of Shallow Marsh. This management regime achieves an

TABLE 3-1. ESTIMATED HORIZONTAL ACREAGE FOR EACH COVER TYPE IN FERMI 2 SURVEY AREA, AUGUST 1992.

CODE	LAND USE/COVER TYPE	1978	1980	1983	1987	1988	1990	1992
1	Deciduous Forest							
1A	Upland Hardwoods	468	462	465	372	536	533	522
1B	Riparian Hardwoods	258	257	347	345	356	353	270
1C	Lowland Hardwoods	360	354	477	498	415	464	495
	SUBTOTAL	1,086	1,073	1,289	1,215	1,307	1,350	1,287
2	Wetlands							
2A	Marshland Meadow	331	268	517	427	416	514	495
2B	Shallow Marsh	694	361	563	520	615	697	821
2C	Deep Marsh	413	237	10	148	112	316	124
	SUBTOTAL	1,438	866	1,090	1,095	1,143	1,527	1,440
3	Inactive							
3A	Early Successional	333	351	329	531	516	531	860
3B	Advanced Successional	305	280	86	109	154	258	79
3C	Transitional	250	248	192	241	122	545	309
3D	Abandoned Orchard	10	10	0	0	0	0	0
	SUBTOTAL	898	889	607	881	792	1,334	1,248
4	Water	606	1,208	2,697	2,730	2,411	2,201	2,349
5	Maintained Pasture and Crop	16,858	16,713	16,139	14,902	14,968	13,472	12,993
6	Transportation Rights of Way	422	422	422	618	617	712	849
7	Recreational	160	160	168	170	202	161	157
8	Industrial	193	193	244	175	333	343	388
9	Residential/ Commercial	1,819	2,005	2,181	2,544	2,725	3,120	3,451
10	Barren Land	153	104	248	230	324	261	281
	TOTAL	23,633	23,633	25,084	24,560	24,822	24,481	24,392

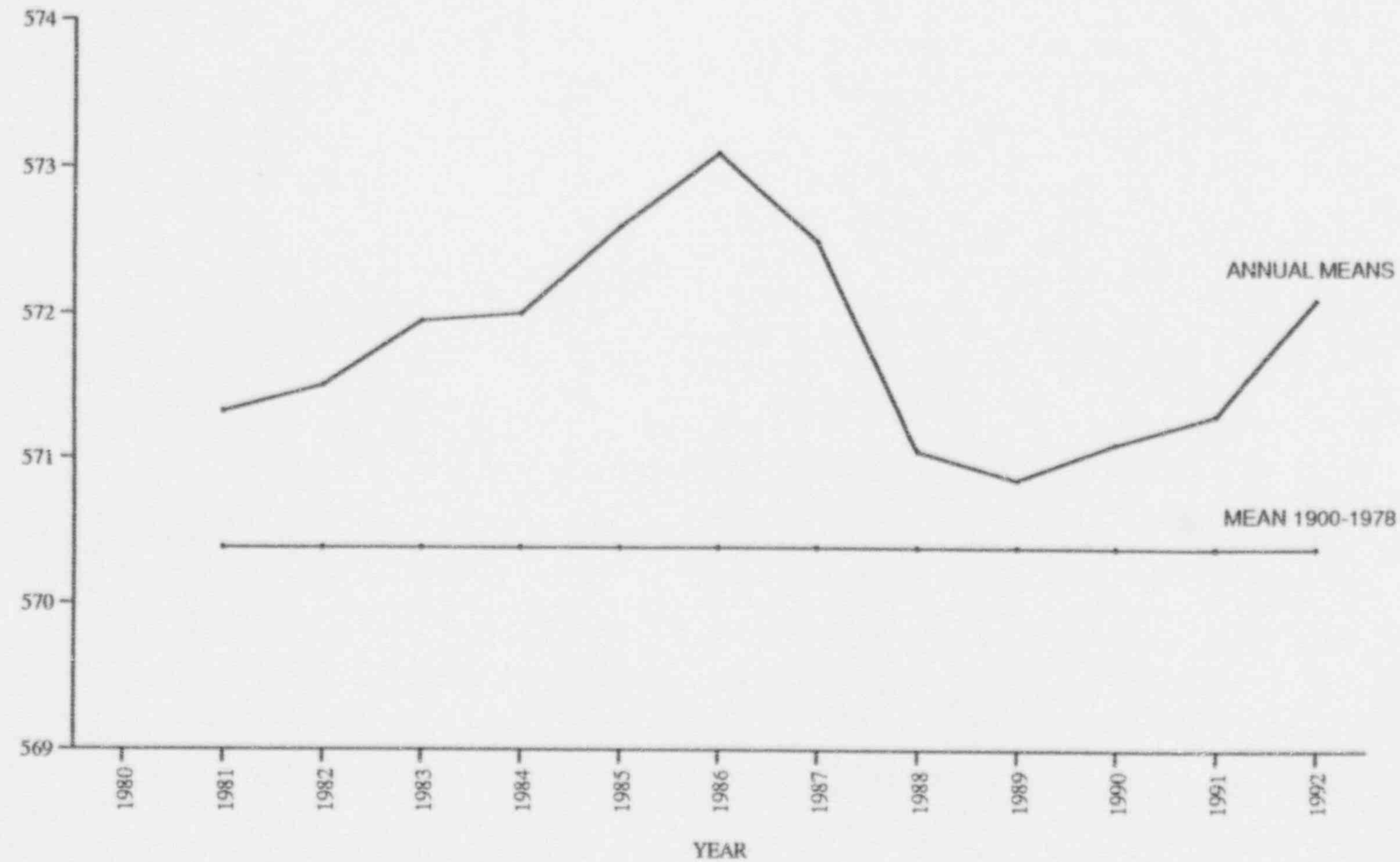


Figure 3-2. Mean annual water level of Lake Erie at Stony Point, Michigan for the period 1981-1992, compared with the 78-year mean for 1900-1978.

effect similar to that of the natural hydroperiod on Great Lake wetlands, sustaining a broad transitional zone of emergent and wet meadow plant species between open water on the one hand and woody vegetation on the other (Keddy 1990). The difference between natural and artificial hydroperiods lies mainly in the resultant species composition. The former regime selects for robust emergents adapted to rising lake levels that peak annually around August (Keddy ibid.). The latter promotes quick-growing and prolific seed-setting species that provide food and cover to foraging ducks and geese, by any combination of damming and drawdown, no matter how irregular in periodicity, that best gains this end. According to Ainslie (1993), the planned rotation of the three water-regulation units at Pointe Mouillee from Deep Marsh to Shallow Marsh to regenerating mudflat ensures that two of the three units will be in a predominantly emergent condition at any one time. The periodic Deep Marsh condition helps discourage infestation by the aggressive Purple Loosestrife (*Lythrum salicaria*).

Urbanization continues to encroach on the farmland surrounding the Fermi 2 plant. The 1992 estimates show a 479-acre diminution in the Maintained Pasture and Crop type and a concurrent increase in Residential/Commercial (341 acres), Industrial (34 acres) and Transportation Rights of Way (137 acres), or a total area of 523 acres representing the general urban category. In addition to Pasture and Crop the Inactive category probably made the next most important contribution to urbanization. The large area in the Early Successional category (860 acres) suggests that additional farmland continues to be retired and held in readiness for future development.

The totals for the Maintained Crop and Pasture cover type (Table 3-1) and for all crop types (Table 3-4) differ by 164 acres out of about 13,000, or by slightly over 1% of each other's values, near enough to represent normal discrepancies in image transfer and area calculations between one cover-type map and the other.

The immediate environs of the Fermi 2 site are illustrated in color infrared in Figure 3-3. Cover types delineated for this specific area are matched with the imagery on overlay and described in Table 3-2.

3.2 VEGETATION STRESS

Fifteen discrete areas of apparent vegetation stress were recorded during 1992, totalling 93 acres or much less than one per cent of the Fermi 2 survey area (Table 3-3). The comparable figures for 1983, 1987, 1988 and 1990, the four most recent years of record, are 198, 176, 500 and 366 acres respectively. The stressed areas for 1992 are shown on the cover-type map (Figure 3-1, see back pocket). These represent the smallest amount of stress ever recorded as part of this monitoring exercise.

The decrease in number and total acreage of areas of stressed vegetation from 1990 is chiefly attributable to a cool growing season with adequate rainfall. The distribution of stress areas follows the main axis of previous NAI studies, a band running roughly northeast by southwest parallel to the shoreline but in no way clustered so as to suggest any correlation with the predicted pattern of solids deposition from the cooling towers. This historical axis marks the fluctuating margin of Lake Erie, now in a phase of renewed advance.

The primary cause of stress in 1992 was waterlogging along the Lake Erie shoreline, aggravating the effects of similar conditions in the past from which many woody plants were still recovering. No insect infestations or symptoms of drought were observed or reported. Physical, biotic and chemical factors are discussed further below.

For the same reason that soil samples were taken where the environment showed least sign of recent physical disturbance, notice of stress symptoms was confined to naturally vegetated areas (see NAI 1987 for full discussion). These consist primarily of remnant lowland

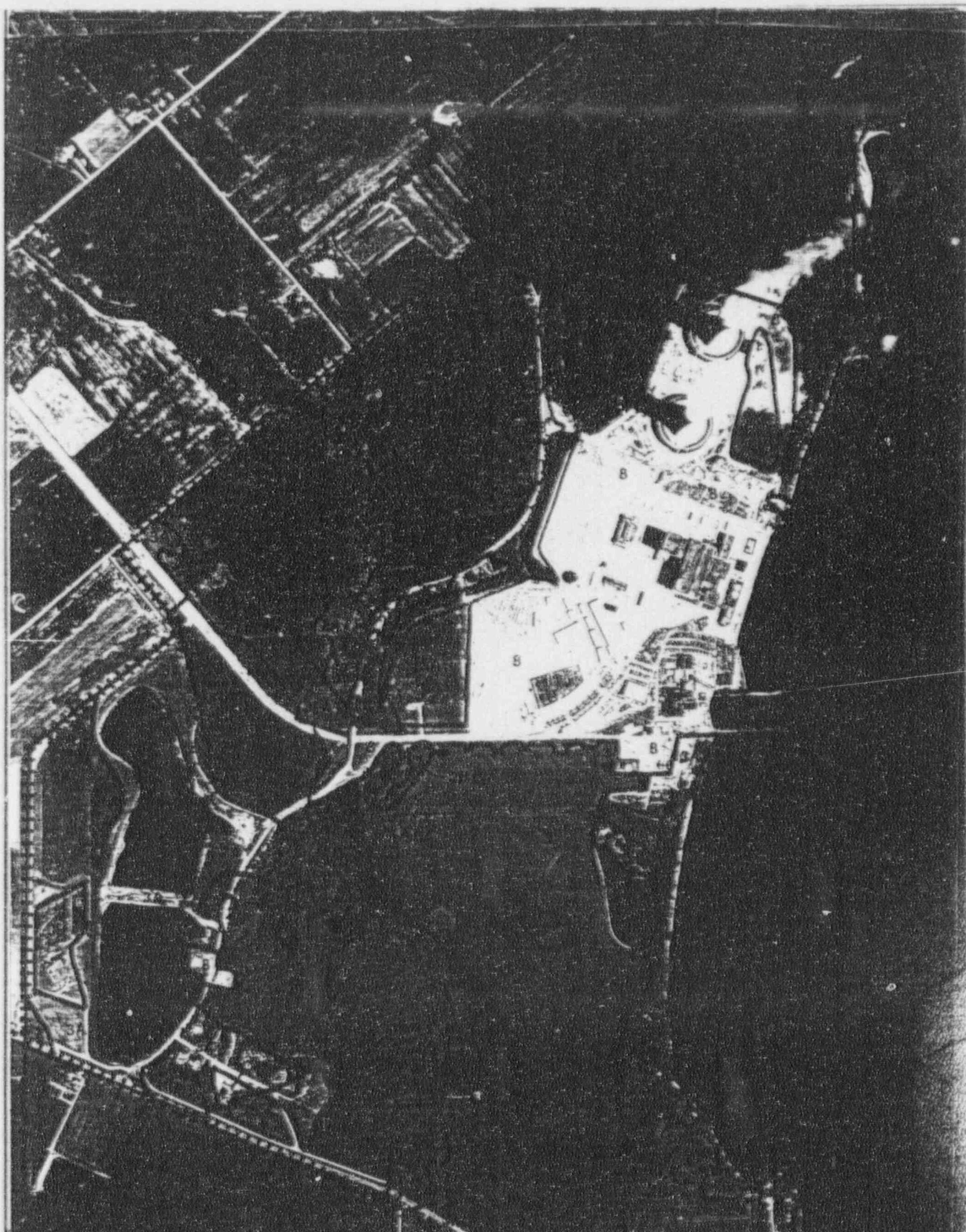


Figure 3-3. Color infrared photograph of the Fermi 2 Site, showing generating station, cooling towers, and cover type areas, 12 August 1992. (see Figure 3-1 for explanation of cover type)

TABLE 3-2. ESTIMATED HORIZONTAL ACREAGE FOR EACH COVER TYPE IN FERMI 2 SITE AREA, 12 AUGUST 1992.

CODE	LAND USE/LAND COVER TYPE	1990 (acres)
1	Deciduous Forest	
1C	Lowland Hardwoods	194
	SUBTOTAL	194
2	Wetlands	
2A	Marshland Meadow	6
2B	Shallow Marsh	87
2C	Deep Marsh	11
	SUBTOTAL	104
3	Inactive Land	
3A	Early Successional	180
3B	Advanced Successional	14
3C	Transitional	84
	SUBTOTAL	278
4	Water	300
8	Industrial	177
9	Residential	12
10	Barren Land	2
	TOTAL	1,067

TABLE 3-3. SUMMARY OF VEGETATION STRESS AREAS OBSERVED WITHIN THE FERMI 2 SURVEY AREA, 9-11 SEPTEMBER 1992. AREAS < 1 ACRE NOT MAPPED. MAP LOCATION COORDINATES FROM FIG.3-1.

LOCATION	COVER TYPE	NUMBER OF AREAS	TOTAL ACRES	STRESSED PLANTS	SYMPTOMS	PROBABLE CAUSES OF STRESS
6B	Hardwood fencerow	1	< 1	Green Ash, Hawthorn	Early leaf yellowing	Exposure as open-site fencerow plantings.
6C	"	1	< 1	Multiple species	Early leaf color	Exposure as open-site plantings.
5D	3C	1	4.6	Hardwoods	"	Intense inter- and intra-specific competition among young trees.
5E-6E	3C	1	12.6	Silky Dogwood	Leaf reddening	Species-specific seasonal effect aggravated by intense competition.
				American Elm	Leaf yellowing	Necrosis resulting from onset of Dutch Elm Disease.
5E	1C	3	29.0	Green Ash American Elm	Leaf yellowing " "	Two-year lake-level rise. " " " " ", Dutch Elm Disease.
5E-5F	3A	1	2.9	Willow (Salix sp.)	Early leaf yellowing	Exposure on open site with disturbed soil.
4B	1C	1	< 1	Hardwoods	Early leaf color	Exposure, impeded drainage and road de-icing contamination from location inside highway interchange.
4G	2A	1	2.9	Green Ash	Early leaf yellowing	Species-specific seasonal effect on stump-sprout regeneration aggravated by partial return of high lake-water level.
3B	3A,3B	1	21.2	Hardwoods	Early leaf color	Intense inter- and intra-specific competition among young trees and shrubs.
3G	2A	1	2.3	Green Ash	Early leaf yellowing	Species-specific seasonal effect on stump-sprout regeneration aggravated by partial return of high lake-water level.
3G	1C	1	2.3	"	"	As above.

(continued)

TABLE 3-3. (Continued)

LOCATION	COVER TYPE	NUMBER OF AREAS	TOTAL ACRES	STRESSED PLANTS	SYMPTOMS	PROBABLE CAUSES OF STRESS
2F	Hardwood fencerow	1	< 1	Hardwoods including Green Ash	Early leaf color	Exposure as open-site fencerow plantings.
2H	1C,3A	1	14.9	Sapling and pole-size Green Ash and American Elm		Species-specific seasonal effect on young trees, aggravated by Dutch Elm Disease in elms; in openings, seasonal senescence of Purple Loosestrife and Reed Canary Grass.
TOTAL		15	92.7			

forest, meadow and marsh bordering Lake Erie, riverine forest along the lower reaches of major streams, and woodlots of varying maturity scattered throughout the upland farms.

3.2.1 Physical Factors

As in 1990, the growing season experienced rainfall in sufficient quantity and periodicity to sustain the natural vegetation well. Data from Detroit, Toledo and Monroe (Michigan) indicate above-average precipitation during April, falling somewhat below-average through May and June (National Climatic Data Center 1992; Michigan State University 1992). However, June ranged 2-3°F below the long-term mean for the above stations of record, thus alleviating the potential heat stress of a hot month.

The statistically hottest month, July, enjoyed rainfall 2-3 inches above normal and temperatures 1-3°F below. Although August precipitation fell 1-2 inches short of the normal amount, temperatures for this month again averaged considerably lower than normal, as much as 3.8°F less at Detroit Metropolitan Airport. The worst weather of the 1992 growing season probably occurred in the form of violent squalls of the kind experienced by NAI 9-11 September 1992 during fieldwork. In such wind storms, exposed trees are particularly vulnerable to defoliation and the loss of branches (Figure 3-4).

After a two-year period of relative stability at one-half foot above the long-term annual mean (570.4 feet), Lake Erie's water level has begun to rise again to over 572 feet above mean sea level (msl), or within 1.5 feet of its peak during the 1980s of over 573 feet above msl (Figure 3-2). Trees that had died back to the main stem during the mid-1980s, then resprouted near the base as the water receded three straight years (1987-1989), began to experience new stress, evident in the premature coloring of some stump sprout foliage. Ground-truth photo-

Figure 3-4. Moderate defoliation in exposed Cottonwood *(Populus deltoides)* following severe overnight squalls. Note downed branch. Sterling State Park.

graphs show the early autumn color to be prevalent among most lakeshore populations of Green Ash (*Fraxinus pennsylvanica*), whether as stump or sapling regeneration.

Ground truthing makes it possible to distinguish between those aerial photographic images that depict ordinary seasonal effects and those of an extraordinary nature. For instance, injury to waterlogged woody growth often takes place in the midst of seasonally browning Reed Canary Grass (*Phalaris arundinacea*) (Figures 3-5 and 3-6). In other cases, the whole plant community appears to be undergoing natural senescence or color change (Figures 3-7 and 3-8). Alternatively, a whole plant community may appear to be under unusual stress from lake-level fluctuations that have been more drastic than average in recent years (Figure 3-9).

Despite the generally favorable climate for growth in 1992, fencerow vegetation still showed a tendency, noted in other study years, to turn color early, regardless of species composition (Figure 3-10). The most prominent of these essentially linear features have been located by the map coordinates of Figures 3-1 and 3-13 and listed in Table 3-3. However, because of their relatively small number and area, they do not contribute to the total acreage calculated for Table 3-3.

Starting in 1992, the Pointe Mouillee State Game Area introduced artificial water-level changes to the study area to improve and increase habitat for both nesting and migrating waterfowl and shorebirds, on the rotational schedule described in Section 3.2 (Ainslie 1993). Figure 3-11 records injury to American Lotus (*Nelumbo lutea*) as the result of a late-summer drawdown to stimulate germination of emergents. The damage was of such recent origin that no sign of it appeared in the aerial photographs taken the previous month. All future observations of the study area will probably include examples of this new source of stress.

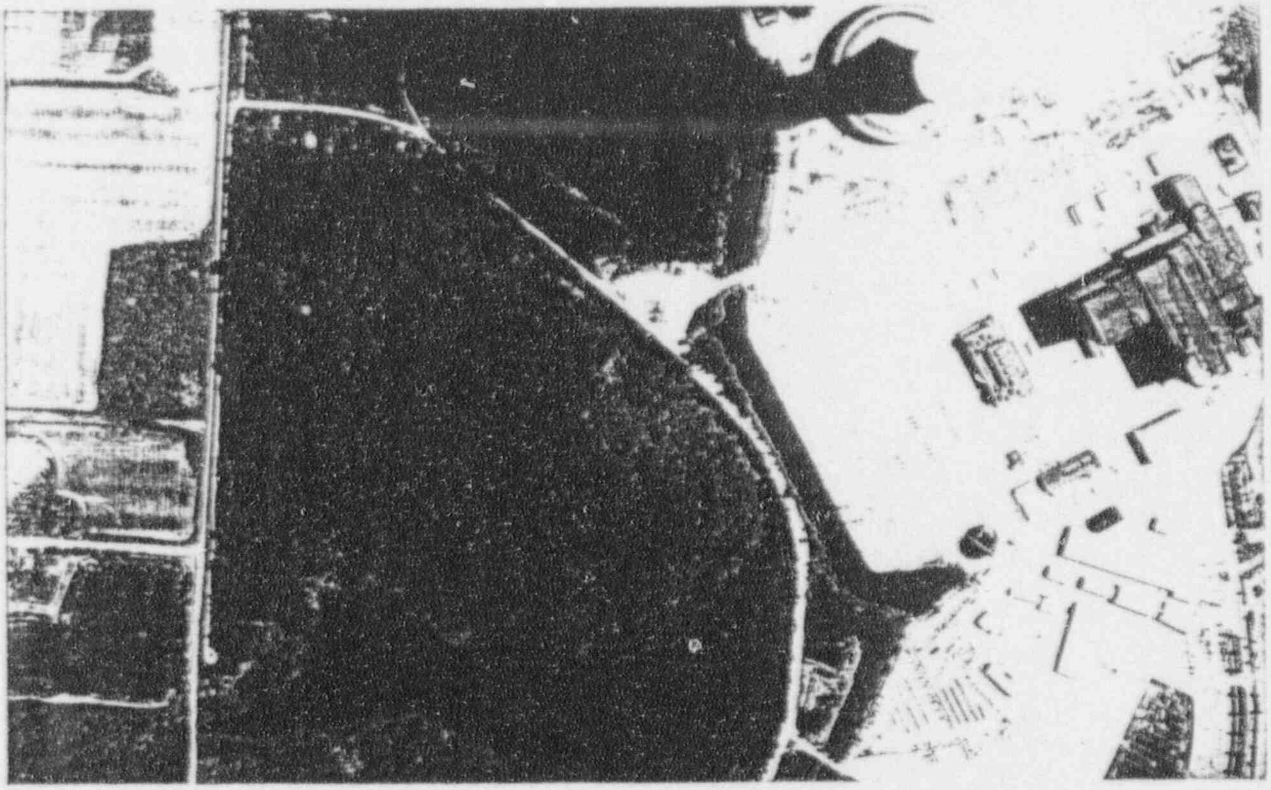


Figure 3-5. Aerial view in color infrared showing a typical forest-wet meadow transition zone of robust grasses tolerant of lake-level changes, and bottomland hardwoods periodically killed or stressed by the same cause. Area of particular stress lies within dashed line. See Figure 3-6 below for close-up detail of similar lakeshore area.

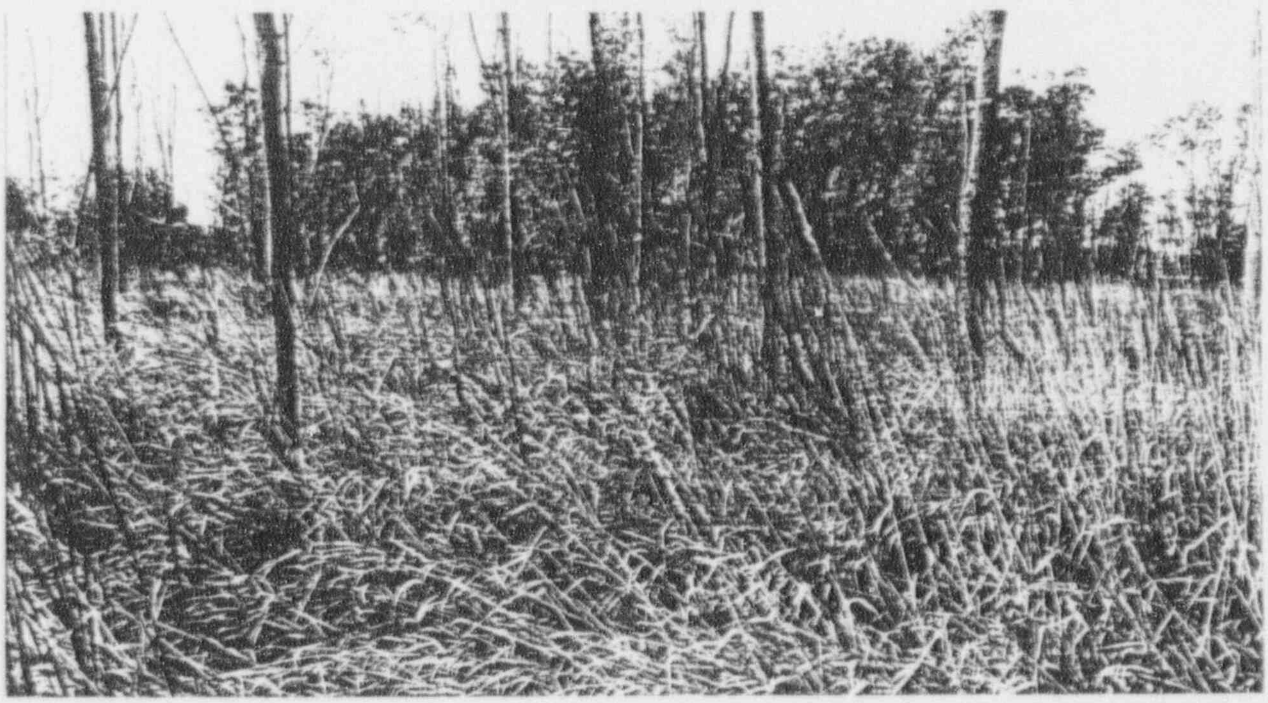


Figure 3-6. Seasonally senescent Reed Canary Grass with Green Ash stem sprouts from severe previous dieback, typical result of relatively low recent lake levels following highs of the mid-1980's. Roberts Road.

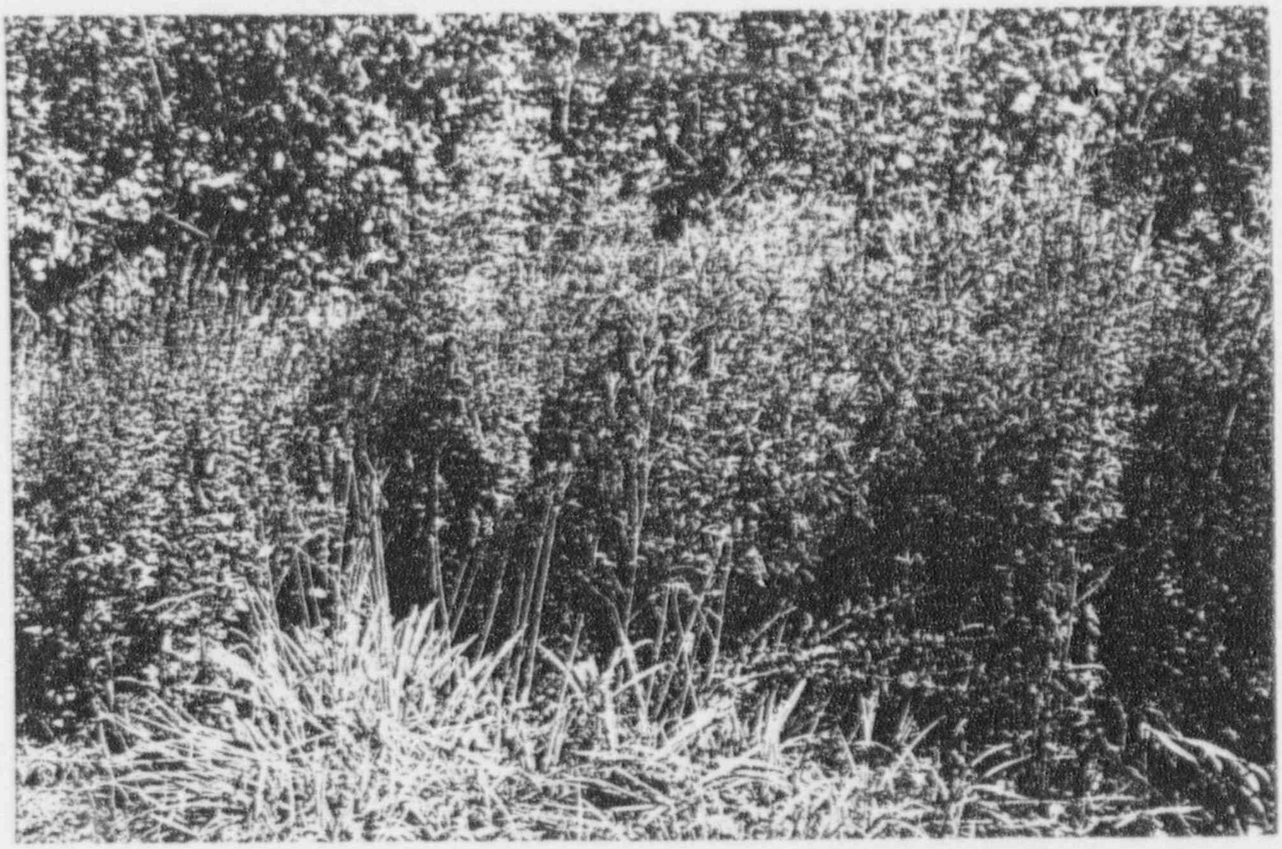


Figure 3-7. Seasonal senescence in Purple Loosestrife (*Lythrum salicaria*) and day lily (*Hemerocallis* sp., foreground), seasonal color in Sandbar Willow (*Salix exigua*). Acorn Path, Fermi 2 compound.

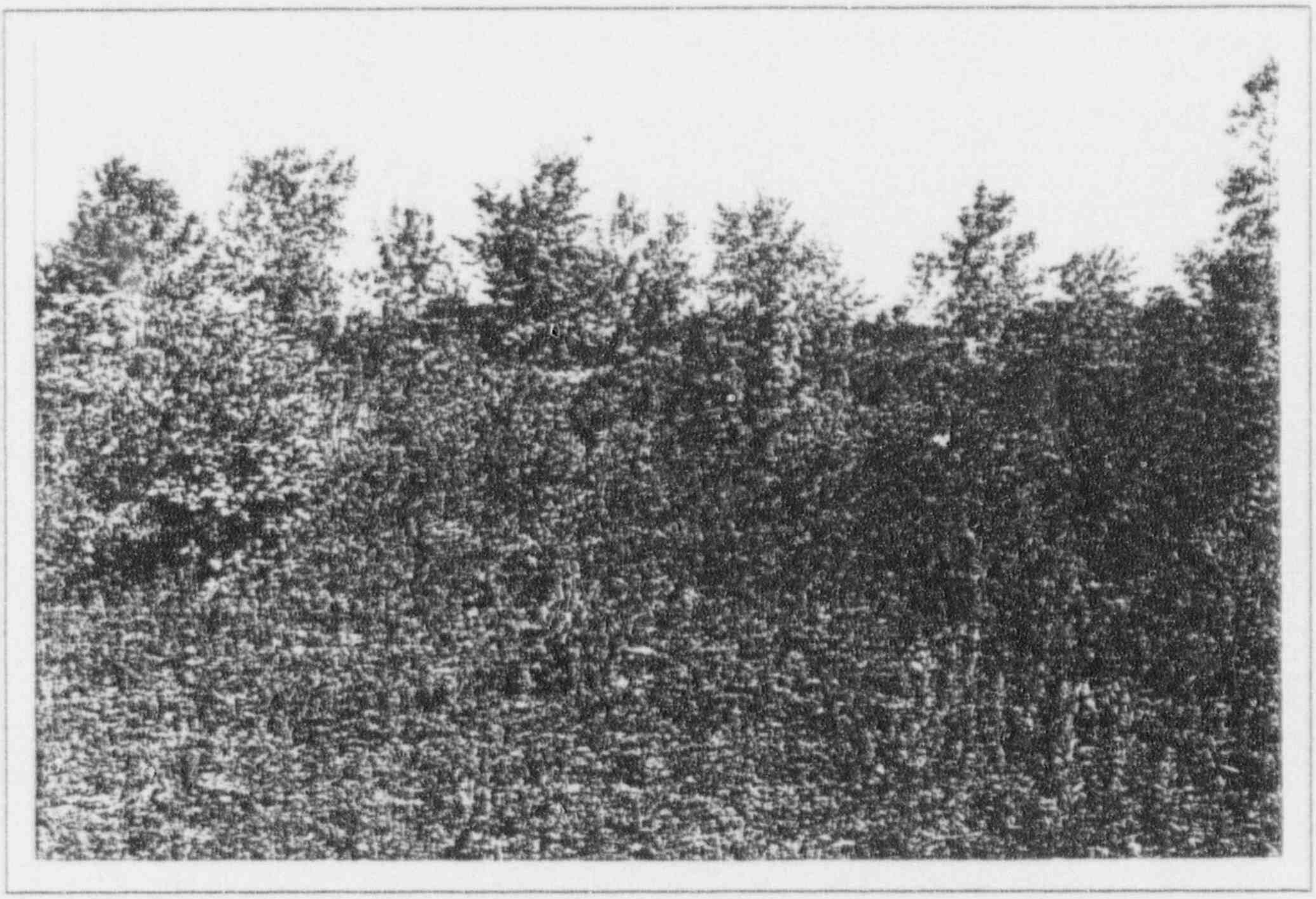


Figure 3-8. Seasonal color in Silky Dogwood (*Cornus amomum*, reddish hue), young Cottonwood and associated hardwoods. Fox Road, Fermi 2 compound.

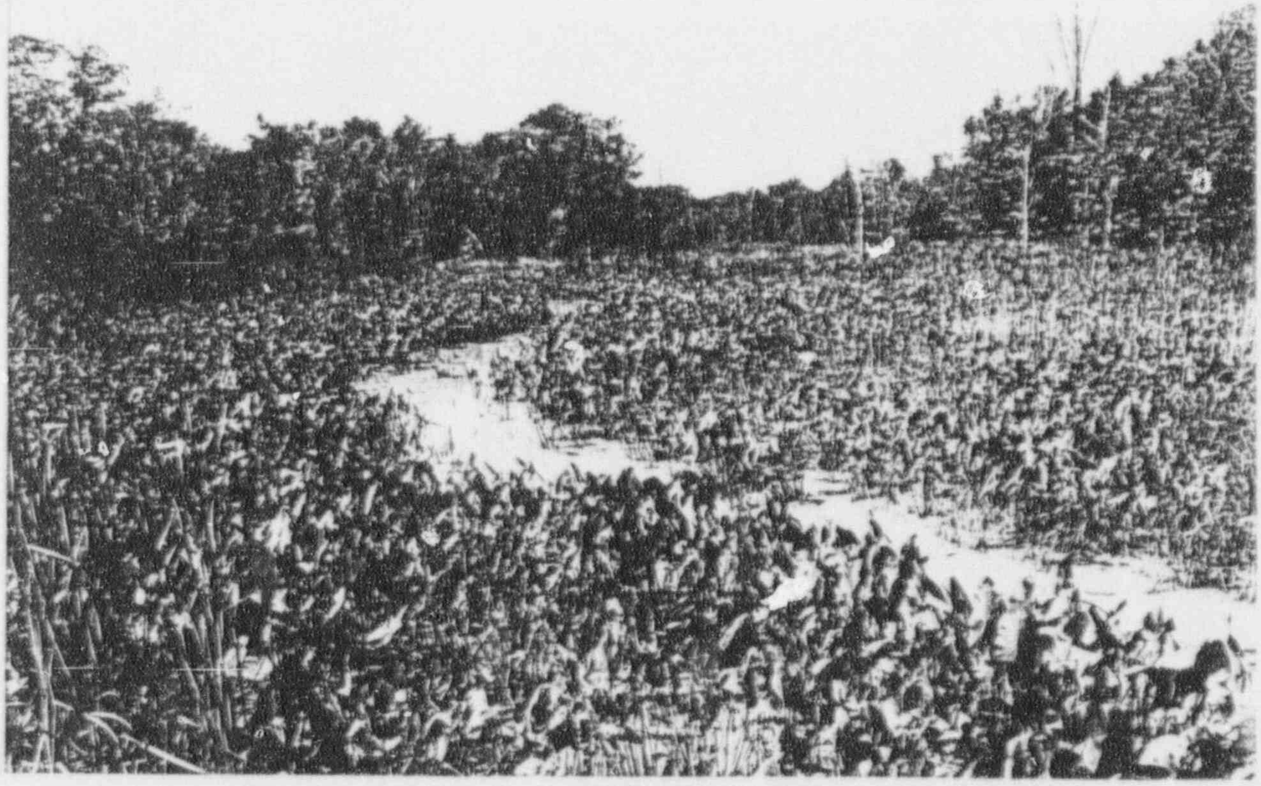


Figure 3-9. Fresh-water marsh dominated by Arrowhead (*Sagittaria latifolia*) browning prematurely from previous month of alternating high and low water. Fringing hardwoods show dead stems and early color response to recent lake-level fluctuations including present year. North Bullit Road.

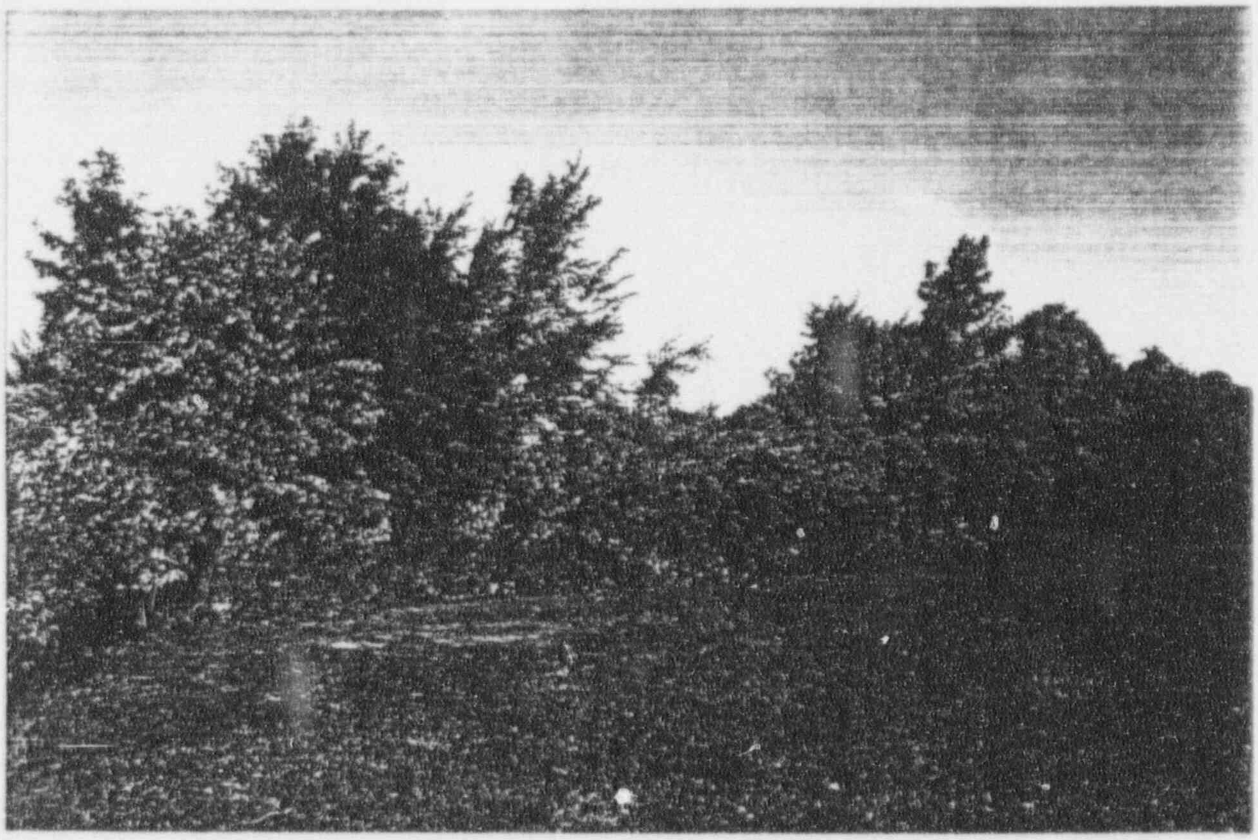


Figure 3-10. Early fall color in exposed fencerow including Green Ash (*Fraxinus pennsylvanica*), Basswood (*Tilia americana*), and Hawthorn (*Crataegus mollis*). Fix Road.

Figure 3-11. Early browning of American Lotus (*Nelumbo lutea*) resulting from exposure by water drawdown. Bad Creek Unit, Pointe Mouillee State Game Area.

3.2.2 Biotic Factors

Previous reports by TI (1980) and NAI (1980 et seq.) have mentioned the long-term effects of Dutch Elm Disease on American Elm populations, and the short-term effects of defoliating agents like Fall Webworm on deciduous trees in general. Neither of these sources of stress by itself appears to have caused damage at levels detectable in the 1992 CIR imagery of the study area. However, American Elms continue to die at an early age in otherwise relatively healthy plant communities (Figure 3-12).

At least two successional forests exhibited signs of stress, most likely resulting from the intense intra- and interspecific competition occurring during mid-succession. In general, establishment and growth of new individuals dominates the initial successional process. However, after a relatively short period, a dense stand of trees develops, precluding further establishment. From this point, forest succession becomes a thinning process, in which the less vigorous trees are out-competed for nutrients and light and subsequently die (Peet and Christensen 1980). Those individuals in the Fermi 2 study area that had been weakened by previous insect infestations or physico-chemical factors were most susceptible to the intense competition, thereby exhibiting stress effects.

A new biotic source of injury to emergent marsh communities has accompanied the development of the Pointe Mouillee State Game area. The population of Muskrats (*Ondatra zibethicus*) in the area has attained an undesirably high level (Ainslie 1993). Muskrats may now be consuming marsh vegetation faster than it can regenerate. Each Muskrat lodge typically consists of an emergent pile of dead marsh plants surrounded by a "moat" of open water and the living marsh beyond. This highly distinctive evidence of plant stress leaves no doubt as to its origin.

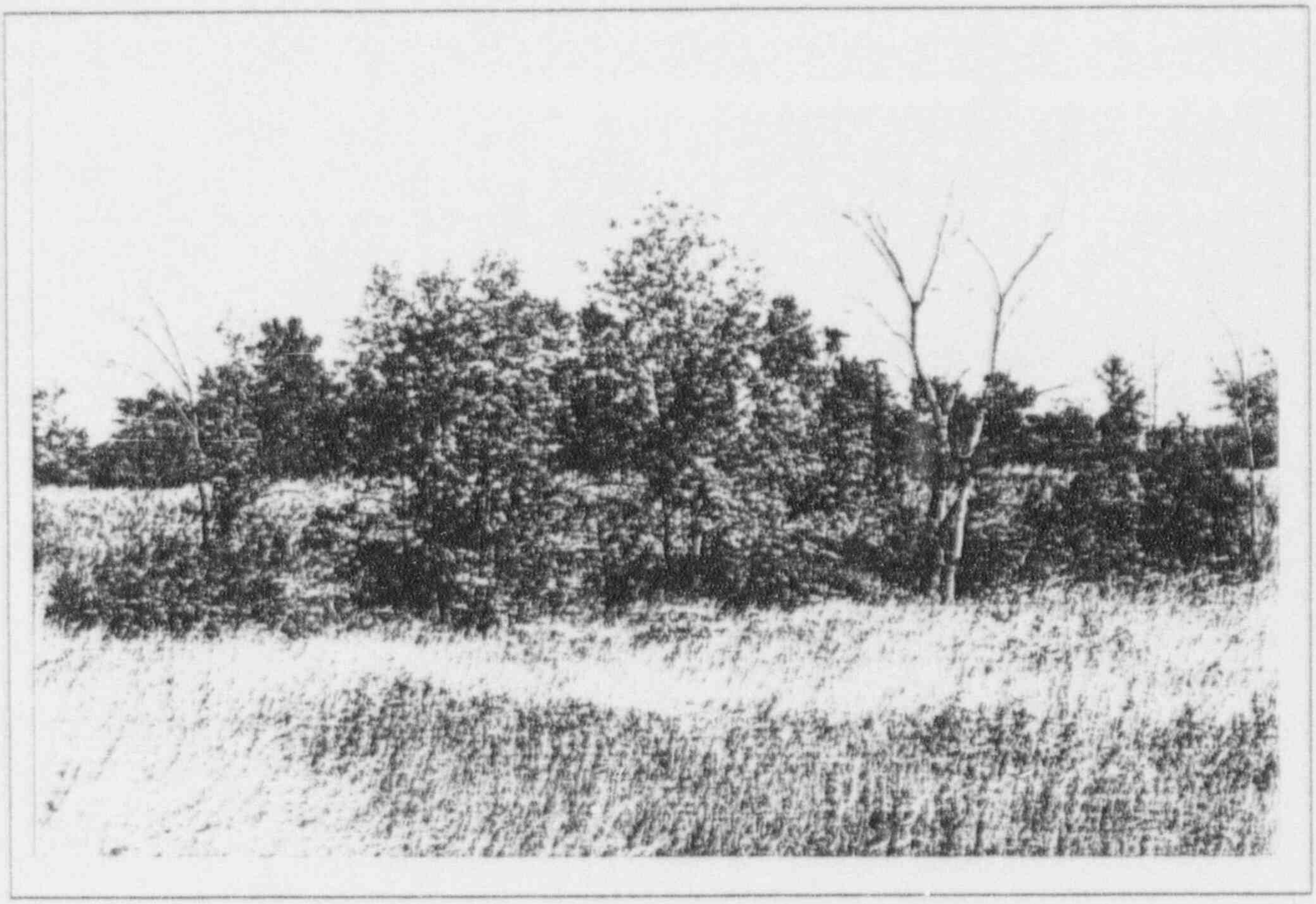


Figure 3-12. Abandoned field (Wet Meadow wetland type) dominated by seasonally senescent Reed Canary Grass (*Phalaris arundinacea*) dissected by fencerow of dead American Elm (*Ulmus americana*) and yellowing young Green Ash (*Fraxinus pennsylvanica*). Port Sunlight Road.

3.2.3 Chemical Factors

The only stress effects likely attributable to chemical factors occurred in one area where impeded drainage permitted the accumulation of road de-icing compounds (Table 3-3). While no stress attributable to chemical by-products associated with the Fermi 2 plant was noted by the 1992 or previous surveys, continued monitoring is appropriate. Essentially unchanged since 1988, the scale/deposit control program currently makes use of Betz 3450, a copolymer of acrylic acid and hydroxypropylacrylate that acts as a scale inhibitor/dispersant. Betz 3450 is fed into the cooling water to maintain a concentration of 1-5 ppm. In 1991 and 1992 bromo-chlorodimethylhydantoin, an oxidizing biocide, was applied to cooling water for microbiological control. To lower pH and improve biocide effectiveness, this treatment was reinforced eight times during 1992 by the bulk addition to cooling water of 16% sodium hypochlorite and 93% sulfuric acid, at 5,000 and 3,000 gallons respectively per dose (Lehmann 1993). None of these compounds is anticipated to cause measurable impacts beyond the immediate cooling system environment. Specifically, soil buffering capacity should be adequate to neutralize the two agents applied in bulk.

3.2.4 Species-specific Signatures

Many of the potential stress areas originally delineated represented species-specific spectral reflectance signatures rather than areas of actual injury. Two types of species-specific signatures were identified by NAI during the 1992 field survey:

(1) Species uniformly exhibiting natural end-of-season color changes (Figure 3-8).

(2) Herbaceous species naturally terminating their life cycles (Figure 3-7).

None of the areas exhibiting uniform species-specific spectral reflectance signatures was considered a stress area.

3.3 CROP SURVEY

The mapped results of the 1992 crop survey are shown in Figure 3-13 (see map in second back pocket). Acreage figures by crop type are given in Table 3-4.

TABLE 3-4. SUMMARY OF 1992 CROP SURVEY.

CROP TYPE	TOTAL ACREAGE	PERCENT OF TOTAL
Soybean	6,840	52.4
Hay, other grass crops, pasture and fallow	4,003	30.6
Earth, plowed or bare	274	2.1
Corn, all varieties	1,940	14.9
TOTAL	13,057	100.0

Over 50 percent of total crop acreage consisted of soy cultivation, up about 2% from 1990. The next largest cover type, Hay including other grass crops, pasture and fallow, had grown since 1990 nearly 22 percentage points to 4,003 acres or 30.6 percent of total acreage. The smaller cover type, Plowed or bare earth, had dropped steeply by nearly 81 percentage points, while Corn retained almost exactly the same acreage as two years ago.

The 1992 growing season in Monroe County proved to be the coolest ever, extending over about a century of records (Birkey 1993). While the combination of damp and cool conditions stimulated vigorous vegetative growth it resulted in phenomenally poor-quality crops. Much of the August tillage recorded as the Earth cover type in previous NAI

studies grew up to wheat for eventual harvest the following summer. With the current low expectation of favorable growing conditions through at least the middle of 1993, farmers were apparently choosing no-tillage or conservation tillage options as provided for in the 1985 Farm Bill. These in combination with the usual set-aside option no doubt account for the relatively greater proportion of the miscellaneous Hay cover type and the relatively lower proportion of Earth in the 1992 aerial imagery.

3.4 SOIL DESCRIPTIONS AND ANALYTIC RESULTS

Soils selected for sampling belong to the Lenawee and the Toledo series, both silty clay loams with restricted drainage. These two soil series have many properties in common (NAI 1983). Both soils are very fine-grained, level, and often wet, with mottles in the subsoils. The land capability classification of Lenawee soils is IIW; that of Toledo soils IIIW. These correspond to moderate and severe limitations, respectively, that reduce the choice of crop plants due to wetness, or that require conservation practices. These soils are derived from lacustrine deposits of fine particles, carried by the continental glacier, which settled in still, ponded water during the Wisconsin glaciation (SCS 1981). These soils are typically underlain by bedrock of limestone, dolomite, and gypsum, which help to buffer the soils and provide dissolved ions of calcium (Ca^{2+}), magnesium (Mg^{2+}), bicarbonate (HCO_3^-) and sulfate (SO_4^{2-}) in the surface and groundwater (NUS Corporation 1974).

Results from the 1992 sample analysis varied within acceptable limits (Table 3-5). Values for pH ranged from 5.61 at Sample Station 3 to 7.00 at Sample Station 5. When the six sample station pH values were averaged as pairs by zone of predicted deposition intensity (Table 3-6), the range narrowed considerably, from a mean of 6.26 in the zone of highest predicted intensity to a mean of 6.91 in the zone of intermediate predicted intensity. The fact that all three mean pH values lie

TABLE 3-5. MEAN VALUES* FOR SOIL PARAMETERS FROM EACH SAMPLING STATION. 1990, 1988, 1987 AND 1983 DATA IN PARENTHESES CHRONOLOGICALLY ORDERED BELOW.

SAMPLE NO.	PROJECTED DISSOLVED SOLIDS DEPOSITION RATE (lb/ac/yr) DURING PLANT OPERATION	SOIL TYPE	pH	CONDUCTIVITY umho/cm	PERCENT ORGANIC LOSS ON IGNITION	WATER-SOLUBLE CONCENTRATIONS IN mg/kg CALCIUM Ca^{2+}	SULFATE SO_4^{2-}	CHLORIDE Cl^-
1	Less than .1	Toledo	6.74	227	13.10	47.00	5.45	6.35
			(7.12)	(398)	(13.90)	(40.30)	(7.00)	(10.70)
			(7.75)	(530)	(12.00)	(49.85)	(14.50)	(5.20)
			(7.60)	(240)	(12.80)	(21.20)	(16.00)	(3.40)
			(7.30)	(262)	(13.00)	(4.70)	(35.50)	(15.40)
2	Less than .1	Toledo	6.85	149	16.70	37.40	10.85	8.90
			(6.73)	(208)	(16.00)	(34.85)	(6.45)	44.45
			(6.80)	(550)	(15.80)	(55.90)	(66.95)	(12.70)
			(6.90)	39)	(15.25)	(31.60)	(9.00)	(5.10)
			(6.80)	(170)	(14.50)	(3.30)	(9.70)	(4.90)
3	Gr. than .5	Lenawee	5.61	165	15.30	36.05	4.15	5.65
			(6.70)	(198)	(13.70)	(32.65)	(6.50)	(10.20)
			(6.55)	(485)	(13.80)	(55.60)	(137.20)	(8.40)
			(6.50)	(325)	(13.95)	(46.55)	(102.00)	(4.10)
			(7.10)	(227)	(16.10)	(4.30)	(ND)	(4.30)
5	.1 to .5	Lenawee	7.00	317	9.50	79.45	3.55	5.10
			(7.47)	(285)	(9.55)	(55.75)	(4.45)	(20.70)
			(8.20)	(505)	(10.85)	(74.05)	(40.30)	(9.15)
			(7.95)	(710)	(7.25)	(63.10)	(72.50)	(8.05)
			(7.70)	(394)	(8.40)	(8.00)	(5.20)	(3.80)
7	Gr. than .5	Toledo	6.91	231	16.35	46.60	4.20	6.50
			(7.36)	(255)	(17.90)	(47.55)	(5.70)	(22.30)
			(7.20)	(635)	(13.25)	(75.50)	(55.15)	(9.15)
			(6.95)	(298)	(14.05)	(36.00)	(45.50)	(3.60)
			(6.90)	(244)	(15.10)	(4.50)	(23.50)	(4.60)
8	.1 to .5	Toledo	6.82	182	15.30	37.65	2.70	4.85
			(7.09)	(253)	(14.15)	(40.05)	(5.20)	(13.00)
			(6.60)	(520)	(15.75)	(62.35)	(38.90)	(12.65)
			(6.40)	(223)	(13.70)	(12.35)	(41.00)	(2.65)
			(6.60)	(216)	(14.10)	(3.80)	(7.30)	(4.90)

*Mean based on two replicates per station. Soil types based on SCS mapping.
Sampling stations 4 and 6 were not used. ND = none detected (less than 0.5 mg/kg).

TABLE 3-6. MEAN VALUES* FOR SOIL PARAMETERS BY DEPOSITION ZONE. FIGURES IN PARENTHESES ARE THE FOUR-YEAR MEANS OF PREVIOUS DATA FOR EACH SAMPLE STATION.

ZONE OF PREDICTED DEPOSITION INTENSITY	pH	CONDUCTIVITY umho/cm	PERCENT ORGANIC LOSS ON IGNITION	WATER-SOLUBLE CONCENTRATIONS IN mg/kg		
				CALCIUM Ca^{2+}	SULFATE SO_4^{2-}	CHLORIDE Cl^-
Low	6.80 (7.13)	188 (337)	14.90 (14.16)	42.20 (30.21)	8.15 (20.64)	7.63 (12.73)
Moderate	6.91 (7.25)	250 (388)	12.40 (11.72)	58.55 (39.93)	3.13 (26.86)	4.98 (9.36)
High	6.26 (6.91)	198 (333)	15.83 (14.73)	41.33 (37.83)	4.18 (46.94)	6.08 (8.33)

*Mean based on two sample stations per zone.

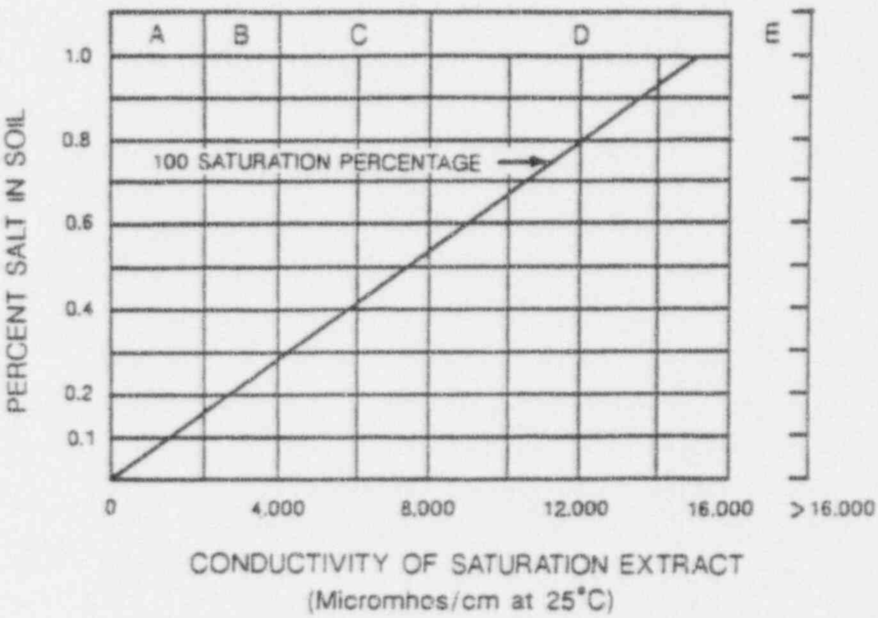
below their respective four-year means (Table 3-6) suggests loss of solutes by a somewhat stronger than usual leaching of dissociated mineral ions from the upper soil horizon as a result of heavy summer precipitation. Since the highest paired mean comes from the zone of intermediate predicted deposition intensity, there is no detectable trend in values by zone. In all three zones, the recorded mean pH remains well within the range of roughly 6 to 7 that favors the most ready availability of nutrients to plants (Buckman and Brady 1960).

The 1992 values for conductivity represent the lowest yet recorded at every sample station except No. 5, where one previous value (that for 1990) is lower. As for pH, values averaged by predicted deposition zone for conductivity ranked the lowest ever. Similarly, no apparent correlation with deposition zone existed, the highest mean value falling in the intermediate location. The hypothetical leaching action associated with low pH also probably accounts for the prevalence of low conductivity in 1992. The actual values (149 to 317 µmhos) lie far below the stress level of 2,000 to 4,000 µmhos (Figure 3-14), the upper limit of which is widely recognized as the threshold of salinity (Richards 1954).

Percent organic matter underwent no marked change from the values recorded for previous years. All values were within or close to the previous range. No correlation with the predicted deposition gradient is apparent (Table 3-6).

Despite the probably intensified removal of soluble ions by the unusually heavy July rains, calcium ion readings by deposition zone came in uniformly somewhat above their respective four-year means. This seeming contradiction can be explained by the lower pH values for 1992, because the calcite rock comprising much of the mineral component of the soil becomes increasingly soluble with increasing acidity. The solution would likely produce high ion concentrations of both calcium and bicarbonate, only the former of which was sampled. Thus high calcium ion concentrations are not inconsistent with the lower concentrations

CROP PLANT RESPONSE TO SALINITY*



*A. Negligible Effects on Yields

B. Restricted Yields of Only Very Sensitive Crops

C. Restricted Yields of Many Crops

D. Restricted Yields of All but Tolerant Crops

E. Satisfactory Yield of Only a Few very Tolerant Crops

Figure 3-14.. Relation of the percent salt in the soil to the electrical conductivity of the saturation extract and to crop response (in the conductivity ranges designated by letters A, B, C, D, E). (These ranges are related to crop response by salinity scale, after Richards, 1954, p. 9).

found for sulfate and chloride. Indeed, lower-than-average values for sulfate and chloride may suffice on their own to support the hypothesis of increased leaching in 1992. Gypsum, the major source of autochthonous sulfate in the subject soils, weathers more readily than calcium carbonate (Buckman and Brady 1960). The mobility of chloride as a leachate is well known (Westing 1969, Jones and Jeffrey 1986). The predominance of calcium ions in the soil solution may simply reflect a relatively inexhaustible supply of calcite over sulfates and chlorides during dissociation. In any case, none of the data for the three subject ions showed any correlation, positive or negative, with the zones of predicted deposition intensity (Table 3-6).

The above soil analysis is intended as a largely qualitative adjunct to the primary evidence of plant stress. For rigorous statistical validation of soils data, as many as 80 samples, each in triplicate, have been required to show significance for one parameter at the 5% confidence level in one 1/40-acre plot (Temple et al. 1979). The present method permits efficient scanning of a relatively large area in sufficient detail to detect environmental trends over several years. Considerable variations in one or another parameter in any one year are to be expected, and must be cross-checked against the data for all parameters in other years in order to determine the possible significance.

3.5 SIGNIFICANCE

An exercise of this nature needs to be kept in perspective. In this survey, the majority of stress symptoms consisted of relatively slight changes in infrared reflectance (red to pink). These occurred in no pattern that could indicate cooling-tower emissions to be the cause. Other explanations appeared more probable.

Figure 3-15 shows the Fermi 2 power plant record of operation for 1991 and 1992. It is evident that during this period power was

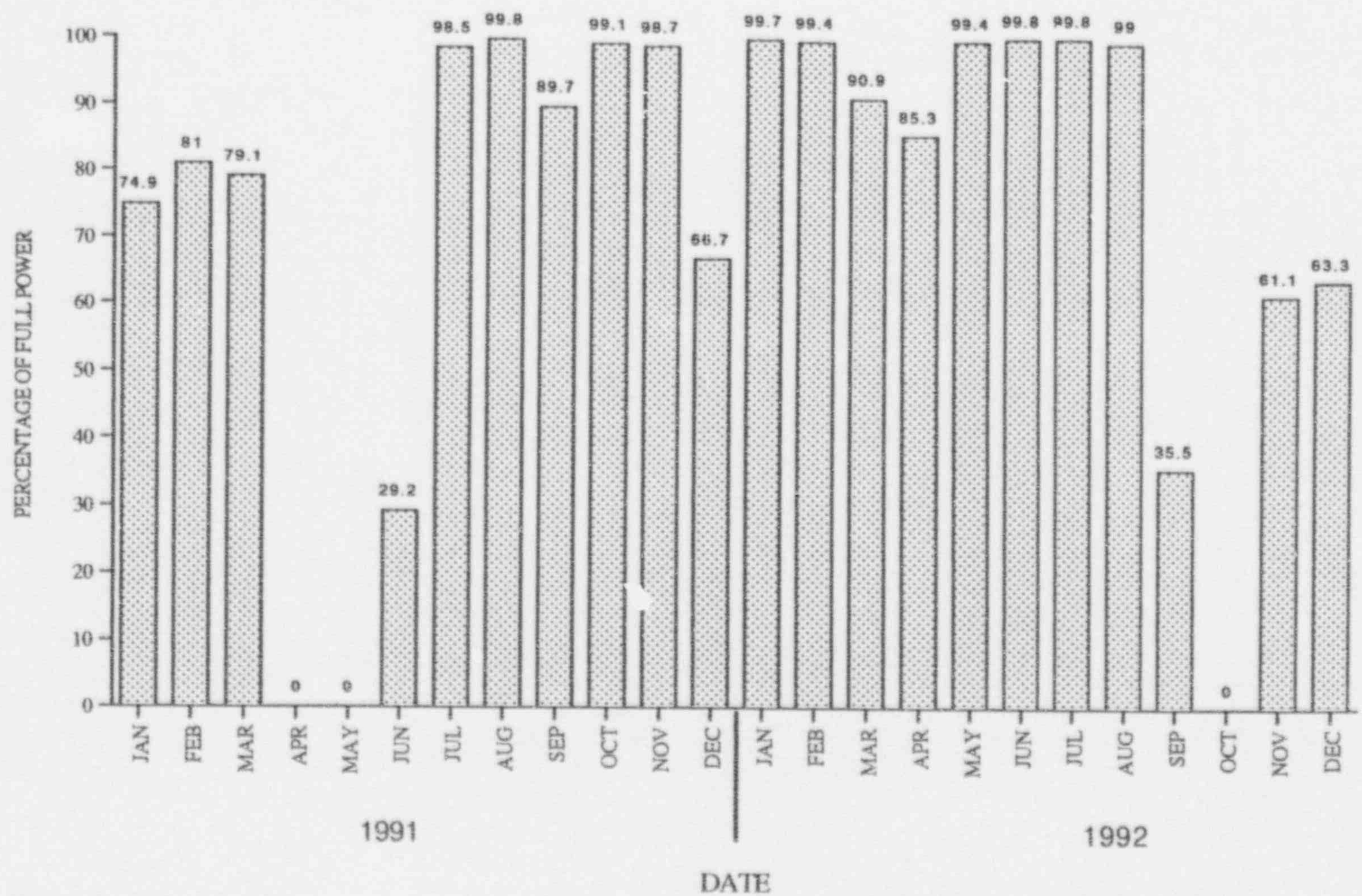


Figure 3-15. Monthly thermal capacity factor values at the Fermi 2 Power Plant for 1991 and 1992, expressing percentage of full power production.

often being generated at levels near full capacity. The predicted maximum impact of dissolved-solids deposition from the cooling towers has been estimated at about .5 lb/ac/yr. Shipley et al. (1979) estimate that stress effects on vegetation are not readily discernible by the best remote-sensing imagery (color infrared) at a deposition rate of less than .9 kg/ha/day. This figure is the equivalent of about 293 lb/ac/yr, or nearly 600 times higher than the maximum rate of deposition predicted for Fermi 2.

At the Chalk Point, Maryland power plant, which uses brackish cooling water, no changes in sodium and chloride deposition rates above baseline values were detectable beyond about 1.6 km from the drift emission source (Mulchi et al. 1982). Other studies indicate that cooling tower drift from saltwater cooling towers apparently does not have a significant environmental impact (Hu et al. 1981). It may be inferred that freshwater drift from Fermi 2, with its burden of relatively innocuous calcium, carbonate and sulfate, would have even less impact.

The absence of conclusive data is acknowledged in both the above studies. The chronic effects of long-term cooling-tower operation are not known (Talbot 1979). Since salts can accumulate in the soil and affect vegetation over several years, periodic monitoring still may be necessary during the time the power plant runs at full operation levels.

4.0 REFERENCES

Ainslie, Rex. 1993. pers. com. Game Area Manager's Office, Pointe Mouillee State Game area, Monroe and Wayne Counties, MI.

Birkey, Ned. 1993. pers. com. Agricultural Agent's Office, Monroe County Cooperative Extension Service, Raisinville Township, MI.

Crawford, R.M.M. 1982. Physiological responses to flooding. Encyclopedia of Plant Physiology 12B:453-437.

Fitter, A.H. and R.K.M. Hay. 1987. Environmental physiology of plants. Academic Press, N.Y., NY.

Harrington, C.A. 1987. Responses of red alder and black cottonwood seedlings to flooding. Physiol. Plantarum 69:35-48.

Hu, M.C., G.F. Pavlenco, G.A. Englerson. 1981. Executive summary for power plant cooling system water consumption and nonwater impact reports. United Engineers and Constructors, Inc., Philadelphia, PA.

Jones, P.H. and B.A. Jeffrey. 1986. Environmental impact of road salting - state of the art. Ontario Ministry of Transportation and Communications, Research and Development Branch, Downsview, Ontario, Technical Report RR 237.

Keddy, Paul A. 1990. Water level fluctuations and wetland conservation. In Kusler, J. and R. Smardon eds. Wetlands of the Great Lakes, Proceedings of an International Symposium, Niagara Falls, New York. Association of State Wetland Managers and State University of New York Great Lakes Research Consortium.

Lehmann, Fritz. 1993. pers. comm. Nuclear Operations Center, Enrico Fermi Power Plant, Unit 2, Detroit Edison Company, Newport, MI.

Michigan State University. 1990. Local Climatological Data for Raisin River, Monroe. State of Michigan Department of Agriculture.

Mulchi, Charles L., J.A. Armbruster, D.C. Wolf. 1982. Chalk Point: a case study of the impact of brackish-water cooling towers on an agricultural environment. J. Environ. Quality 11:(2)212-220.

NAI. 1983. Enrico Fermi Atomic Power Plant, Unit II (Fermi 2) Remote Sensing and Vegetation Ground Truth Program 1983 Final Report. Normandeau Associates Inc., Bedford, NH.

__________. 1984. Enrico Fermi Atomic Power Plant, Unit II (Fermi 2) Remote Sensing and Vegetation Ground Truth Program -- Four-year Summary Report. Normandeau Associates Inc., Bedford, NH.

__________. 1987. Enrico Fermi Atomic Power Plant, Unit II (Fermi 2) Remote Sensing and Vegetation Ground Truth Program 1987 Final Report. Normandeau Associates Inc., Bedford, NH.

__________. 1988. Enrico Fermi Atomic Power Plant, Unit II (Fermi 2) Remote Sensing and Vegetation Ground Truth Program 1988 Final Report. Normandeau Associates Inc., Bedford, NH.

__________. 1990. Enrico Fermi Atomic Power Plant, Unit II (Fermi 2) Remote Sensing and Vegetation Ground Truth Program 1990 Final Report. Normandeau Associates Inc., Bedford, NH.

National Climatic Data Center. 1992. Local climatological data for Detroit Metropolitan Airport and Toledo Express Airport. National Oceanic and Atmospheric Administration, U.S. Department of Commerce.

NUS. 1974. The 1973-1974 Annual Report of the terrestrial ecological studies at the Fermi site. Prepared for Detroit Edison Co., Detroit, MI. NUS Corporation, 1910 Cochran Road, Pittsburgh, PA.

Peet, R.K. and N.L. Christensen. 1980. Succession: a population process. Vegetatio 43:131-140.

Richards, L.A. ed. 1954. Diagnosis and improvement of saline and alkali soils. USDA Handbook, U.S. Government Printing Office, Washington, DC.

SCS. 1981. Soil survey of Monroe County, Michigan. U.S. Department of Agriculture and Michigan Agricultural Experiment Station.

Shipley, B.L., S.B. Pahwa, M.D. Thompson, R.B. Lantz. 1979. Remote sensing for detection and monitoring of salt stress on vegetation: evaluation and guidelines. Final Report prepared for U.S. Nuclear Regulatory Commission by INTERA Environmental Consultants, Inc., Houston, TX.

Talbot, J.J. 1979. A review of potential biological impacts of cooling tower salt drift. NAS, 2101 Constitution Ave., Washington, D.C. Atmospheric Environment 13(3):395-405.

Temple, Patrick J. and Ronald Wills. 1979. Sampling and analysis of plants and soils. In Methodology for the Assessment of Air Pollution Effects on Vegetation, ed. W.W. Heck et al., Air Pollution Control Association.

Terrasi, William. 1989. pers. com. Nuclear Operations Center, Enrico Fermi Power Plant, Unit 2, Detroit Edison Company, Newport, MI.

__________. 1991. pers. com. as above.

TI. 1978. Enrico Fermi Atomic Power Plant, Unit 2 (Fermi 2) Remote Sensing and Vegetation Ground Truth Program. Final Report, March 1979. Texas Instruments, Inc., Ecological Services, Dallas, TX.

__________. 1980. Enrico Fermi Atomic Power Plant, Unit 2 (Fermi 2) Remote Sensing and Vegetation Ground Truth Program. Draft Report, November 1980. Texas Instruments, Inc., Ecological Services, Dallas, TX.

Westing, Arthur H. 1969. Plants and salt in the roadside environment. Phytopathology 59, 1174-1181.

OVERSIZE DOCUMENT PAGE PULLED

SEE APERTURE CARDS

NUMBER OF OVERSIZE PAGES FILMED ON APERTURE CARDS 2

9305040124-01,02

APERTURE CARD/HARD COPY AVAILABLE FROM

RECORDS AND REPORTS MANAGEMENT BRANCH

Normandeau Associates, Inc.
25 Nashua Road
Bedford, NH 03110-5500
(603) 472-5191
(603) 472-7052 (Fax)