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NATURAL RESOURCE RESTORATION PLAN

FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
FERNALD, OHIO

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U.S. DEPARTMENT OF ENERGY
FERNALD AREA OFFICE

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LIST OF ACRONYMS

BTV	benchmark toxicity value
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DOE	U.S. Department of Energy
DOE-FEMP	U.S. Department of Energy, Fernald Field Office
EPA	United States Environmental Protection Agency
FCAB	Fernald Citizens Advisory Board
FEMP	Fernald Environmental Management Project
FRL	final remediation level
HEA	Habitat Equivalency Analysis
IEMP	Integrated Environmental Monitoring Plan
IRDP	Integrated Remedial Design Package
NEPA	National Environmental Policy Act
NRDA	Natural Resource Damage Assessment
NRIA	Natural Resource Impact Assessment
NRRDP	Natural Resource Restoration Design Plan
NRRP	Natural Resource Restoration Plan
NRTs	Natural Resource Trustees
ODNR	Ohio Department of Natural Resources
OEPA	Ohio Environmental Protection Agency
OSDF	On-Site Disposal Facility
pls	pure live seed
PRCRP	Paddys Run Conceptual Restoration Plan
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
SCS	Soil Conservation Service
SEP	Sitewide Excavation Plan
TSS	total suspended solids
USFWS	U.S. Fish and Wildlife Service

1.0 INTRODUCTION

The Natural Resource Restoration Plan (NRRP) outlines the overall objectives for restoration and final land use at the Fernald Environmental Management Project (FEMP). It also identifies the institutional controls necessary to restore and commit portions of the FEMP to an undeveloped park with an emphasis on wildlife habitat. The NRRP presents the strategy for site restoration, and provides a programmatic approach for expediting natural resource restoration to the extent practical. The final land use at the FEMP will be determined with the full involvement of the public and other stakeholders. It is possible that some areas of the site could be identified for alternative uses based on stakeholder input. The NRRP is based on a series of restoration projects that are designed to address compensatory requirements on the part of the U.S. Department of Energy (DOE) for natural resource impacts, as well as regulatory-driven mitigation requirements. The NRRP is an integral aspect of the sitewide remediation process and has been developed in coordination with the excavation plans outlined in the Sitewide Excavation Plan (SEP).

1.1 ADMINISTRATIVE GOALS OF THE NRRP

O46 The ultimate goal of the NRRP is to resolve DOE liability for past and future natural resource injuries at the FEMP while meeting regulatory commitments and addressing stakeholder concerns. It is essential that the Natural Resource Trustees (NRTs) concur with the approaches and projects outlined in the plan before detailed design can begin on individual projects. In addition, other stakeholders will be provided the opportunity to review the plan to ensure a general consensus is reached on the conceptual final land use for the site. The specific administrative goals that guided the development of the NRRP are as follows:

- Establish a restoration plan that is satisfactory to all NRTs, and upon implementation, will resolve DOE liability for injuries to natural resources associated with the FEMP
- Propose a future land use for the FEMP site that considers the interests of all stakeholders and will benefit the surrounding area
- Propose a future land use that is consistent with the established risk levels in the various operable unit records of decision
- Establish a restoration plan that can be fully integrated with the ongoing remedial design and remedial action processes at the FEMP.

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1.2 NATURAL RESOURCE RESTORATION STRATEGY

The natural resource restoration strategy for the FEMP is to implement a series of specific projects both during and after the completion of site remediation. The restoration projects will be fully integrated with the remedial design and remedial action processes for Operable Unit 5 (i.e., soil excavation and remediation) where appropriate. The strategy includes:

- Initiating restoration activities at the completion of area-specific remedial activities wherever possible
- Coordinating restoration activities under the scope of this plan with FEMP remediation activities
- Incorporating ecological restoration goals into the design of grading activities.

The initial strategy for natural resource restoration at the site is to begin restoration projects in parallel with site remediation activities, and accomplish full restoration through additional projects at the completion of site remediation. Projected ecological restoration projects are discussed in Section 4.0. The conceptual final land use of the FEMP, once all ecological restoration projects have been implemented, is shown on Figure 1-1.

The NRRP strategy will also incorporate the restoration goals of the NRTs and the input of other stakeholders in establishing an acceptable final land use for the FEMP (See Section 5.0). Institutional controls for the FEMP property will be developed to support final land use agreements.

1.3 SUMMARY OF NATURAL RESOURCE IMPACT ASSESSMENT

The Natural Resource Impact Assessment (NRIA) identified the impacts (i.e., injuries) at the site resulting from past contamination, and those impacts expected to occur as part of future remedial actions. The NRIA identified impacts to the extent possible on an acreage basis sorted by habitat type. Groundwater impacts were identified on both an acre and volumetric basis as groundwater does not constitute a "habitat." In general, impacts were quantified using existing remedial investigation/ feasibility study information. Past impacts were measured using the soil excavation footprint, which included soils that were considered a risk to human receptors [i.e., soil concentrations exceeding final remediation levels (FRLs)]. Future impact acreage was identified in cases where physical disturbances have resulted from or will result in the destruction of or reduction in the quality of a particular habitat.

The purpose of the NRIA is to establish a "baseline" level of impact from which appropriate restoration activities can be developed. The NRIA was designed to function in a manner analogous to an Injury Determination in the formal Natural Resource Damage Assessment (NRDA) process (43 CFR 11). Since the intent of the NRTs is to pursue a more streamlined evaluation and assessment process and not to conduct a formal NRDA, the NRIA and NRRP were designed to meet the substantive aspects of the formal NRDA process to the extent practicable.

The level of impacts identified in the NRIA was used to assess a required level of natural resource restoration as presented in the NRRP. Habitat Equivalency Analysis (HEA), described in Section 1.4 and Addendum B was used to determine the amount of restoration required to compensate for impacts to terrestrial habitats. The Fernald NRTs have negotiated other projects to compensate for groundwater impacts as discussed in Section 1.5 of this plan. The results of the HEA and NRT negotiations were used to establish the restoration activities outlined in Section 4.0 of this plan. The NRIA and NRRP will be approved as a final document with no further revisions. However, the progress of restoration at the FEMP will be tracked by the NRTs to ensure proper implementation of the NRRP.

O50 Implementation of the NRRP will facilitate a resolution of DOE's natural resource damage liability. Any liability settlement documentation among the NRTs will include re-opener provisions in the event of an unanticipated release and subsequent injuries to natural resources.

1.4 SUMMARY OF HABITAT EQUIVALENCY ANALYSIS

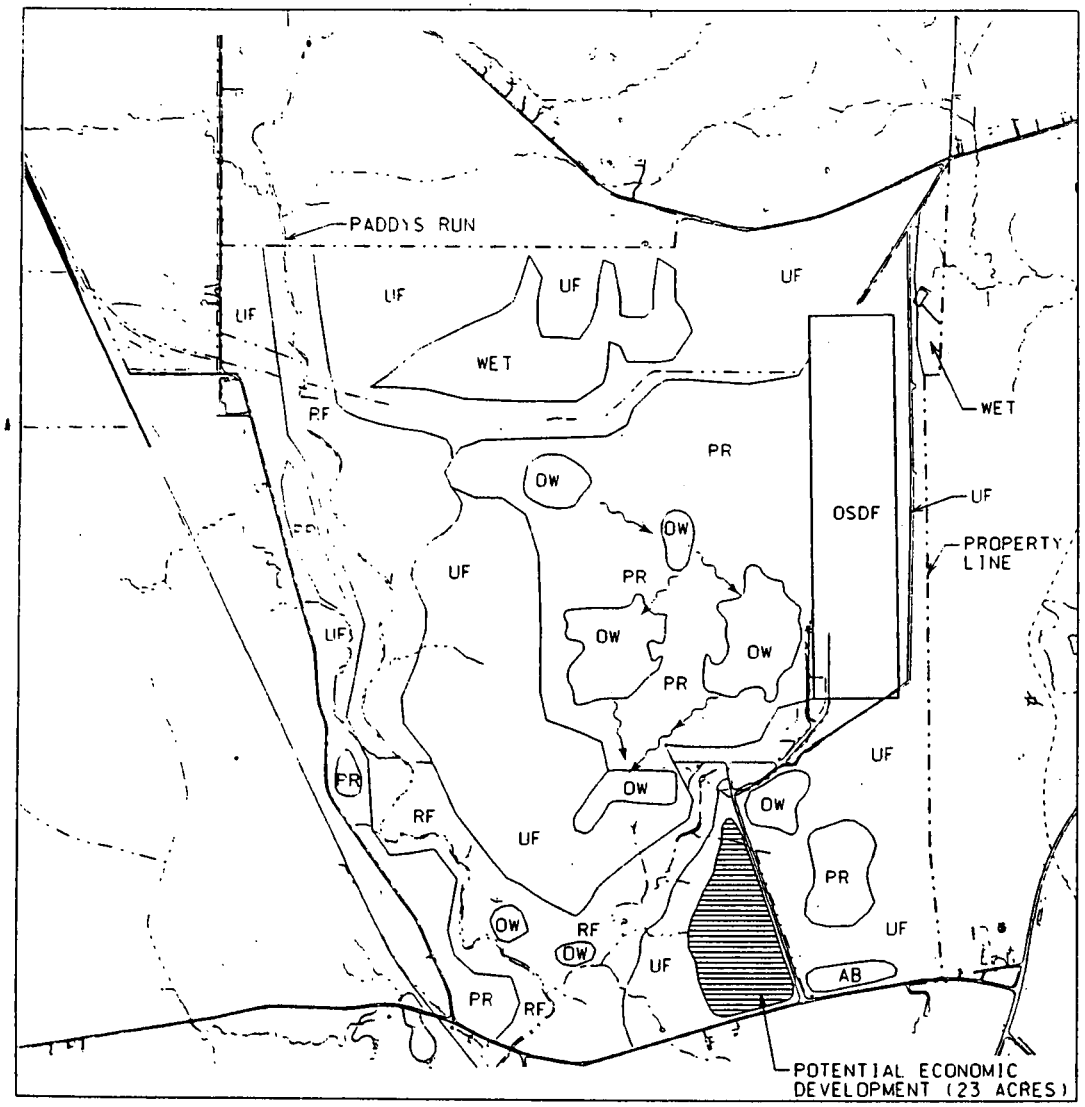
D2 The HEA process was utilized to ensure that the level of natural resource restoration outlined in this NRRP is commensurate with the level of impact identified in the NRIA (Addendum B). HEA methodology provides a means of compensating for natural resource injury through the calculation of habitat restoration acreage. By linking estimates of service loss over time to service gains through restoration projects, potentially contentious dollar damage estimates may be avoided.

From the information presented in the NRIA, conservative assumptions and qualitative judgements were used to develop the HEA calculations. This streamlined process allowed for an "order of magnitude" justification for on-property restoration. Also, as described in Section 1.5, HEA was used to calculate terrestrial and surface water habitats only.

1.5 APPROACH FOR GROUNDWATER

O4,26, 39,40, 41,42, 43,47, 48, D2 The HEA process is appropriate for estimating restoration acreage when injuries are associated with ecological functions and habitat loss. Service losses to humans, such as contamination of a drinking water supply, cannot easily be equated to habitat restoration. Restoration activities must be conducted to replace, restore, or acquire the equivalent of the injured natural resource. Therefore, it is very difficult to compensate for groundwater impacts through ecological restoration.

O23 Because the FEMP NRTs agreed to focus on habitat restoration as compensation for all impacts, an attempt was made to calculate restoration acreage due to groundwater impact. Several scenarios for using HEA were proposed, but the NRTs were not satisfied that justification was adequate. As a result, the FEMP NRTs agreed to abandon the use of HEA for groundwater compensation. Instead, the NRTs agreed to ensure that all on-property areas [minus the On-Site Disposal Facility (OSDF) and the 23 acres of land under consideration for potential economic development by the Community Reuse Organization (CRO)] are ecologically restored. This would protect a portion of the Paddys Run watershed, which contributes to the recharge of the Great Miami Aquifer. In addition, DOE agreed to develop a groundwater education module, which may be either permanently displayed at the FEMP or made available to area schools. By implementation of these projects, and by completion of remedial activities, the FEMP NRTs agreed that DOE would adequately compensate for injuries to groundwater.



LEGEND:

AB	AESTHETIC BARRIER
PR	PRAIRIE
UF	UPLAND FOREST
RF	RIPARIAN FOREST
OW	OPEN WATER
WET	WETLAND
←~~	DRAINAGE PATTERN

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FIGURE 1-1. CONCEPTUAL FINAL LAND-USE

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2.0 RESTORATION PLANNING

The ecological restoration projects proposed in this NRRP have been developed by considering the extent of excavation and grading and the sequence of remediation activities so that restoration and establishment of the future land use can be expedited. In addition, consideration was given to uncertainties and a variety of other regulatory and technical considerations. This section will provide the basis for the proposed ecological restoration projects and conceptual final land use outlined in this plan.

2.1 ECOLOGICAL RESTORATION GOALS

Ecological restoration goals form the foundation from which conceptual restoration planning decisions are made. They also provide the basis for monitoring to determine the progress of restoration. The ecological restoration goals are stated and described below.

2.1.1 Restoration of Native Vegetation

Goal: *Enhance, restore, and construct, as feasible given postexcavation landforms and soils, vegetative communities native to presettlement southwestern Ohio.*

Ecological restoration at the FEMP will be conducted to promote the native flora of southwestern Ohio. This primarily involves the restoration of contiguous tracts of upland and riparian forest, interspersed with open water and/or wetland systems. Section 3.0 provides a more detailed description of habitat types which existed at the FEMP prior to industrial and agricultural development. The intent of this restoration plan is to use the natural dynamics of ecological systems to the extent possible. For example, to convert an introduced grassland to an upland forest, an early and mid-successional tree mix will be emphasized rather than focusing on late successional or climax species. Native species would be used in excavated areas, since they are naturally suited for colonizing disturbed soils. Where existing forest is to be enhanced, shade-tolerant species may be planted to take advantage of the existing forest canopy. The vegetative species mix will depend on many factors, including soil, elevation, slope, drainage, adjacent existing vegetation, cost, and availability.

2.1.2 Paddys Run Restoration

Goal: *Enhance, restore, and reconstruct the natural dynamic stream characteristics and aquatic systems of Paddys Run, as necessary and feasible.*

Just as most other streams in southwestern Ohio, Paddys Run has been significantly altered due to channeling, erosion control, and removal of sand and gravel. In most instances, existing development prevents the restoration of a natural stream function. However, since undeveloped land is available at the FEMP, the potential exists to restore Paddys Run floodplain and subsequent natural stream habitat. Section 3.1.4 provides additional information regarding Paddys Run stream restoration.

2.1.3 Wildlife Promotion

Goal: *Enhance, restore, and construct ecological systems that promote the habitation of wildlife populations native to southwestern Ohio.*

Wildlife will not be introduced into any particular habitat. Wildlife use will be considered when selecting flora. Wildlife structures and cover (i.e., bird boxes, brush piles) may be included in ecological restoration designs.

2.1.4 Meet Mitigation Requirements

Goal: *Integrate all regulatory mitigation requirements into natural resource restoration plans.*

DOE is required to mitigate certain impacts to natural resources through laws and regulations. These include commitments under the National Environmental Policy Act (NEPA) and wetland mitigation under Section 404 of the Clean Water Act. To the extent possible, these actions will be conducted on-property and combined with adjacent restoration projects to allow for the contiguous restoration of the FEMP. Similar constraints as outlined in Section 2.1.1 must be taken into consideration during design and implementation.

2.2 INTEGRATION WITH SITEWIDE EXCAVATION PLAN

The sequencing of the implementation of the restoration projects proposed in this plan will be coordinated with the timing and sequencing of soil excavation. In addition, the final restoration of the site will be a function of the extent of excavation and final grading required during soil remediation. This section addresses how implementation of the projects outlined in the NRRP will be integrated with the guidelines established in the SEP and its appendices.

2.2.1 Sitewide Excavation Plan

The NRRP is fully integrated into the SEP. Many issues identified in the SEP apply directly to the NRRP, such as:

- Restoration strategy
- Regulatory drivers
- Certification and benchmark toxicity values (BTVs)
- Restoration grading guidelines
- Environmental monitoring
- Quality assurance/quality control.

2.2.2 Postexcavation Strategy

A key component of the proposed future land use is a series of interconnected open water and wetland habitats. A fundamental assumption was that excavations required for soil remediation would be utilized for natural resource restoration to the maximum extent possible. There will be a variety of excavations in and adjacent to the Former Production Area that could potentially accommodate wetland and open water habitat (Figure 2-1). The specific locations and sizes of the open water/wetland areas were based on the requirements for excavation. In addition, the general pattern of site drainage for proposed final land use was established through the utilization of excavations formed through removal of site utilities.

2.2.3 Sitewide Sequencing Plan

The Sitewide Sequencing Plan, which is Appendix B in the SEP (DOE 1998), dictates the sequence and timing of soil remediation activities which will dictate the schedule for implementation and completion of long-term restoration projects. For example, revegetation of the Former Production Area would be delayed until the certification process is complete for the area-specific constituents of concern of a remediation area. The near-term restoration projects have been designed to be implemented in tandem with soil remediation. However, the certification of certain areas to below FRL concentrations will occur prior to the implementation of on-site, near-term restoration projects.

2.2.4 Implementation of Construction

Implementation of Construction, which is Appendix F of the SEP (DOE 1998) will provide the transition from the excavated areas resulting from soil remediation to the appropriate grades to support natural resource restoration. The final grading designs established in the IRDPs will ensure that appropriate drainage is established, slopes are stabilized, and appropriate surface water diversion and retention are established to support open water/wetland habitats. These designs will also ensure that the floodplain of Paddys Run is not restricted as a result of soil remediation and that areas of the site for alternative use will be graded appropriately.

2.3 UNCERTAINTIES AND CONSIDERATIONS FOR ACCELERATED RESTORATION

There are several aspects of the NRRP and the acceleration of the natural resource restoration process that involve uncertainties that must be addressed through careful consideration in the project specific design processes. These issues are discussed in the following sections.

2.3.1 Potential for Cross-Contamination During Phasing of Excavation

The potential for cross-contamination is a concern that must be addressed during the excavation and grading processes. The overall excavation and grading processes will require that particular areas of the site be excavated and graded before or in parallel with other areas. Appropriate administrative and engineering controls must be in place so that cross-contamination is avoided. The specific projects outlined in this plan will not be implemented until the certification process is complete for each respective project area and appropriate controls are established to ensure the risk of cross-contamination has been minimized.

2.3.2 Ecological Risk Factors

A process must be established to ensure that the projects proposed are not implemented in areas that contain contaminants posing a risk to ecological receptors. The process will be designed to effectively address the impact of potential contaminants to ecological receptors.

Appendix C of the SEP contains the sitewide review of contaminants of ecological concern. The results of this review indicate that antimony, cadmium, lead, molybdenum, silver, and several PAHs may be a concern in certain areas of the site. Remedial activities are anticipated to address any ecological concerns, and the presence of these constituents will be verified during the certification

process. If ecological concerns remain, further action may be necessary. Additional actions include qualitative or quantitative risk characterization, additional excavation, or revisions to restoration design that would reduce the potential for exposure to an ecological receptor. These design revisions will be addressed through individual natural resource restoration design plans (NRRDPs). Addendum A of the NRRP provides a summary of Appendix C of the SEP (DOE 1998).

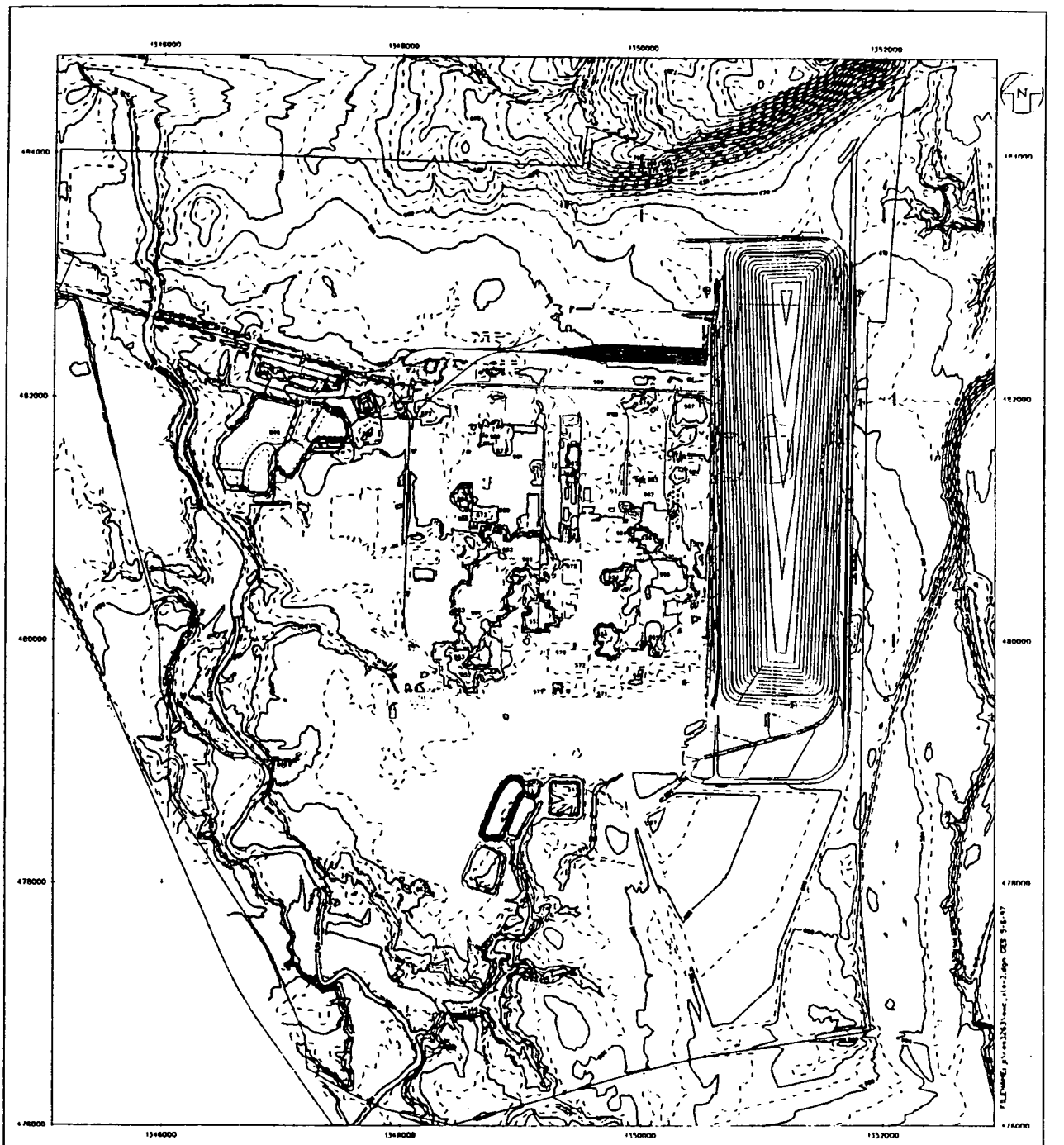

FIGURE 2-1. PROJECTED POST-EXCAVATION TOPOGRAPHIC MAP WITH O.S.D.F. DESIGN FEATURES

3.0 GENERAL ECOLOGICAL RESTORATION PLAN

The purpose of this section is to present the general plans for restoring specific habitats at the FEMP. This section also presents the factors that will be considered during the ecological restoration design of specific areas.

3.1 SITEWIDE RESTORATION CONSIDERATIONS

This section outlines other considerations that were factored into the establishment of the specific restoration projects and the final land use outlined in this plan in addition to the issues outlined in Section 2.0.

3.1.1 Soil Balance and Pre-FEMP Topography (i.e., Cut and Fill Maps)

Topographic maps for the site prior to the construction of the Fernald Plant have been utilized to construct a profile of the topography and drainage in the years prior to 1952. In designing the natural resource restoration projects, every effort will be made to re-establish original drainage patterns by restoring pre-site topography and elevations to the extent possible. The premise for this approach is that the site, over the long term, will tend to erode back to conditions that existed prior to construction of the FEMP. Therefore, reestablishing the "natural" drainage patterns should facilitate restoration projects (i.e., wetlands and open water) in the long term.

3.1.2 Sequence of Natural Resource Restoration Projects

The general approach for sequencing the projects outlined in the NRRP is to implement the near-term restoration projects starting in 1998, with approximately one project a year for the next eleven years. The long-term restoration projects will be implemented as soil remediation is completed and areas can be graded to support restoration. Specific schedules are provided on a project basis (to the extent they can be defined) in Section 4.0.

Sequencing in conjunction with remediation of individual excavation areas will require that some areas undergo interim restoration. Interim restoration involves grading to stabilize slopes and seeding with native grasses pursuant to guidelines established in the SEP. These actions are required when an area is excavated and certified clean, but cannot undergo final restoration until project activities are

completed, such as the possible need for borrow material within the area and sequencing with adjacent projects.

3.1.3 Available Watershed

The Water Availability Study (Addendum C) provides quantitative modeling results regarding the surface water routing involving four open water areas under post-remediation conditions at the FEMP. The modeling results indicate that four on-property open water areas can be established in the Former Production Area and its vicinity as a result of soil excavation activities.

Average water depths were determined by dividing the pond storage capacity by the surface water area. The average water depths in the four open water areas are 8.2, 10.5, 4.5, and 14.8 feet respectively. The acreage associated with the four open water areas under normal conditions at the minimum stage are 10, 12.5, 6.1, and 3.3 acres, respectively. This evaluation concludes that the postremediation topography could support the establishment of open water/wetland systems. The size and configuration of open water areas are not limited by this study and will be determined during natural resource restoration design.

3.1.4 Conceptual Restoration Plan for Paddys Run

Within certain reaches of the FEMP property, Paddys Run is characterized by extremely high banks and a stream bed that is deeply cut into the surrounding topography. These features primarily result from the natural geology and stream dynamics of Paddys Run, but may have been exacerbated by historic activities at the FEMP (i.e., stream relocation, dredge of materials). Consequently, the current floodplain of Paddys Run has been greatly reduced from its previous extent, and undissipated flow is carried downstream during storm events. This increased downstream flow works to further cut existing stream banks, causing accelerated loss of riparian habitat, and lowering the elevation of the stream bed.

To counter this process, U.S. Department of Energy, Fernald Field Office (DOE-FEMP) is committed to a long-term management and restoration strategy for the Paddys Run corridor. Essentially, this effort will involve determining the appropriate extent of Paddys Run floodplain and designing and implementing restoration projects to accommodate this required floodplain. Interim management strategies will also be established to ensure that these long-term restoration goals are considered when immediate erosion measures are required.

Adequate floodplain for Paddys Run will be determined through investigations of historic and present-day watershed conditions. The current dimensions, pattern, and profile of Paddys Run will be determined and used to characterize flow conditions for a one- to two-year storm event using standard watershed modeling procedures. This information will then be used to determine the floodplain needed to absorb the flows generated by these one- to two-year events. Flows from one- to two-year storm events are considered the "channel forming" flows because of their increased frequency over time when compared to larger, more powerful, but infrequent storm events (Leopold 1994, Rosgen 1996). Natural meander patterns will also be characterized for the on-property reach of Paddys Run. This information will be used to support specific restoration design decisions, as summarized below.

Specific restoration activities would include one or more of the following measures. First, Paddys Run floodplain may be re-established based on minor changes to postexcavation topography. The Waste Storage Area and the Southern Waste Units offer the best opportunities for this type of restoration. Next, the elevation of the Paddys Run stream bed may be raised by the placement of rocks in existing riffle areas. This action would not only add substrate to riffles but also increase settling in upstream pools. Additionally, revegetation plans could be designed to allow the natural formation of floodplain in some areas. This would be accomplished by permitting continued erosion to define the future boundaries of the Paddys Run stream bed and floodplain. In other words, some areas may be left alone, and intensive revegetation would not be conducted.

DOE-FEMP, with assistance from the Ohio EPA and the Ohio Department of Natural Resources (ODNR), will prepare a separate conceptual restoration plan that will present the methodology and findings of the Paddys Run floodplain modeling determinations and the specific restoration design recommendations. Detailed restoration designs for each excavation area affected will then incorporate the provisions set forth in both the NRRP and the Paddys Run Conceptual Restoration Plan (PRCRP). In addition, short-term management guidelines will be established to ensure that the long-term restoration goals of Paddys Run are considered when immediate erosion control measures are required. Also, bioengineering principles and techniques will be promoted whenever feasible. Thus the PRCRP will be developed as a tool for use by excavation area project managers when erosion control measures must be undertaken.

3.1.5 Final Land Use

O45 The projects outlined in the following sections will result in natural resource restoration for the final land use of the majority of the FEMP. Natural resource restoration will occur over approximately 850 acres of the FEMP. Excluded from restoration are the area committed to the OSDF, the areas utilized for the environmental projects agreed to in the 1997 OU4 Dispute Resolution Agreement and the area under consideration for potential economic development by the CRO. Figure 1-1 presents the most current version of the conceptual final land use. The primary focus of the restoration activities will be to establish a system of wetland and open water habitats with supporting woodlands and grasslands to support a diverse natural system. In addition, the Paddys Run corridor will be preserved and enhanced to further contribute to ecosystem diversity. Other areas such as the buffer zone for the OSDF will also support a natural habitat while providing an aesthetic buffer for the local community.

O49 Other potential aspects of the plan could include the following depending on public input and feasibility as determined through design:

- Provide a wetland system to passively treat stormwater runoff from the OSDF prior to its discharge off property.
- Provide an area for the reburial of Native American human remains as part of the final land use of the site.
- Provide access to the site through a series of walking/bike trails with interpretive signs.

This approach will provide the basis for future land use and allow DOE-FEMP to meet its NRT and regulatory responsibilities, while at the same time satisfying the future use recommendations of the Fernald Citizens Advisory Board (FCAB) and other stakeholders.

3.1.6 Soil Preparation

Specific ecological restoration designs will take into consideration the types of soil present when determining vegetation plans. In general, the restoration design will establish vegetation that would eventually occur naturally if left alone. For undisturbed areas, Hamilton and Butler County soil survey maps will be used as a preliminary guide [Soil Conservation Service (SCS) 1982a, 1982b]. Where

necessary, analysis may be conducted to determine the specific characteristics of the soil, such as moisture and organic content.

For excavated areas, the remaining subsoils may not be amenable to revegetation. The NRRP addresses nutrient deficient excavated areas by considering native prairie grasses and pioneer tree and shrub species that survive in nutrient-poor soil conditions. Nevertheless, soil amendments may be necessary. Research is being conducted on site to assist in determining the optimal amendment strategy for the restoration of native prairie grasses. If applicable, results of this effort will be used to guide soil preparation activities in excavated areas.

3.1.7 Use of Plants and Seeds and Invasive Plant Species Management

All plants and seeds used for Ecological Restoration at the FEMP will be native to southwest Ohio. To preserve regional genotypes, an effort will be made to obtain plants and seeds from local sources. However, because of the scope and scale of restoration projects planned at the FEMP, non-local seedlings and seeds may be needed. When feasible, restored areas may be interseeded with seeds collected on-property. Invasive species control will be incorporated into applicable NRRDPs.

Currently, an invasive plant species management plan is being developed for the Northern Woodlot. This plan will be used as a sitewide guide to develop invasive plant species management provisions within individual NRRDPs, as appropriate. Management efforts will focus on enhancing natural resource areas.

3.1.8 Long-Term Maintenance

Ecological restoration design will take into consideration the long-term maintenance requirements of a restored area. For instance, restored prairies that require periodic controlled burns will be located with appropriate buffers in place. Access to restoration areas must also be considered.

3.2 HABITAT-SPECIFIC RESTORATION PLANS

The majority of ecological restoration at the FEMP will consist of a combination of upland forest, riparian forest, tallgrass prairie/savanna and wetland/open water systems, as well as enhancement of existing habitats such as pine plantations. The individual restoration projects set forth in Section 4.0

specify each habitat that will be designed, and describe the area-specific factors that must be considered in the design. The descriptions below provide the basis for restoration of these specific habitats.

3.2.1 Upland Forest

Prior to settlement of the area, the land now occupied by the FEMP probably consisted of forest. The sitewide characterization report describes the FEMP as existing in a transition zone between the Oak-Hickory and Beech-Maple sections of the Eastern Deciduous Forest province (DOE 1993). Braun (1989) describes the area slightly differently, as a transition from Beech-Maple to Western Mesophytic forest. Regardless, these forests share many similar species, such as American beech (*Fagus grandifolia*), sugar maple (*Acer saccharinum*), tulip poplar (*Liriodendron tulipifera*), white ash (*Fraxinus americana*), northern red oak (*Quercus rubra*), Ohio buckeye (*Aesculus glabra*), and shagbark hickory (*Carya ovata*). Therefore, restoration of upland forests at the FEMP will focus on the establishment of this Beech-Maple, Oak-Hickory transition zone.

Specific planting plans will be detailed in individual NRRDPs. Each NRRDP will specify soil preparation, species mix, species density, planting instructions, cover, short-term maintenance, herbivore control, and monitoring. Other revegetation design methodologies may be used as well, depending on the specific needs identified in individual NRRDPs. Revegetation of each area will depend on a variety of factors, including soils topography, hydrology, existing vegetation availability, cost, and relation to other restoration projects. Most trees and shrubs will be selected from the tree and shrub guide established for the FEMP on Table 3-1. As stated in Section 2.1, considerations will be given to mimic natural successional processes. Pioneer tree species will be planted in disturbed areas, while late successional species will be used to enhance existing woodlots.

Table 3-1 has been established as a guide for generation of NRRDPs. The trees listed are all native to southwestern Ohio, as described by Braun (1989). The master list has been divided into general categories of upland and riparian trees and shrubs. However, site-specific conditions will dictate the species mix within each NRRDP. To assist in these decisions, supplemental information is included in Table 3-1. In addition to scientific and common names, the U.S. Fish and Wildlife Service wetland indicator status for Region 3 (which includes Ohio) is included for each species (Resource Management Group 1992). This information provides an indication of what trees and shrubs would be suitable in areas where wetland conditions exist. Also, the successional status of each species is provided. This

information will be used in determining species mixes for specific ecological restoration projects. Further information is included in the Comments section of Table 3-1.

3.2.2 Riparian Forest

The Paddys Run floodplain will be expanded as part of the long-term management plan for Paddys Run. Within these floodplain areas, the corridor of Paddys Run and the Storm Sewer Outfall Ditch will be expanded through revegetation as described above for upland forests. The trees species chosen from Table 3-1 are those that can withstand periodic inundation. Wetland indicator status will be used as a guide for specific planting designs. Typical species that will be planted in floodplain areas include eastern cottonwood (*Populus deltoides*), swamp white oak (*Quercus bicolor*), black willow (*Salix nigra*), American sycamore (*Platanus occidentalis*), and green ash (*Fraxinus pennsylvanica*). As with the upland forest revegetation, individual NRRDPs will establish planting plans based on a variety or site-specific factors.

3.2.3 Tallgrass Prairie/Savanna

The FEMP is generally located east of the range where tallgrass prairies and savannas are found [Society for Ecological Restoration (SER 1997)]. However, remnant wet meadow has appeared as part of a wetland restoration several miles west of the FEMP (Klein 1996). Also, since prairie grasses and forbs prefer nutrient-poor soils, they are potentially ideal for re-establishing vegetation in excavated areas. A tallgrass prairie restoration has been successfully completed on an interstate borrow pit outside of Dayton, Ohio (Geiger 1997).. This effort involved similar sub-soil conditions that will be present in several deep excavations at the FEMP. For these reasons, tallgrass prairie and savanna restoration will be undertaken at the FEMP, primarily in disturbed areas.

Prairie restoration will involve application of soil amendments (if determined necessary), seeding of grasses and forbs, and maintenance through mowing and/or controlled burns. Research is currently being conducted to determine the optimal use of soil amendments for prairie grass establishment. Results of the research and area-specific soil sampling will guide NRRDP specifications for each area.
O65 After required soil preparation, seeding of grasses will primarily be conducted with a Truax seed drill. Forbs will usually be interseeded into existing grasses a few years after the initial seeding. This is because the forbs tend to out compete grasses initially. Therefore, grasses will receive a two-year head start" free of competition from forbs. The planned grass mix for the FEMP consists of big bluestem

(*Andropogon gerardii*) at 3 pounds (lbs) per acre pure live seed (pls), little bluestem (*Schizachyrium scoparium*) at 2 lbs/acre pls, Indian grass (*Sorghastrum nutans*) at 2 lbs/acre pls, Canada wild rye (*Elymus canadensis*) at 2 lbs/acre pls, switch grass (*Panicum virgatum*) at ½ lb/acre pls, and sideoats grama (*Bouteloua curtipendula*) at ½ lb/acre pls. Additionally, a cover crop of live oats (*Avena sativa*) will be seeded at 20 lbs/acre pls. This mix is specified in the SEP as a permanent seed mix for areas undergoing interim restoration. Any deviations from this mix will be specified in individual NRRDPs. The forbs interseeded into established grasses will be those native to southwest Ohio as described by the Society for Ecological Restoration (SER 1997).

Where specified, savannas will be established by planting a sparse mix of bur oak (*Quercus macrocarpa*), along with white oak (*Quercus alba*) and shrubs such as gray dogwood (*Cornus racerosa*), hazelnut (*Corylus americana*), and smooth sumac (*Rhus glabra*) and seeding the area with the grass mix described above. Specific mixes and densities will be established in NRRDPs.

3.2.4 Wetlands/Open Water

Prior to the rise of agriculture in the region, much of the FEMP and surrounding area may have consisted of wetlands. Several areas of poorly drained soils are located on FEMP property (DOE 1993). High-quality forested wetlands are also located just west of the FEMP (Davis 1994). In addition, DOE has a responsibility to provide 15 acres of mitigated wetlands under Section 404 of the Clean Water Act, as described in more detail below. For these reasons, wetland mitigation will be pursued in appropriate areas of the FEMP. Some open water areas will also be established as a result of deep excavations within the Former Production Area. These areas will provide additional wildlife habitat.

Approximately 10 acres of jurisdictional wetlands have been or will be dredged or filled as a result of remedial activities at the FEMP. In June 1995, DOE met with U.S. Environmental Protection Agency (EPA), Ohio Environmental Protection Agency (OEPA), U.S. Fish and Wildlife Service (USFWS), and ODNR to discuss mitigation of the impacted wetlands. DOE agreed to mitigate wetlands at a 1.5 to 1 ratio, replacing 1.5 acres of wetlands for every one acre dredged or filled. DOE also agreed to implement the mitigation on property if possible. Because wetland design will be area-specific, conceptual design details are described in the area-specific descriptions (Sections 4.2 and 4.6).

In addition to the wetland mitigation process, upland and riparian forest revegetation in various areas could be designed to restore wet woods. Soil characteristics and hydrology will be considered when planting areas with wetland trees and shrubs. Detailed analyses will be conducted and presented in NRRDPs to determine specific planting schemes.

TABLE 3-1
MASTER LIST OF TREES AND SHRUBS THAT COULD BE USED IN NATURAL RESOURCE RESTORATION AT THE FEMP

Scientific Name	Common Name	Wetland Indicator Status(a)	Successional Status(b)	Notes
Upland Trees				
Acer rubrum	red maple	FAC	any	Survives in a wide variety of conditions. Can pioneer on disturbed sites.
Acer saccharum	sugar maple	FACU	climax	Shade tolerant - will occupy gaps in canopy. Most common in rich mesic woods. Flood intolerant.
Aesculus glabra	Ohio buckeye	FAC+	transitional	Prefers moist woods.
Carya cordiformus	bitternut hickory	FAC	traditional	Moderately shade tolerant - common in mesic settings and can survive a variety of conditions.
Carya ovata	shagbark hickory	FACU	climax	Intermediate shade tolerant - prefers lower elevations of upland slopes. Associated with *Quercus* sp.
Celtis occidentalis	hackberry	FAC-	any	Flood tolerant, drought tolerant
Fagus grandifolia	American beech	FACU	climax	shade tolerant - will grow faster in canopy openings
Fraxinus americana	white ash	FACU	pioneer	Seedlings shade tolerant - will occupy gaps in canopy. Prefers deep, well drained, moist soils.
Gledista triacanthos	honey locust	FAC	pioneer	Shade intolerant - Occupies degraded streams. Flood tolerant, drought tolerant. Tolerates low nitrogen conditions.
Gymnocladus dioica	Kentucky coffeetree	no record	transitional	Prefers open woods
Hamamelis virginiana	witch hazel	FACU	transitional	Shade tolerant - prefers mesic woods and bottomlands.
Juglans cinera	butternut	FACU+	any	Shade intolerant - prefers well drained sites such a slopes. Toxic to some vegetation.

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TABLE 3-1
MASTER LIST OF TREES AND SHRUBS THAT COULD BE USED IN NATURAL RESOURCE RESTORATION AT THE FEMP
(Cont'd)

Scientific Name	Common Name	Wetland Indicator Status(a)	Successional Status(b)	Notes
Juglans nigra	black walnut	FACU	any	shade intolerant - survives as single species occupying canopy openings. Prefers rich agricultural soil. Toxic to some vegetation.
juniperus virginiana	eastern redcedar	FACU	pioneer	occupies old fields and disturbed woods. Grows in both wet and dry conditions.
Liriodendron tulipifera	tulip poplar	FACU+	pioneer	Shade intolerant - occupies open sites and old fields. Prefers moist, deep, well drained loams.
Morus rubra	red mulberry	FAC-	transitional	Moderately shade tolerant - tolerates a wide range of conditions. Occupies pastures and field edges.
Prunus serotina	black cherry	FACU	transitional	Shade intolerant - rapid occupation and growth in canopy openings. Prefers mesic sites. Common in old fields.
Pyrus coronaria	crab apple	no record	transitional	Occupies old fields. Forms thickets.
Quercus alba	white oak	FACU	any	Shade intolerant - associated with *Quercus macrocarpa* in savannas.
Quercus coccinea	scarlet oak	no record	transitional	Shade intolerant - occupies gaps in canopy. Prefers xeric conditions.
Quercus imbricaria	shingle oak	FAC-	any	Occupies a wide variety of habitats.
Quercus macrocarpa	bur oak	FAC-	any	Moderately shade intolerant - ideal for savanna establishment in association with *Quercus alba*
Quercus muehlenbergii	chinkapin oak	NI	transitional	Intermediate shade tolerant - prefers forest margins. Associated with *Celtis occidentalis*, *Carya ovata*, *Quercus* sp.
Quercus prinus	chestnut oak	FACU-	transitional	Slow growing - prefers drier sites - intermediate shade tolerance
Quercus rubra	northern red oak	FACU	transitional	Intermediate shade tolerant - prefers rich mesic soils at the edge of floodplains.

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TABLE 3-1
MASTER LIST OF TREES AND SHRUBS THAT COULD BE USED IN NATURAL RESOURCE RESTORATION AT THE FEMP
(Cont'd)

Scientific Name	Common Name	Wetland Indicator Status(a)	Successional Status(b)	Notes
Quercus velutina	black oak	no record	transitional	Prefers dry slopes and woods.
Robinia pseudocacia	black locust	FACU-	pioneer	Shade intolerant - survives in nitrogen-poor soils. Prefers rich moist soils. Moderately flood tolerant.
Sassafras albidum	sassafras	FACU	any	Pioneers in old fields. Occupies canopy gaps, exists as an understory shrub. Prefers sandy loam in open woods. Intolerant of poor drainage
Upland Shrubs				
Asimina triloba	pawpaw	FAC	transitional	Moderately shade tolerant. Prefers deep, rich, damp, sandy or clayey soil, slopes and floodplains.
Carpinus caroliniana	ironwood	FAC	any	Prefers moist and mesophytic woods.
Celastrus scandens	climbing bittersweet	FACU*	any	Climbing vine.
Cercis canadensis	eastern redbud	FACU	transitional	Intermediate shade tolerant - increases in disturbed areas. Prefers alkaline soils. Associated with *Cornus florida*.
Cornus florida	flowering dogwood	FACU-	transitional	Shade tolerant - occupies old fields and canopy gaps. Grows in mesic woods, slopes, and floodplains.
Cornus racemosa	gray dogwood	no record	transitional	Intermediate shade tolerant - grows in fields, woodlands, riparian zones, and forest margins.
Corylus americana	hazel	FACU-	transitional	Shade tolerant. Occupies forest margins and hedgerows.
Crataegus crus-galli	cockspur hawthorn	FAC	any	Prefers alkaline soils.
Crataegus mollis	downy hawthorn	FACW-	any	Prefers alkaline soils.
Crataegus pruinosa	frosted hawthorn	no record	any	Prefers alkaline soils.

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TABLE 3-1
MASTER LIST OF TREES AND SHRUBS THAT COULD BE USED IN NATURAL RESOURCE RESTORATION AT THE FEMP
(Cont'd)

Scientific Name	Common Name	Wetland Indicator Status(a)	Successional Status(b)	Notes
Hydrangea arborescens	wild hydrangea	FACU-	any	Prefers rich, moist soil.
Ostrya virginiana	Eastern hophornbeam	FACU-	any	Tolerates a wide variety of conditions.
Physocarpus opulifolius	ninebark	FACW-	any	Prefers upland terraces of streams.
Rhus aromatica	fragrant sumac	no record	any	Occupies forest margins. Tolerates a wide range of conditions.
Rhus trilobata	smooth sumac	NI	any	Tolerates a wide variety of soils - grows well on depleted soils. Flood intolerant, drought tolerant.
Rosa carolina	Carolina rose	FACU-	any	Prefers drier open woods and prairies.
Rosa setigera	prairie rose	FACU+	any	Occupies open areas.
Rubus occidentalis	black raspberry	no record	any	Prefers mesic open woods.
Staphylea trifolia	bladdernut	FAC	any	Prefers shaded streambanks.
Symphoricarpos orbiculatus	corralberry	FACU	pioneer	Occupies disturbed dry pastureland and slopes.
Vaccinium staminium	common deerberry	FACU	transitional	Associated with pin oak in floodplains
Viburnum acerifolium	mapleleaf viburnum	UPL	transitional	Shade tolerant - occupies upland forests and hillsides. Tolerant of acid soils.
Viburnum dentatum	southern arrowood	FAC	any	Occupies a wide variety of habitats. Forms thickets.
Riparian Trees				
Acer negundo	boxelder	FACW-	any	moderate shade tolerant - prefers moist sites along lakes and streams, floodplains. Flood tolerant, drought tolerant.

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TABLE 3-1
MASTER LIST OF TREES AND SHRUBS THAT COULD BE USED IN NATURAL RESOURCE RESTORATION AT THE FEMP
(Cont'd)

Scientific Name	Common Name	Wetland Indicator Status(a)	Successional Status(b)	Notes
Acer rubrum	red maple	FAC	any	Survives in a wide variety of conditions. Can pioneer on disturbed sites.
Acer saccharinum	silver maple	FACW	transitional	Shade tolerant on good sites. Prefers bottomlands, river, lake edges. Follows *Populus deltoides* to form in disturbed sites.
Carya laciniosa	shellbark hickory	FACW	any	Prefers moist woods and floodplains
Fagus grandifolia	American beech	FACU	climax	Shade tolerant. Will grow faster in canopy openings
Fraxinus pennsylvanica	green ash	FACW	transitional	Shade intolerant. Prefers bottomlands. Follows *Populus deltoides*. Flood tolerant.
Nyssa sylvatica	blackgum	FAC	transitional	Shade tolerant. Occupies canopy openings. Tolerates a variety of conditions. Flood tolerant.
Platanas occidentalis	American sycamore	FACW	any	Shade intolerant. Pioneers disturbed sites, but persists through later stages. Prefers bottomlands, but will pioneer old fields. Flood tolerant.
Populus deltoides	eastern cottonwood	FAC+	pioneer	Shade intolerant. Pioneers floodplains. Tolerates a wide variety of soils. Flood tolerant.
Quercus bicolor	swamp white oak	FACW+	transitional	Moderately shade tolerant. Prefers bottomlands, wetlands. Replaces *Populus deltoides*.
Quercus palustris	pin oak	FACW	transitional	Shade intolerant. Flood tolerant in dormant season. Replaces *Populus deltoides*.
Salix nigra	black willow	OBL	pioneer	Shade intolerant. Occupies dense, even-aged stands. Prefers bottomlands and wetlands. Flood tolerant, drought intolerant.
Ulmus rubra	slippery elm	FAC	transitional	Shade tolerant. Prefers bottomlands, also found in upland areas. Moderately flood tolerant.

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TABLE 3-1
MASTER LIST OF TREES AND SHRUBS THAT COULD BE USED IN NATURAL RESOURCE RESTORATION AT THE FEMP
(Cont'd)

Scientific Name	Common Name	Wetland Indicator Status(a)	Successional Status(b)	Notes
Riparian Shrubs				
Cephalanthus occidentalis	common buttonbush	OBL	pioneer	Flood tolerant. Prefers periods of inundation. Prefers wetlands and bottomlands.
Cornus drummondii	rough-leaf dogwood	FAC	transitional	Prefers wet woods.
Euonymus atropurpureus	burning bush	FAC-	transitional	Prefers woods and sunny stream banks.
Hypericum spathulatum	shrubby St. John's wort	FACU	any	Occupies a wide variety of habitats.
Ilex verticillata	common winterberry	FACW+	transitional	Prefers wetlands and bottomlands.
Lindera benzoin	common spicebush	FACW-	transitional	Prefers wet woods.
Physocarpus opulifolius	ninebark	FACW-	any	Prefers upland terraces of streams.
Salix interior	sandbar willow	OBL	pioneer	Pioneers on stream deposits
Smilax rotundifolia	common greenbrier	FAC	any	Occupies thinned woodlands. Prefers acidic soils.
Sambucus canadensis	common elderberry	FACW-	any	Occupies a wide variety of habitats.
Smilax glauca	cat greenbrier	FACU	any	Vine that occupies clearings. Prefers acidic soils.

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TABLE 3-1
MASTER LIST OF TREES AND SHRUBS THAT COULD BE USED IN NATURAL RESOURCE RESTORATION AT THE FEMP
(Cont'd)

(a) From U.S. Fish and Wildlife Service Region 3 (Resource Management Group 1992). The key is as follows:

OBL	Obligate Wetland: occurs with estimated 99% probability in wetlands.
FACW	Facultative Wetland: estimated 67%-99% probability of occurrence in wetlands.
FAC	Facultative: equally likely to occur in wetlands and nonwetlands (34%-66% probability).
FACU	Facultative Upland: 67%-99% probability in nonwetlands, 1%-33% in wetlands.
UPL	Obligate Wetland: >99% probability in nonwetlands.
NI	No Indicator: insufficient information available to determine an indicator status.
+/-	Indicates a frequency toward higher (+) or lower (-) frequency of occurrence within a category.
*	Indicates tentative assignments based on limited information.

(b) The successional status designations and corresponding notes are intended to provide the reader with an idea of what species will be used in different ecological restoration design scenarios. Information obtained from Braun (1989) and the U.S. Forest Service (1998).

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4.0 NATURAL RESOURCE RESTORATION PROJECTS

This section describes the restoration projects proposed for the FEMP. These descriptions provide conceptual components required for each project. Once the design process is implemented, NRRDPs may be revised. Figures 4-1 and 4-8 show the general location of individual restoration projects in relation to the site. The following restoration projects are discussed below in the sequence of implementation.

4.1 AESTHETIC BARRIER ALONG WILLEY ROAD

This restoration project involves establishment of an aesthetic barrier using densely planted trees to provide a visual buffer between Willey Road and FEMP construction activities (Figure 4-2). Effective visual screening will be achieved through dense planting of evergreens and deciduous trees. The aesthetic barrier will be typical of rural roadsides in agricultural landscapes. This area would be part of restoration required to compensate for impacts to grasslands. The restoration will encompass slightly more than one acre of land.

4.1.1 Functional Objectives for Aesthetic Barrier

The functional objectives for the aesthetic barrier are immediate visual screening, and aesthetic appeal. To provide immediate visual screening, two alternating rows of evergreens will be planted along the back line of the barrier. The barrier will consist of evergreens (Eastern white pine, Eastern red cedar, Norway spruce) and deciduous trees (e.g., red maple, green ash, American crabapple).

Aesthetic appeal will be provided by using spring flowering trees (e.g., American crabapple) and trees with vivid yellow and red fall foliage (e.g., red maple). By designing the barrier to include a mixture of evergreens and deciduous trees, the barrier will provide quality habitat to wildlife species.

4.1.2 Design Considerations for the Aesthetic Barrier

To provide immediate visual screening, two alternating rows of 1.5-inch caliper nursery stock balled and burlapped evergreens will be planted on 10-foot centers along the back line of the barrier with two additional rows of deciduous trees on staggered 10-foot centers. The barrier will be approximately 50 feet wide at planting and 55 feet wide at maturity, and will consist of evergreens (eastern white pine,

eastern red cedar, Norway spruce) and deciduous trees (e.g., red maple, green ash, and American crabapple).

A key consideration in the design of visual buffers is the safety hazard which can be created by restricting visibility or creating additional deer habitat too close to the road. These conditions will be avoided by setting the barrier back at least 50 feet from the edge of the roadway. This project is proposed for implementation in the Fall of 1998.

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4.2 WETLAND MITIGATION - PHASE I

This restoration project would be conducted in Area 1, Phase I, which is a certified clean area. Approximately 10 acres of jurisdictional wetlands have been dredged or filled as a result of remedial activities at the FEMP. As stated in Section 3.2.4, DOE negotiated a 1.5:1 wetland mitigation ratio with regulatory agencies (EPA, OEPA, ODNR, USFWS). Phase I wetland mitigation is being performed to address a portion of the required 15 mitigated acres of wetlands.

4.2.1 Functional Objectives for Wetland Mitigation - Phase I

The functional objectives for wetland mitigation are to provide permanent replacement for a portion of 10 acres of impacted wetlands at the FEMP and to provide wildlife habitat. Wetland mitigation performed in Area 1, Phase I will consist of native plant vegetation of sufficient species diversity to provide a variety of food and habitat for various species of wildlife. Phase I wetland mitigation is expected to produce between six and eight areas of constructed wetlands.

4.2.2 Design Considerations for Wetland Mitigation - Phase I

Design considerations will consist of grading, hydrology, planting, wildlife features and erosion control. Grading will be performed using naturally occurring curves and shapes to provide a natural appearance and will consider specifications and details related to topsoil requirements and placement.

The hydrologic regime of the mitigation site and the surrounding landscape will be assessed to efficiently use available water sources to maximize wetland conditions. If water control structures are to be used they will be designed and specified. Open water areas will have specified depths designed for specific biological needs and choices of habitat.

The planting of vegetation will include species native to the existing and/or nearby counties. Standard vegetation literature and local site descriptions will be used as the basis for selections of plant species and plant community cover types.

Types of wildlife features such as species of birds, mammals, reptiles, amphibians and their associated habitat requirements will be specified as needed. To the extent possible, herbaceous and woody plant species will be selected and specified based on their ability to provide food or cover for selected wildlife species.

Standard erosion control practices will be employed during wetland construction. To the extent possible, natural materials (coconut logs, coconut fiber matting) will be used to control erosion as part of the planting specifications. All sedimentation and erosion control measures will be consistent with the stormwater pollution prevention program.

4.3 AREA 8, PHASE II REVEGETATION

O59 This demonstration project involves the creation of native forest cover in the grazed pasture located in the northwestern corner of the FEMP, west of Paddys Run (Figure 4-3). The purpose of this project is to provide an area of finished reforestation early in the overall restoration process that will effectively demonstrate to the public the feasibility and advantages of restoring natural habitats. The demonstration forest will provide upland and riparian habitat, and provide ecotones for many forms of wildlife. The grazing lease in this area will be terminated, as part of the continued phase-out of grazing lease agreements at the FEMP.

4.3.1 Functional Objectives for Area 8, Phase II Revegetation

This forested area will be one of the first to be revegetated and will serve as a demonstration project for reforestation. The functional objective is to expand a native ecosystem within southwest Ohio, provide habitat, serve as a buffer, and provide aesthetic appeal. This project will consist of two forest types, upland and riparian forest. The upland forest would be located along a portion of the north property boundary and the west property boundary, extending southward to the rail spur. The riparian forest would extend along the existing riparian corridor of the west bank of Paddys Run from the northern property line southward to the rail spur. This project will be part of the required restoration for

impacts to the Paddys Run Corridor. It will consist of approximately 20 acres of restored vegetative community.

4.3.2 Design Considerations for Area 8, Phase II Revegetation

The upland and riparian forest will be planted in a random patch design toward the goal of a target density of vegetation within a specified area. The target density will be typical of the local area. This methodology will be implemented within other restoration project areas where applicable.

The upland forest will be typical of a midwestern upland successional forest, consisting of a canopy and shrub layer by randomly planting hardwood trees and shrubs. Within Area 8, Phase II, a large number of native trees already exist. The NRRDP will take this existing vegetation into consideration when designing the planting plan for Area 8, Phase II.

The riparian forest will be typical of a plant community found in somewhat poorly drained soils, consisting of a canopy and shrub layer of plant materials which have root systems that are tolerant of prolonged moisture. Sections 3.2.1 and 3.2.2 provide characteristics of upland and riparian forest.

O59 A phase-out of grazing lease agreements has been negotiated with the lessee. This schedule calls for the cessation of grazing in Area 8, Phase II in 1999. The lease for Area 1, Phase III will be terminated in 2001. For Area 8, Phase III, grazing will continue until 2002.

4.4 AREA 2, PHASE I REVEGETATION

The remediation of Area 2, Phase I will result in a significant change in the topography of this area. The current Inactive Flyash Pile and Active Flyash Pile will be removed, causing in a decrease of the existing elevation. Because this area is adjacent to Paddys Run, the proposed restoration would involve revegetating remediated areas in a manner that will expand the riparian corridor along Paddys Run and incorporate provisions of the long term management plan for Paddys Run. The sediment ponds that are currently proposed for use during remediation may be relined to control sediment loading to Paddys Run (Figure 4-4).

A portion of this project will constitute the required restoration for impacts to the Southern Pines and waste units. The completed project will encompass approximately 20 acres of restored vegetative

community. The remediation of Area 2, Phase I is expected to be completed in the year 2000. Therefore, revegetation efforts will be targeted for implementation in the Spring of 2001. However, coordination with several other projects may delay implementation for several years. For instance, the existing sediment basins may be left in place for several years until future uses can be decided.

4.4.1 Functional Objectives for Area 2, Phase I Revegetation

The functional objectives for Area 2, Phase I are to incorporate Paddys Run Stream restoration, if necessary, and to expand the riparian corridor. Enhancement of the riparian corridor would provide a native vegetative community, terrestrial wildlife habitat, increased water quality, and reduced erosion. In low-order streams such as Paddys Run, riparian vegetation provides shading that reduces water temperature, discourages eutrophication, and provides organic material in the form of detritus, which is important for the health of the stream.

Pursuant to the long-term management plan for Paddys Run, restoration of Area 2, Phase I could serve to increase the Paddys Run floodplain, thereby absorbing surface water flow stress during typical storm events. If feasible, the lower elevation areas of Area 2, Phase I, such as the sediment basins, could be converted into floodplain habitat, with water tolerant plant species that can withstand periods of innundation.

Higher elevation areas will be restored to an upland forest and tied into existing adjacent vegetation. This effort will not meet the ecological restoration goals of restoring native vegetative communities and promoting wildlife habitat.

4.4.2 Design Considerations for Area 2, Phase I Revegetation

O56 Lower elevations of A2PI will be restored to riparian forest. Since most of Area 2, Phase I will be excavated, topsoiling or some other amendment may be necessary. An additional consideration involves securing access to a series of groundwater injection and extraction wells that will be installed as part of the Aquifer Restoration Project. Also, plans may be revised if the South Field contingency borrow area is needed. The NRRDP will include the specific requirements for addressing restoration of the contingency borrow area. Until a final decision is made, Area 2, Phase I will be seeded with native grasses pursuant to the guidelines set forth in Appendix F of the SEP (DOE 1998). Revegetation of upland and riparian areas will be conducted pursuant to Section 3.2.1 and 3.2.2.

DOE 4.5 ENHANCEMENT OF EXPANDED AREA 1, PHASE I WOODLOTS

This restoration project involves the enhancement of the Northern Pine Plantation by interplanting deciduous trees and shrubs among thinned pines (Figure 4-5). The existing stand of deciduous trees in the northern portion of Area 1 would remain unchanged. Deciduous planting sites would be formed within the blocks of white pines (*Pinus strobus*) by girdling and/or removing individual pines, while the Austrian pine (*Pinus nigra*) would be cleared. Upland forest species will be interplanted among the pines. Non-native and/or invasive vegetation (e.g., multiflora rose, honeysuckle spp., wild grape) will be controlled pursuant to the invasive species management plan. In addition, openings will be made to diversify habitat and allow brush piles and snags to be created in the Area 1, Phase I woodlots. Openings will be enhanced with brush piles using cut trees.

O56 Some areas of the Area 1, Phase I woodlots will be subjected to construction activity and related impacts since the area is adjacent to the OSDF. Therefore, the near-term activities discussed above will improve the survival of the remaining stand of trees. This project, in part, will constitute the required restoration for impacts to the northern woodlots. The completed project will encompass approximately 49 acres of restored vegetative community.

4.5.1 Functional Objectives for Expanded Area 1, Phase I Woodlots

The functional objectives are the establishment of deciduous forest communities and to provide wildlife habitat. Forest communities will be established by interplanting the pine plantation into an upland forest association, and will transition into the existing upland forest to the north. Plant species selected for planting among the pines will be typical of gently sloping areas with deep, rich, mesic soils. Plant species selected for the transition portion will be typical of drier slopes and ridges.

Wildlife habitat will be provided for interior forest species upon maturation. Prior to maturation of the proposed forest communities, the mosaic of existing forest cover combined with patched plantings of herbaceous vegetation and tree seedlings will provide good habitat for edge-dwelling forest wildlife.

4.5.2 Design Considerations for Expanded Area 1, Phase I Woodlots

O57 The interplanting of upland forest into the pine plantation will require selective thinning of the existing
O56 rows of white pines and clearing of the Austrian pines to promote pine canopy openings for the planting of hardwoods. After the pines have been cleared and thinned, the openings in the northern portion of

the area will be enhanced with upland forest plantings that promote transition to the existing deciduous woodlot. In the middle and southern portions of Area 1, thinned and cleared rows of pines would also be enhanced with upland forest plantings typical of mesic soils. Trees and shrubs more tolerant of filtered shade would be planted in areas where dense stands of pines will be left. Follow-up observations will be made regarding survival of planted vegetation. If survival rates are low, then additional white pines would be selectively thinned as necessary to allow more sunlight and new seedlings of the same species would be planted. Section 3.2.1 provides more detail regarding upland revegetation. The Area 1, Phase I woodlots will be enhanced after remedial action certification for the area is complete in 1998 as funding becomes available.

4.6 ENHANCEMENT AND MANAGEMENT OF AREA 1, PHASE III WOODLOT/WETLAND MITIGATION PHASE II

O59 This restoration project involves the enhancement and expansion of a large woodland, which will provide habitat diversity (Figure 4-6). The improvements to the Area 1, Phase III woodlot will be implemented in the following sequence. First, the grazing lease will be terminated, as part of the continued phase-out of grazing lease agreements at the FEMP. The lessee will be notified of the schedule for lease termination. Areas west of Paddys Run will be available for grazing for one year after the termination.

A comprehensive revegetation program will be implemented in Spring 2002 and involve the connection of fragmented woodlots with native deciduous tree species. Most of the upland areas already support deciduous forest. The existing forest cover will be preserved, with the larger gaps being filled by planting tree seedlings as necessary and allowing natural succession to proceed toward climax forest. In addition, an invasive plant species management program will be implemented as described in Section 3.1.7.

A portion of this project, will constitute the required restoration for impacts to the northern woodlots. Part of this project will contribute to the required restoration of the grasslands and the Great Miami River. Once completed, the restored Area 1, Phase III will encompass approximately 100 acres of restored vegetative communities.

As stated in Section 3.2.4, DOE agreed to mitigate wetlands at a 1.5 to 1 ratio, replacing 1.5 acres of wetlands for every one acre dredged or filled. DOE also agreed to implement the mitigation on property if possible. To meet those two commitments, DOE has proposed the expansion of the northern forested wetland (Area 1, Phase III), if feasible (Figure 4-7). The 1996 watershed study indicated that some wetland expansion is possible, contributing to a portion of the required wetland mitigation, upon agreement by the agencies. DOE will initiate the design process for expansion of the northern forested wetland as part of on-property wetland mitigation with the goal of field implementation by Spring 2003.

Wetland mitigation in Area 1, Phase III can only be implemented after the area is certified, and the entire area must be certified to accommodate drainage of the watershed into the wetlands. Certification scheduling of Area 1, Phase III will need to be accelerated to accommodate wetland mitigation.

4.6.1 Functional Objectives for Area 1, Phase III Woodlot/Wetland Mitigation Phase II

Expansion of existing successional forest will meet the goals of restoring native vegetative communities and promoting wildlife habitat. The enhanced forest cover will provide a significant block of closed canopy native forest to provide suitable habitat for interior forest dwelling wildlife.

The functional objectives for wetland mitigation are to contribute toward meeting the mitigation ratio and to provide wildlife habitat. The wetland mitigation ratio of 1.5:1 will be met if 15 acres of somewhat poorly drained soils can be formed within Area 1, Phase III. The temporary presence of a haul road through this area will reduce the amount of acreage available for near-term wetland mitigation. Upon removal of this haul road, more acreage would be available in this area for future implementation of wetland mitigation.

The proposed area for wetland mitigation is located south and adjacent to the Northern Woodlot which contains a contiguous and diverse mosaic of forest cover which provides good habitat for forest-interior dwelling wildlife. Wetland mitigation performed south of the Northern Woodlot may consist of a palustrine forested, broad-leaved deciduous wetland, which would provide additional habitat for interior forest dwelling species.

4.6.2 Design Considerations for Area 1, Phase III Woodlot/Wetland Mitigation Phase II

The termination of grazing is required to facilitate the progress of natural succession. Gaps in forest cover will be identified and planted using upland tree and shrub seedlings. Considerations will be given to specific conditions, such as soil moisture and existing vegetation, when selecting trees and shrub species. Section 3.2.1 provides more detail regarding upland forest revegetation.

Existing areas of hardwood forest would be inspected for shrub development. In areas with little or no shrub development under the tree canopy, typical upland shrubs could be randomly planted. These shrubs are capable of growing in filtered shade. An invasive plant species management plan (Section 3.1.7) will be implemented to ensure survival of planted vegetation.

Soils in the existing wetlands are mapped in the Ragsdale and Fincastle soil series and soils in the proposed wetland mitigation area are mapped in the Fincastle and Xenia soil series (SCS 1982a). The Ragsdale, Fincastle, and Xenia soils represent a catena of soil series that are of similar mineralogy but have different drainage classifications. The Ragsdale series consists of very poorly drained soils typically found in depressional areas and shallow basins. The Fincastle series consists of somewhat poorly drained soils, often in intermediate landscape positions between Ragsdale and Xenia soils. The Xenia series consists of moderately well drained soils, often found upslope of Fincastle soils. A detailed analysis of the soil and hydrological conditions in this area would be required to determine the suitability of wetland formation.

The successful establishment of wetland soils will involve ensuring the bottom of the wetland area contains impermeable material. Most of the proposed area for wetland mitigation is mapped as containing Fincastle soils with 0-2 percent slopes, which indicates these soils experience brief seasonal periods of poor drainage. The conversion of areas containing Fincastle soils may only require shallow surface excavation (4-6 inches) or it may be possible to form wetland conditions by compacting the soils without excavating. Liners could also be utilized as determined appropriate. During excavation, silt fences would be established to separate the mitigation area from existing wetlands to prevent sediment deposition into the new wetlands until vegetation is established. Soil from the A-horizon will be stockpiled on nearby uplands to topsoil the new wetlands after excavation is complete. It may be necessary to overexcavate by 4-6 inches to provide adequate volume for topsoil.

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Topsoiling involves the manipulation of the surface soil following excavation to form a suitable medium for plant establishment. In natural soils, the upper soil layer (A-horizon) is typically comprised of a surface layer of friable, loamy, dark colored soil underlain by a layer of similar material which is light yellow or orange. The A-horizon is generally 8-12 inches deep in both Fincastle and Xenia soils. Underlying the A-horizon is the B-horizon, which is mineral soil that is more dense and of greater concentration of aluminum and iron.

O61 The best source of available topsoil for this wetland mitigation project would be from the stripped topsoil of the wetland mitigation area, if this soil is certified as clean. Such topsoil would contain a bank of native wetland plant propagules (seeds and rhizome fragments), along with native mycorrhizal fungi, which are symbiotic soil fungi essential to the growth of many plants. If necessary, the applied stockpile soil will be inoculated with mycorrhizal fungi to ensure successful plant growth response. Although the propagule bank will be derived from uplands, many of the plants typical of low lying uplands are also typical of seasonally saturated wetlands. Propagules capable of establishment in the wetlands will survive while the others will perish. If the common reed (*Phragmites australis*), an invasive weed of wetlands and low-lying areas, is present in the stripped topsoil, then off-site sources, such as nurseries, may have to be considered for topsoil.

The mitigated wetlands will initially support woody seedlings amid a cover of emergent herbs typical of wet meadows. Revegetation will involve stabilizing the exposed wetland soils with a seed mix of native wetland grasses, sedges, and forbs, followed by the planting of woody wetland tree and shrub seedlings. The species composition of the herbaceous layer will change over time due to natural succession and will eventually be shaded out by the growth of trees and shrubs.

A dense herbaceous cover would be rapidly established to prevent erosion of exposed soils and sedimentation from existing wetlands. A seed mix consisting of species which are indigenous to wet meadow habitats and provide value to wildlife would be intermixed and broadcast. The seed mix would consist of rice cutgrass (*Leersia oryzoides*), prairie cordgrass (*Spartina pectinata*), woolgrass (*Scirpus cyperinus*), softstem bulrush (*Scirpus validus*), rattlesnake mannagrass (*Glyceria canadensis*), lake sedge (*Carex lacustris*), and redtop (*Brunnichia cirrhosa*). This seed mix is commercially available and is recognized for establishing a dense cover within a moderate time frame. Woody tree

and shrub species would then be randomly planted with the intent to establish forest cover. These species would be typical of seasonally saturated wetland forests and well drained riparian uplands.

4.7 RE-ESTABLISHMENT OF THE CORRIDOR EAST OF PADDYS RUN

The corridor east of Paddys Run is located in Area 2, Phase II (Figure 4-9). The Paddys Run riparian corridor will be restored pursuant to the long term management plan for Paddys Run, as described in Section 2.3.4. The appropriate amount of floodplain will be established along Paddys Run to account for a one-year storm event. Excavated areas will be utilized to the extent possible. Additional grading and clearing of existing vegetation may be necessary to establish the required floodplain. Once floodplain elevations are established, revegetation would be conducted pursuant to the guidelines established in Sections 3.2.1 and 3.2.2.

The Southern Pine Plantation will be converted into an upland forest by clearing of the Austrian pines and thinning the white pines to promote pine canopy openings for the planting of hardwoods, as outlined in Section 4.5.2.

4.7.1 Functional Objectives for the Corridor East of Paddys Run

Restoration of floodplain and expansion of the riparian corridor meets the Paddys Run restoration and native vegetation goals established in Section 2.1. By expanding the floodplain of Paddys Run, erosional stress is relieved on existing cut banks and natural meander patterns would develop. These meanders increase pool and riffle habitat within Paddys Run, thereby increasing habitat quality for aquatic species.

Floodplain revegetation will promote habitats typical of southwest Ohio. This meets the secondary goal of enhancing wildlife habitat, as a contiguous corridor will be established along the length of Paddys Run.

This project will compensate for impacts to the Paddys Run corridor and the Great Miami Aquifer. Restoration of the Paddys Run corridor will result in protection of an important recharge area for the Great Miami Aquifer. Once completed, the ecological restoration of the corridor east of Paddys Run will encompass approximately 77 acres of restored vegetative communities.

4.7.2 Design Considerations for the Corridor East of Paddys Run

The area of floodplain required will be determined through the investigations described in Section 2.3.4. Floodplain establishment must be coordinated with planned excavations to the extent possible.

The restoration design will seek to minimize earth moving, but some regrading will be required. These efforts will be coordinated with excavation and certification activities. It may be necessary for some areas to remain in interim restoration status until adjacent excavation areas are available for final restoration. In these situations the area would be graded and seeded for interim restoration pursuant to the guidelines established in the SEP. Excavated areas that are to be revegetated may require the addition of topsoil or some other amendment to increase organic matter in the existing soil. Soil amendments will be minimized, since periodic flooding will provide organic matter into the soil. Also, the vegetation to be established will consist of pioneer species that naturally root in poor soils. The specific plant species used will also be tolerant of periodic inundation. Section 3.2.2 provides further detail regarding the selection of plant species for floodplain areas. In areas outside of floodplain a separate upland forest would be established in accordance with Section 3.2.1.

4.8 EXPANSION OF THE CORRIDOR WEST OF PADDYS RUN

Expansion of the corridor west of Paddys Run will occur in Area 8 (Figure 4-10). This project is similar in scope to the eastern corridor expansion described above, with the exception of a few additional considerations. Area 8 is a perimeter area addressed under Appendix E in the SEP, and no excavation is expected. Any expansion of floodplain west of Paddys Run would require extensive regrading. Also, portions of Area 8 will be utilized for other activities. In Area 8, Phase I, several environmental projects will be conducted. Just north of Area 8, Phase I is Area 8, Phase III, where prehistoric Native American remains may be reinterred as the result of an agreement with several Native American Tribes and organizations. The coordination of these activities into ecological restoration planning is described in more detail below.

4.8.1 Functional Objectives for the Corridor West of Paddys Run

The functional objectives for this project are similar to those for the corridor east of Paddys Run. In addition, the design will integrate the components of the environmental projects and the Native American reburial into the overall restoration.

4.8.2 Design Considerations for the Corridor West of Paddys Run

The floodplain and revegetation considerations for the western corridor are similar to those for the eastern corridor. Since the environmental projects involve the establishment of native vegetation communities, adjacent revegetation efforts will not require major modification. For the Native American reburial area, the restoration is conceptually planned as a tallgrass savanna. The Native American groups have indicated a preference for this type of habitat, with no development. Therefore, revegetation of this area will be conducted in accordance with Section 3.2.3. Adjacent upland forest revegetation will be modified to transition into the tallgrass savanna.

4.9 AREA 1, PHASE II BORROW AREA AND AREA 2, PHASE III

Excavation of the Area 1, Phase II borrow area will be used to form a wetland system, with upgradient areas revegetated as a tallgrass prairie transitioning through a tallgrass savanna to an upland forest (Figure 4-11). Area 2, Phase III restoration will involve the expansion of upland forest to the border of the potential economic development area (Figure 4-11).

4.9.1 Functional Objectives for Area 1, Phase II Borrow Area and Area 2, Phase III

This restoration project will meet ecological restoration goals by restoring native vegetative communities and protecting wildlife habitat. Wildlife habitat will be provided by establishing a variety of ecosystems and edge habitat. Wetland construction may also be used to partially fulfill regulatory wetland mitigation requirements. This restoration project will provide compensation for impacts to grasslands. Once completed, the restoration of Area 1, Phase II and Area 2, Phase III will encompass approximately 139 acres of restored vegetative communities.

4.9.2 Design Considerations for Area 1, Phase II Borrow Area and Area 2, Phase III

All habitats will be restored pursuant to the guidelines in Section 3.0 for the wetlands/open water, uplands, and tallgrass prairie/savanna. Restoration grading must be designed to maximize the collection of water from upgradient areas. The extent of wetland to be constructed will depend on the

amount of available surface water drainage. Soils and hydrology will be assessed as part of wetland design.

Wetlands generally require gradual shoreline slopes of 6:1 or flatter to a depth of 1 to 3 feet. The vegetation of seasonally inundated wetlands would consist of vegetation typical of pond edge habitats and tolerant of regular to permanent inundation up to 1 foot. Shallow open water areas would consist of nonpersistent and noninvasive plant species which are indigenous to southwestern Ohio in shallow open waters 3 feet in depth. These plant species include a mixture of species that produce submerged growth, emergent growth, and floating leaves which will maximize habitat diversity. Seedlings of floating and submerged species could be planted in equal proportions on approximately 3-foot centers in each open water area.

Possible impacts due to increased human activity must be taken into consideration during revegetation design of boundary areas, including the 23-acre potential economic development area. A selection of hardy, tolerant tree species may be planted along the edges. All revegetation efforts will be conducted pursuant to Sections 3.2.1 and 3.2.3.

4.10 FORMER PRODUCTION AREA RESTORATION

Restoration of the Former Production Area will utilize the postexcavation topography to establish a series of open water/wetland systems surrounded by tallgrass prairie. A transition to upland forest and connection with the expanded riparian corridor will occur in the west portion of the Former Production Area (Figure 1-1).

4.10.1 Functional Objectives for Former Production Area Restoration

The plan for restoring the Former Production Area depends on the postexcavation condition of the area. After remedial activities have been completed, the Former Production Area will consist of several deep excavations and areas of exposed subsoil (Figure 2-1). The postexcavation topography could be converted to open water and/or wetland habitat to meet the goal of providing wildlife habitat. This approach will minimize the amount of backfill and regrading, resulting in a considerable cost savings. Prairie revegetation will stabilize the exposed soil.

Restoration of the Former Production Area will compensate for impacts to grassland and the Great Miami Aquifer. Since this area contributes to the Paddys Run watershed, restoration activities will provide protection of an aquifer recharge zone. Once completed, the restored Former Production Area will encompass approximately 197 acres of restored wildlife habitat.

4.10.2 Design Considerations for Former Production Area Restoration

This project involves formation of wetlands and possibly open waters and as such will require an assessment to determine the type of aquatic habitats. A water availability study has been conducted and is presented in Addendum C. This study shows that the formation of open water and/or wetlands is feasible. However, further investigation will be required once detailed design is initiated. Also, soil types will be assessed to characterize the soil profile underlying the proposed final grade. The properties of these soils will be examined to support the design of a topsoil and soil amendment program. Specific sources of suitable topsoil or other amendments will be identified before the design is finalized.

The final grade will be required to simulate the natural conditions necessary to form the tallgrass prairie-wet meadow complex. Standards for the reclamation of coal strip mines include restoring the mine headwall (the upper slope separating the mine from intact upland soils) to a slope not exceeding 3:1, and other slopes within the mine to less than 5:1. The Former Production and Waste Pit areas may be more representative of conditions requiring a 5:1 slope. The 5:1 slope would represent an upper limit on steepness, with an emphasis on the formation of gently undulating topography where possible. Gentler slopes will facilitate revegetation, reduce the likelihood of gully erosion, and be more compatible with the surrounding landscape. The finished grade would direct surface runoff into distinct subwatersheds, which ultimately would drain into Paddys Run. The lowest lands of each subwatershed would contain a sequence of shallow depressions connected by a channel. The downstream end of each depression will be slightly bermed to induce wetland conditions. Linear swales will be formed to allow runoff within the swales to naturally carve the channels.

O65 Areas surrounding open water would be restored primarily to a tallgrass prairie. The tallgrass prairie may consist of a seed mix which contains Indian grass, big bluestem, little bluestem, side-oats gramma, and switchgrass. The seed mix would contain 2 pounds (lbs) per acre pure live seed (pls) Indian grass,

2 lbs/acre pls big bluestem, 1 lb/acre pls little bluestem, 1 lb/acre pls side-oats gramma, and 0.5 lb/acre switchgrass (Holtzman1997).

If hydrological conditions permit, certain depressions may contain a transition from shallow open water to seasonally inundated wetlands. The vegetation of seasonally inundated wetlands would consist of vegetation typical of pond edge habitats and tolerant of regular to permanent inundation up to 1 foot.

Nonpersistent plant species selected would be noninvasive plant species which are indigenous to southwestern Ohio in shallow open waters 3 feet in depth. These plant species include a mixture of species that produce submerged growth, emergent growth, and floating leaves which will maximize habitat diversity.

The tallgrass prairie and upland forest restoration will be conducted in accordance with Sections 3.2.1 and 3.2.3. Although prairie grasses and forbs are suited for the poor soil conditions after excavation, additional amendments may be needed to optimize growth. On-site research as part of the Environmental Projects will provide further information as to the type of amendment providing optimal plant growth.

Portions of the Former Production Area may undergo interim restoration, since the area consists of several excavation areas. If interim restoration is required, it will be conducted in accordance with the SEP.

4.11 WASTE STORAGE AREA RESTORATION

The Waste Storage Area will be restored similar to the corridor east of Paddys Run (Section 4.7). The results of the Paddys Run floodplain modeling will determine the extent of riparian habitat that will be established. The riparian habitat will transition into an upland forest.

4.11.1 Functional Objectives for Waste Storage Area Restoration

The function objectives for the Waste Storage Restoration Area are similar to those established for the corridor east of Paddys Run listed in Section 4.7.1. Floodplain restoration will meet the goals of native vegetation, Paddys Run Restoration, and Wildlife Habitat. Once completed, the restoration of the Waste Storage Area will encompass approximately 72 acres of restored vegetative communities.

4.11.2 Design Considerations for Waste Storage Area Restoration

Design consideration for the Waste Storage Restoration Area are similar to those established for the corridor east of Paddys Run listed in Section 4.7.2.

4.12 OSDF PERIMETER RESTORATION

The public has requested that a permanent buffer be established around the OSDF to lessen visual impact of the facility. The buffer will be established with appropriate topography and vegetation to function as a wooded corridor. Other possible features of this project include establishing areas of native grasses and providing nest boxes for wildlife species. This project will compensate for the required restoration for impacts to grasslands. Once completed, the OSDF buffer will encompass approximately 110 acres of wildlife habitat.

4.12.1 Functional Objectives for OSDF Perimeter Restoration

The functional objectives are to provide visual screening, edge habitat, and aesthetic appeal. The OSDF visual buffer will lessen the visual impact of the OSDF to the surrounding landscape. This buffer will not be able to completely obscure the 50-foot plus high relief which will comprise the OSDF, but the buffer will appear as a natural dense strip of woody vegetation which will soften the appearance of the mound. Selection of plant material will emphasize the use of evergreens and native deciduous trees.

4.12.2 Design Considerations for the OSDF Perimeter Restoration

Typical upland tree species will be those described in Section 3.2.1. The barrier must accommodate for OSDF stormwater drainage, monitoring wells, and access. These items will be considered during detailed design.

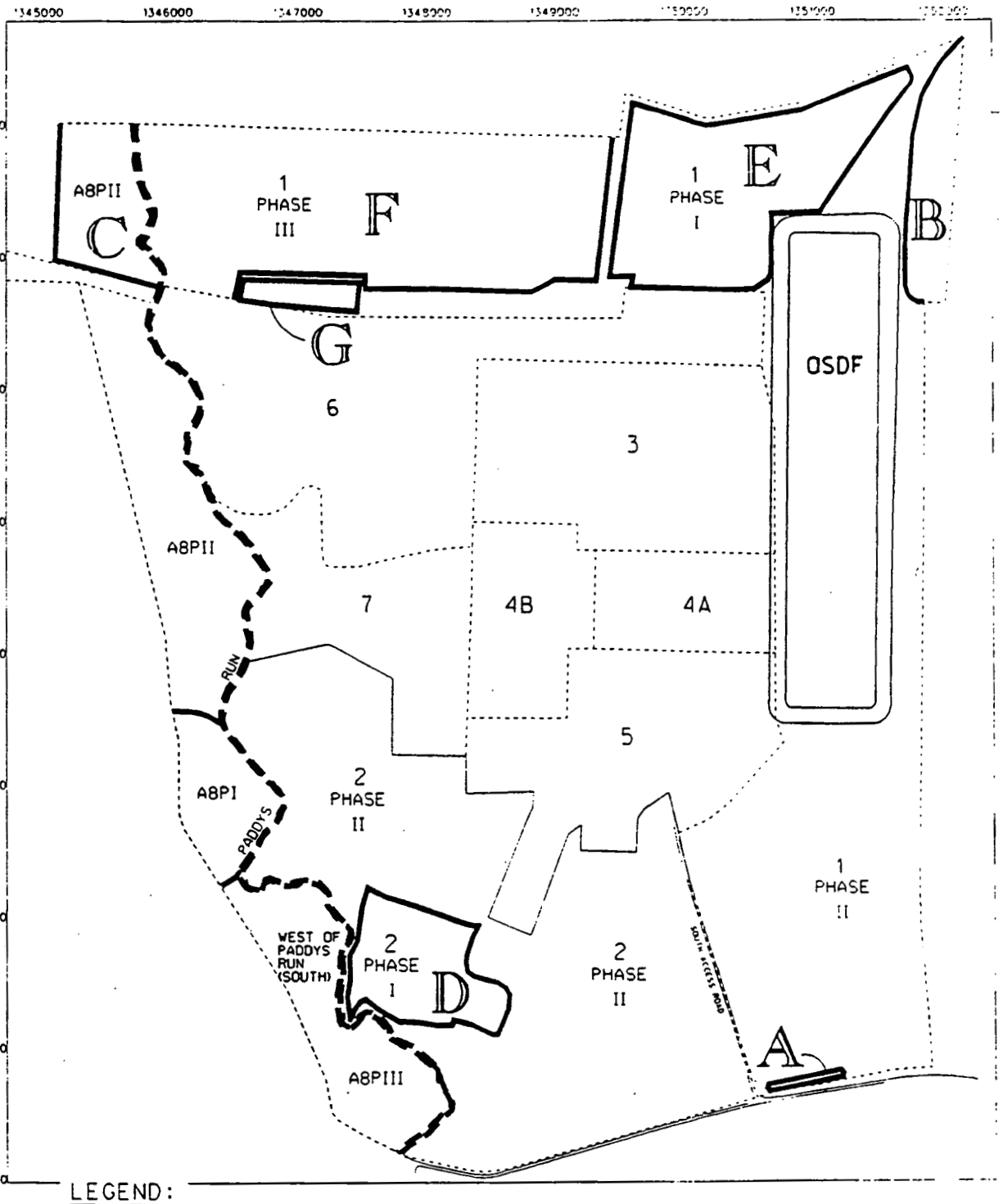
4.13 RESTORATION PROJECT SCHEDULES

O62 The schedules outlined in Table 4-1 have been developed to accomplish restoration as soon as practical after remediation. The dates provided are not intended to be enforceable milestones, but rather target dates that will be dependent upon the completion of remediation commitments. Changes in the completion of remediation for these areas may cause adjustments in design submittals and project implementation which will be addressed as necessary in each NRRDP.

TABLE 4-1

NATURAL RESOURCE RESTORATION PROJECTS IN THE NRRP

Restoration Project	Fiscal Year for Design	Fiscal Year to Implement	Section in NRRP	Acres Restored
Aesthetic Barriers	1998	1998	4.1	1
Wetland Mitigation - Phase I	1998	1999	4.2	6
Demonstration Forest Project	1998	2000	4.3	20
Area 2, Phase I Revegetation	1999	2001	4.4	20
Area 1, Phase I Northern Pines Enhancement	2000	2002	4.5	49
Area 1, Phase III Northern Woodlot/ Wetland Mitigation - Phase II	2001	2002	4.6	103
East Paddys Run Corridor	2002	2003	4.7	70
West Paddys Run Corridor	2003	2004	4.8	77
Area 1, Phase II Borrow Area, Area 2, Phase III	2004	2005	4.9	139
Former Production Area	2005	2006	4.10	217
Waste Storage Area	2006	2007	4.11	72
OSDF Buffer	2007	2008	4.12	110
			TOTAL RESTORED ACRES	884



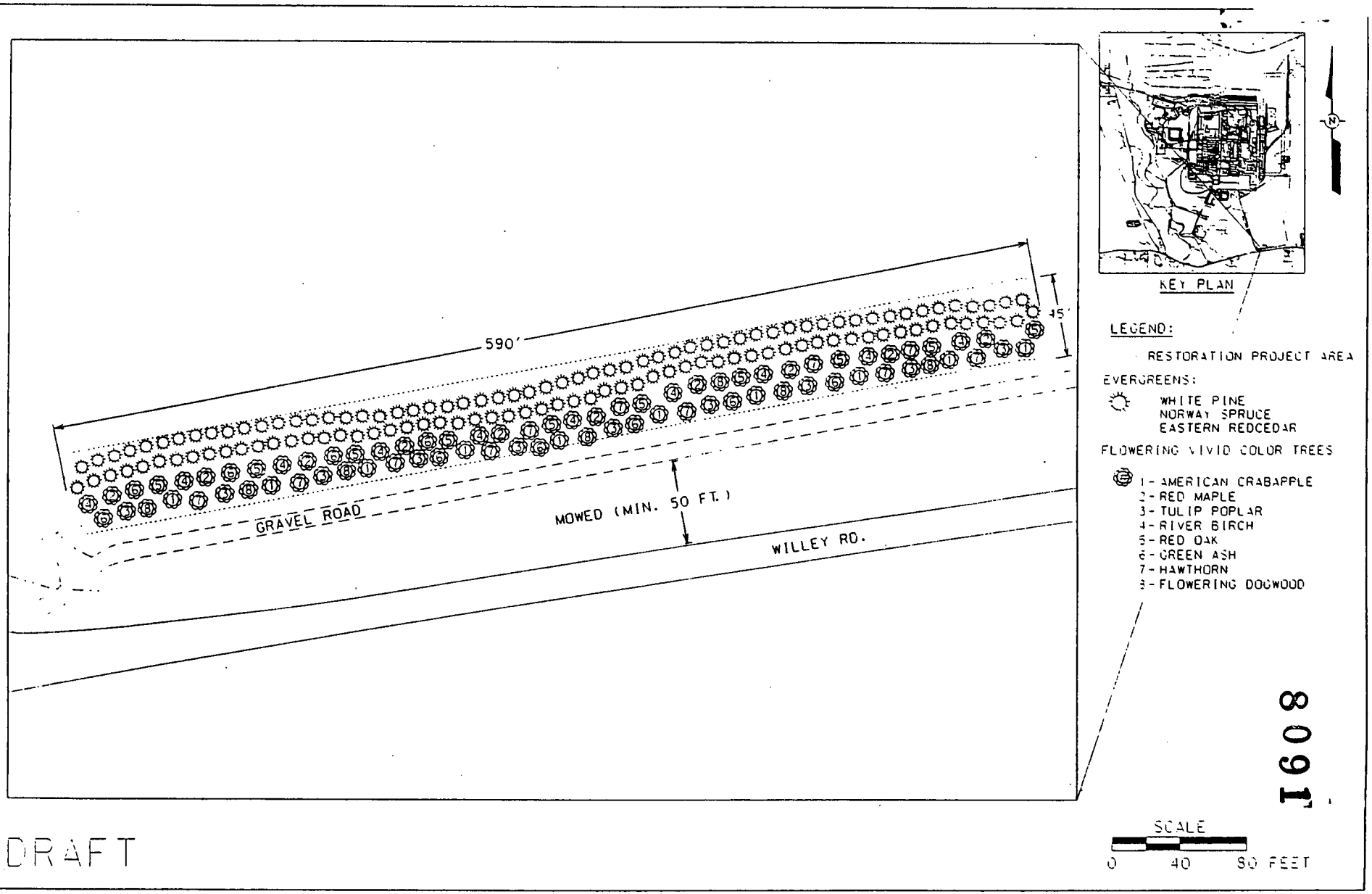
LEGEND:

A	AESTHETIC BARRIER
B	PHASE I WETLAND MITIGATION
C	DEMONSTRATION FOREST PROJECT
D	REVEGETATION OF AREA 2, PHASE 1
E	ENHANCEMENT OF AREA 1, PHASE 1 WOODLOTS
F	ENHANCEMENT AND MANAGEMENT OF AREA 1, PHASE 3 WOODLOTS
G	EXPANSION OF NORTHERN FORESTED WETLAND
.....	SOIL EXCAVATION BOUNDARIES
———	RESTORATION PROJECT AREAS
1-7	REMEDIATION AREAS

SCALE

200 400 0 FEET

FIGURE 4-1. RESTORATION PROJECTS 1998-2001



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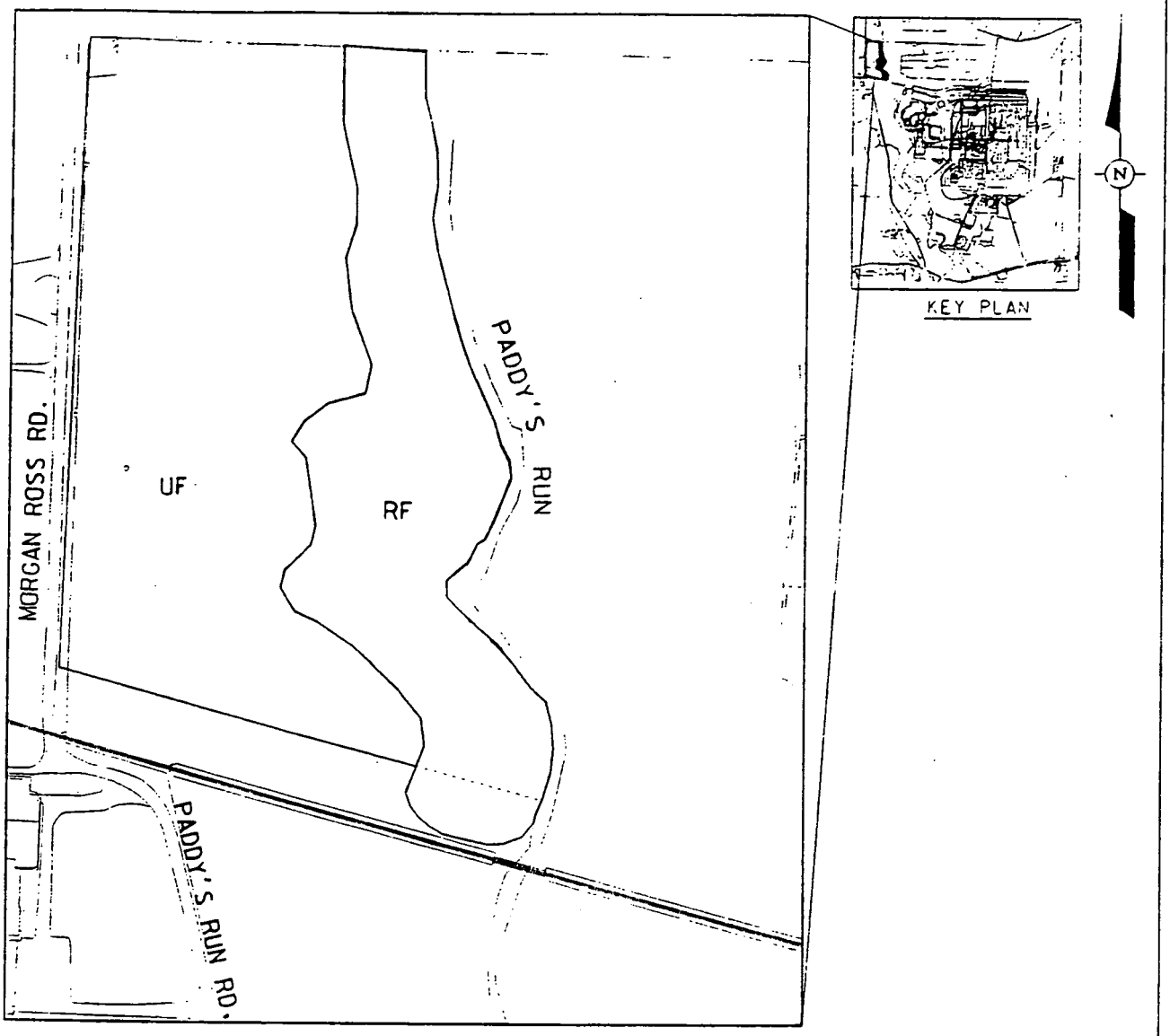
250052

1608

FIGURE 4-2. AESTHETIC BARRIER ALONG WILLEY ROAD



LEGEND:

RF-RIPARIAN FOREST
TYPICAL DOMINANT TREE SPECIES
- RED MAPLE
- BOXELDER
- PIN OAK
- GREEN ASH
- SYCAMORE
- SHAGBARK HICKORY

TYPICAL ASSOCIATE TREE SPECIES
- EASTERN COTTONWOOD
- SLIPPERY ELM
- SWAMP WHITE OAK
- BLACK GUM
- SYCAMORE

TYPICAL SHRUB SPECIES
- COMMON SPICE BUSH
- COMMON ELDERBERRY
- ROUGH - LEAVED DOGWOOD
- SOUTHERN ARROW WOOD

UF-UPLAND FOREST
TYPICAL DOMINANT TREE SPECIES
- SUGAR MAPLE
- AMERICAN BEECH
- TULIP POPLAR

TYPICAL ASSOCIATE TREE SPECIES
- WHITE ASH
- RED OAK
- OHIO BUCKEYE
- BLACK WALNUT
- RED MAPLE

TYPICAL SHRUB SPECIES
- EASTERN REDBUD
- FLOWERING DOGWOOD
- SOUTHERN ARROWWOOD
- MAPLELEAF VIBURNUM
- COMMON DEERBERRY

SCALE
300 150 0 300 FEET

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FIGURE 4-3. AREA 8, PHASE 2 REVEGETATION

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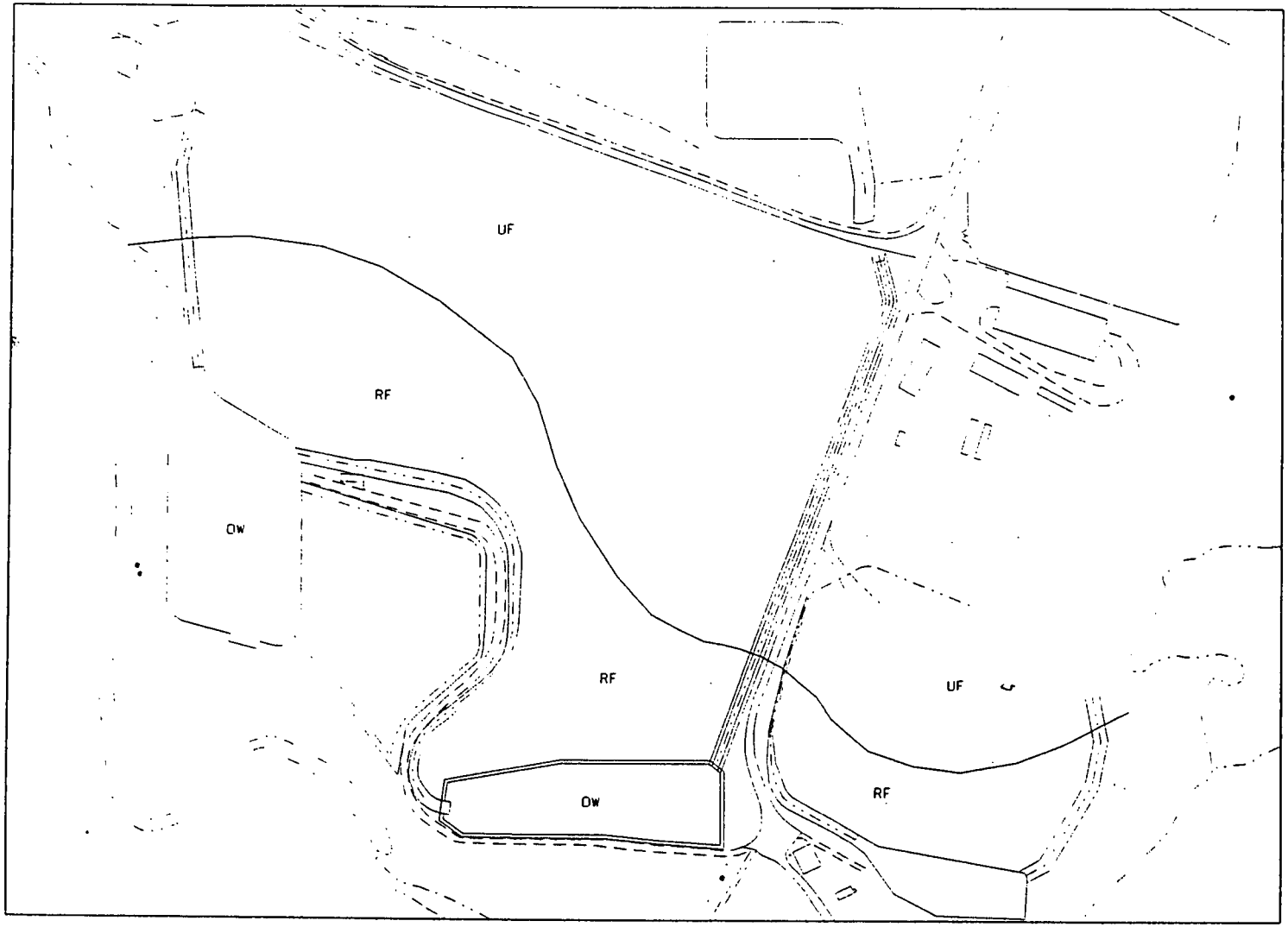

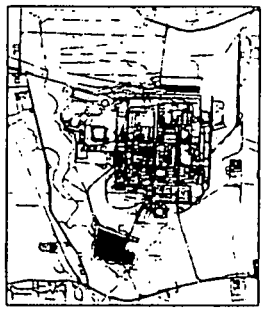

KEY PLAN

LEGEND:

..... RESTORATION PROJECT AREA

RF-RIPARIAN FOREST

TYPICAL DOMINANT TREE SPECIES
- RED MAPLE
- BOXELDER
- PIN OAK
- GREEN ASH
- AMERICAN SYCAMORE
- AMERICAN BEECH
- BLACK WILLOW

TYPICAL ASSOCIATE TREE SPECIES
- EASTERN COTTONWOOD
- SLIPPERY ELM
- SWAMP WHITE OAK
- BLACK GUM

TYPICAL SHRUB SPECIES
- COMMON SPICE BUSH
- COMMON BUTTONBUSH
- ROUGH - LEAVED DOGWOOD
- SOUTHERN ARROW WOOD
- BURNING BUSH

UF-UPLAND FOREST

TYPICAL DOMINANT TREE SPECIES
- SUGAR MAPLE
- AMERICAN BEECH
- TULIP POPLAR

TYPICAL ASSOCIATE TREE SPECIES
- WHITE ASH
- RED OAK
- OHIO BUCKEYE
- BLACK WALNUT
- RED MAPLE

TYPICAL SHRUB SPECIES
- EASTERN REDBUD
- FLOWERING DOGWOOD
- SOUTHERN ARROWWOOD
- MAPLELEAF VIBURNUM
- COMMON DEERBERRY

OW-OPEN WATER

SCALE

0 100 200 FEET

DRAFT

FIGURE 4-4. REVEGETATION OF AREA 2, PHASE 1

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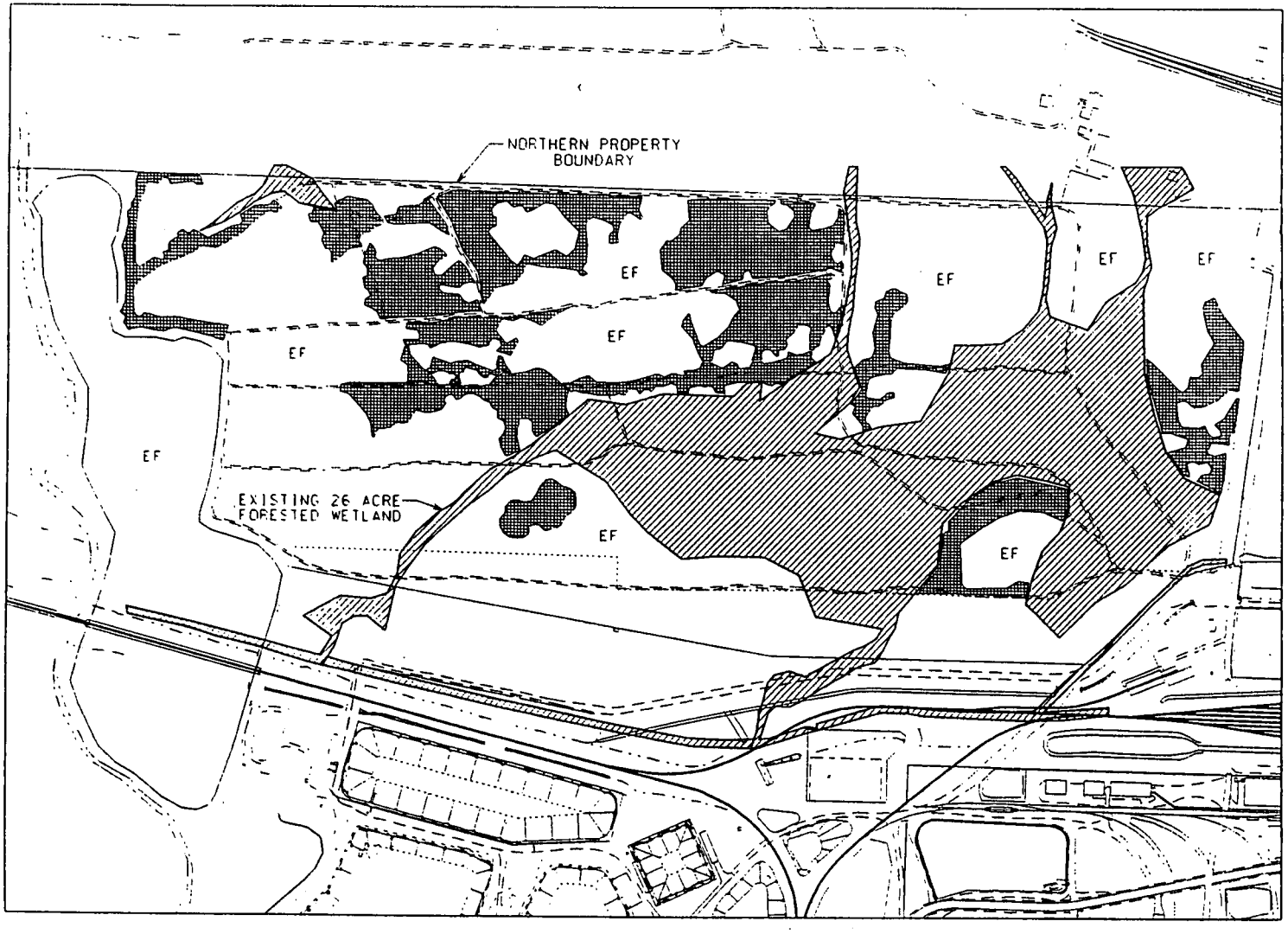

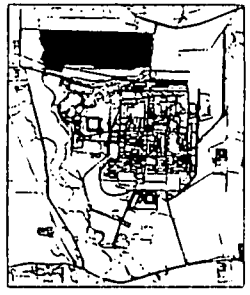

KEY PLAN

LEGEND:

- RESTORATION PROJECT AREA
- EF EXISTING FOREST
- PROPOSED VEGETATION

TREE SPECIES
- NORTHERN RED OAK
- CHESTNUT OAK
- SHAGBARK HICKORY
- SCARLET OAK
- SUGAR MAPLE
- AMERICAN BEECH
- WHITE ASH
- OHIO BUCKEYE

SHRUB SPECIES
- MAPLELEAF VIBURNUM
- EASTERN RED BUD
- FLOWERING DOGWOOD
- COMMON DEERBERRY

SCALE

0 300 600 FEET

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FIGURE 4-6. AREA 1, PHASE 3 WOODLOT

1608

000055

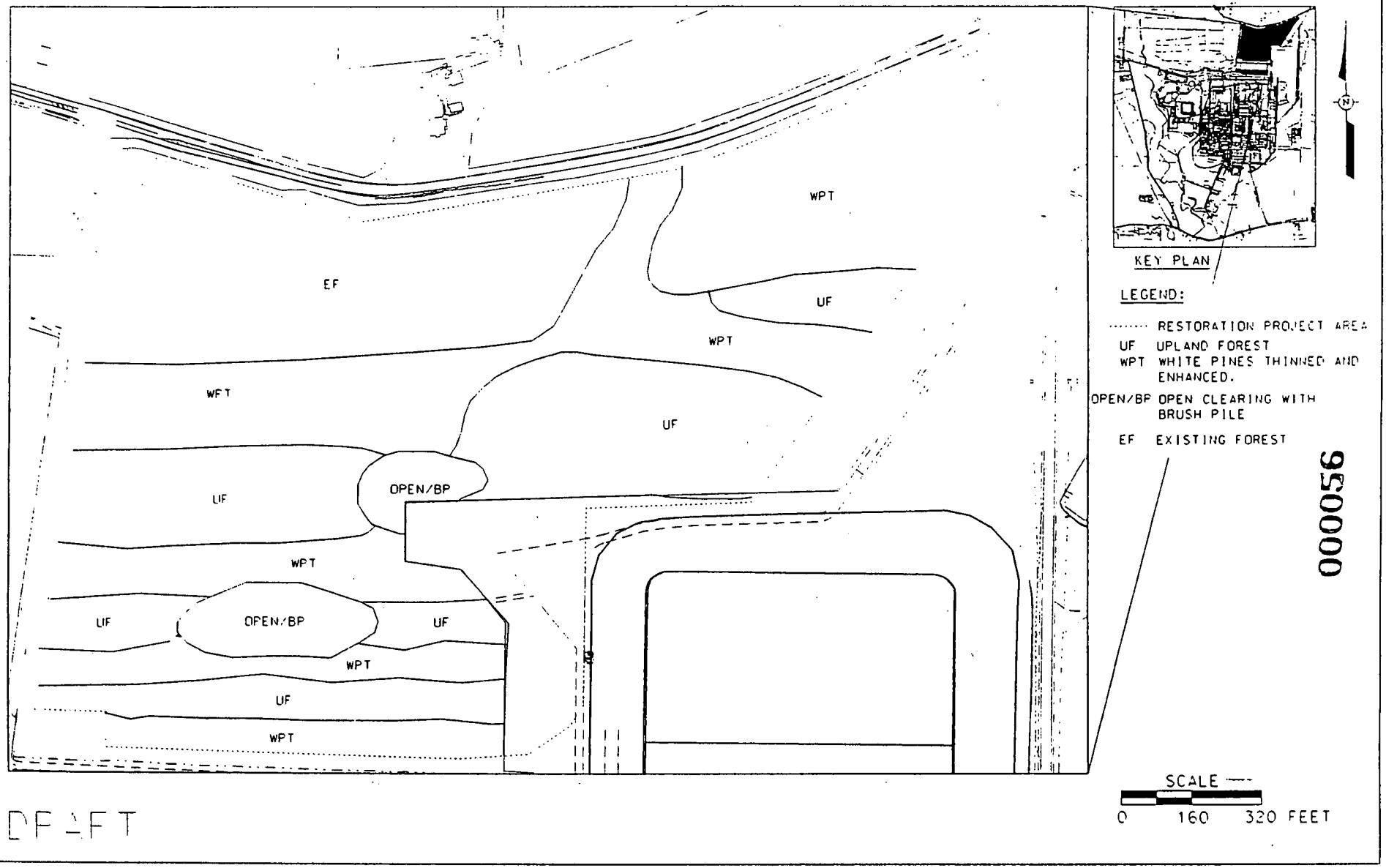

FIGURE 4-5. ENHANCEMENT OF AREA 1. PHASE 1 WOODLOTS

1608

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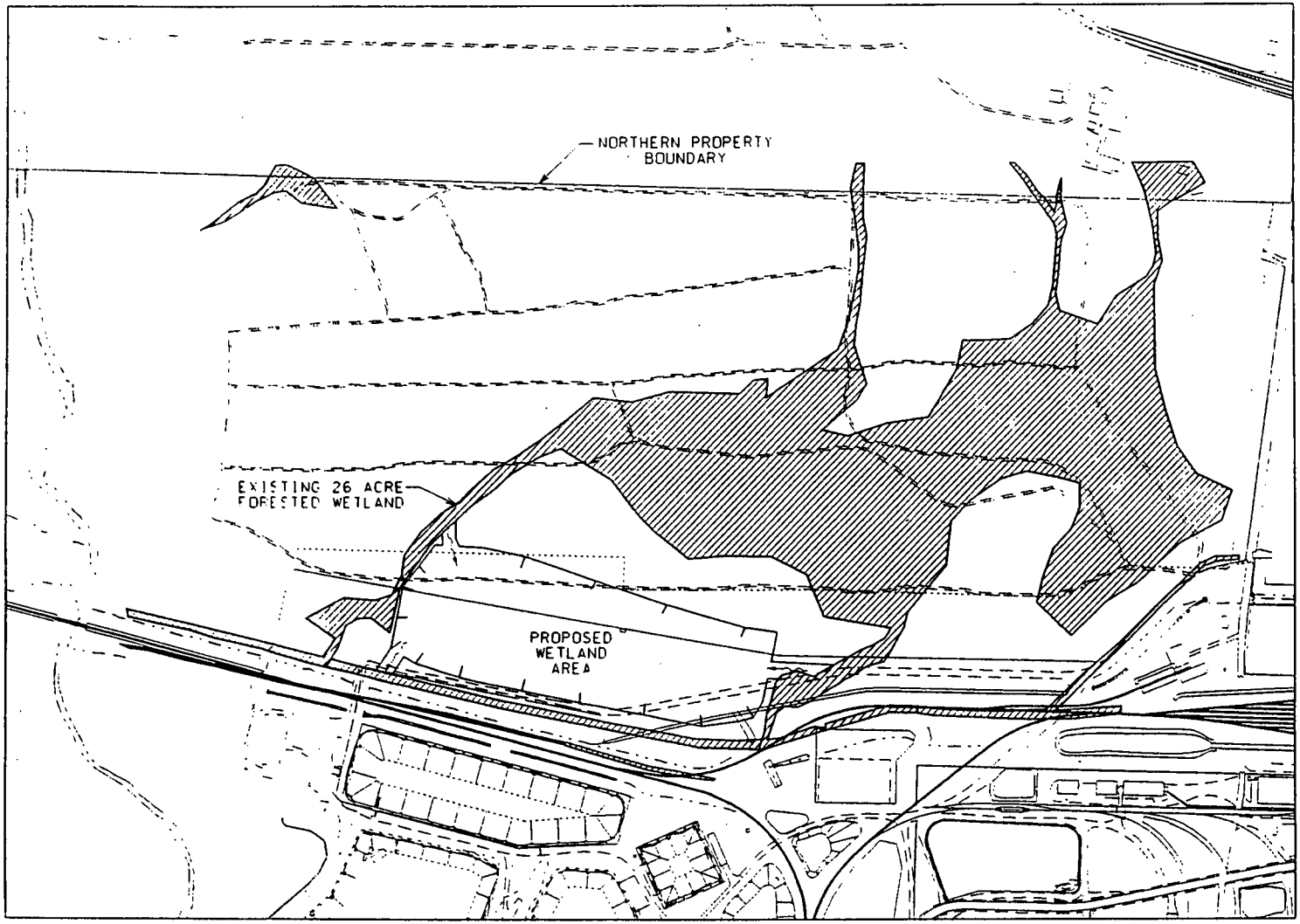

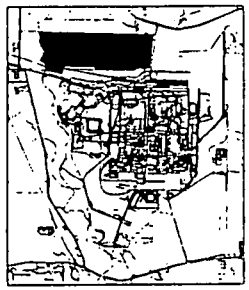

KEY PLAN

LEGEND:

- RESTORATION PROJECT AREA
- WETLAND VEGETATION
  - HERBACEOUS COVER
    - RICE CUTGRASS
    - WOOLGRASS
    - SOFTSTEM BULRUSH
    - RATTLESNAKE MANNAGRASS
    - LAKE SEDGE
    - REDTOP
  - TREE SPECIES
    - RED MAPLE
    - EASTERN COTTONWOOD
    - GREEN ASH
    - AMERICAN SYCAMORE
    - BLACK GUM
    - BOX ELDER
    - SWAMP WHITE OAK
  - SHRUB SPECIES
    - SPICEBUSH
    - BUTTONBUSH
    - COMMON ELDERBERRY
    - SOUTHERN ARROWOOD

SCALE

0 300 600 FEET

DRAFT

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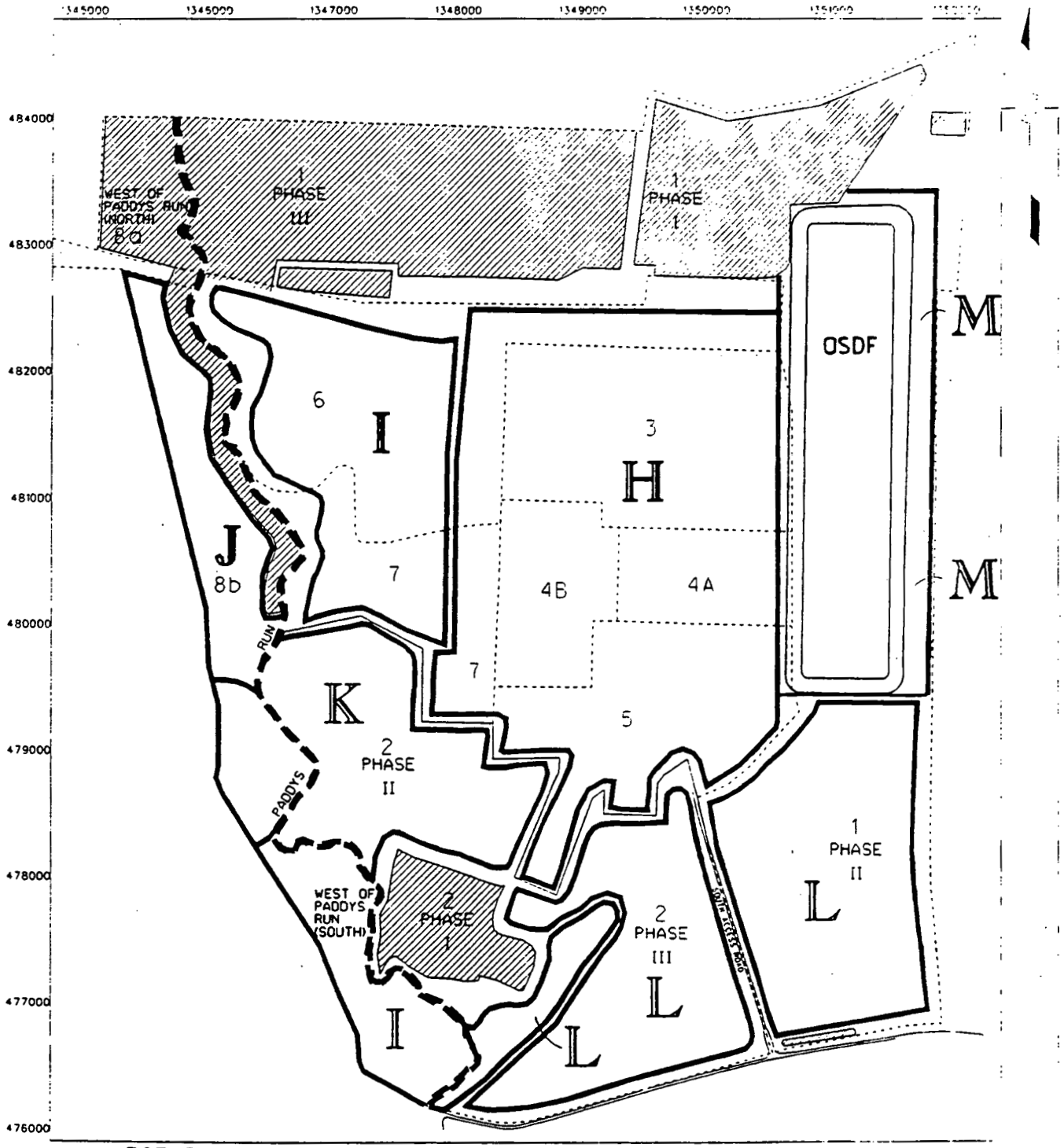
FIGURE 4-7. EXPANSION OF NORTHERN FORESTED WETLAND



LEGEND:

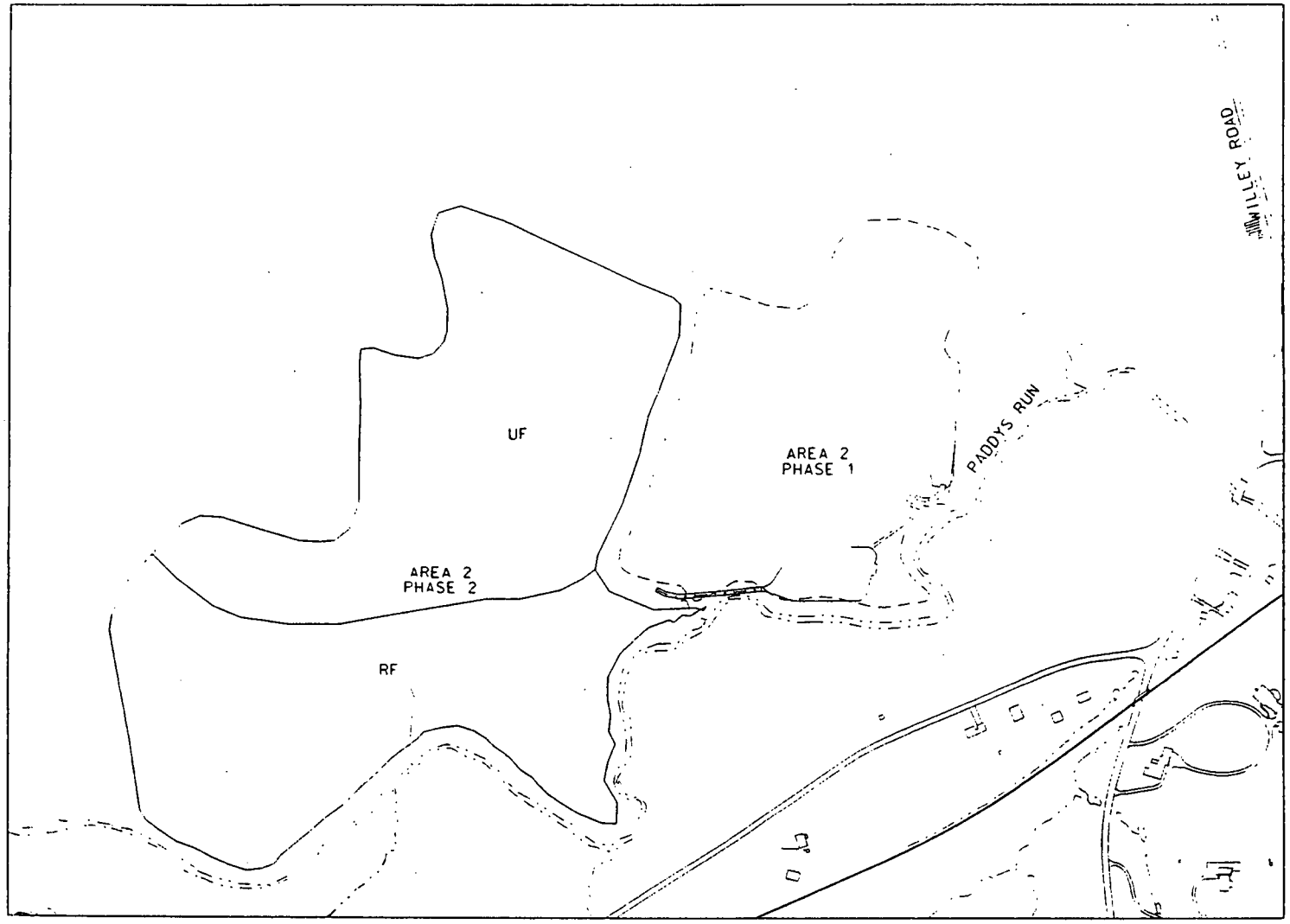
H	OPENWATER/PRAIRIE RESTORATION IN FORMER PRODUCTION AREA
I	OPENWATER/RIPARIAN FOREST RESTORATION IN FORMER WASTE PIT AREA
J	PHASE 2 EXPANSION OF PADDYS RUN CORRIDOR WEST
K	REESTABLISHMENT OF CORRIDOR EAST OF PADDYS RUN
L	BORROW AREA RESTORATION
M	OSDF AESTHETIC BUFFER
1	REMEDIATION AREA
.....	SOIL EXCAVATION BOUNDARIES
▬▬▬	RESTORATION PROJECT AREAS
▨	RESTORATION PROJECT AREAS (1998-2003)

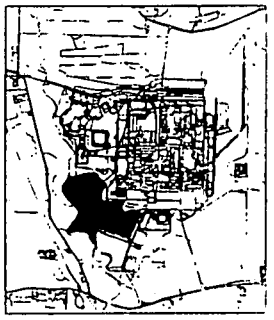
SCALE

1200 600 0 1200 FEET

000058

FIGURE 4-8. RESTORATION PROJECTS 2003-2008





KEY PLAN

LEGEND:

- - - - RESTORATION PROJECT AREA

RF- RIPARIAN FOREST

TYPICAL DOMINANT TREE SPECIES
- RED MAPLE
- BOXELDER
- PIN OAK
- GREEN ASH
- SYCAMORE
- SHAGBARK HICKORY

TYPICAL ASSOCIATE TREE SPECIES
- EASTERN COTTONWOOD
- SLIPPERY ELM
- SWAMP WHITE OAK
- BLACK GUM
- SYCAMORE

TYPICAL SHRUB SPECIES
- COMMON SPICE BUSH
- COMMON ELDERBERRY
- ROUGH - LEAVED DOGWOOD
- SOUTHERN ARROW WOOD

UF-UPLAND FOREST

TYPICAL DOMINANT TREE SPECIES
- SUGAR MAPLE
- AMERICAN BEECH
- TULIP POPLAR

TYPICAL ASSOCIATE TREE SPECIES
- WHITE ASH
- RED OAK
- OHIO BUCKEYE
- BLACK WALNUT
- RED MAPLE

TYPICAL SHRUB SPECIES
- EASTERN REDBUD
- FLOWERING DOGWOOD
- SOUTHERN ARROWWOOD
- MAPLELEAF VIBURNUM
- COMMON DEERBERRY

FIGURE 4-9. REESTABLISHMENT OF CORRIDOR EAST OF PADDYS RUN

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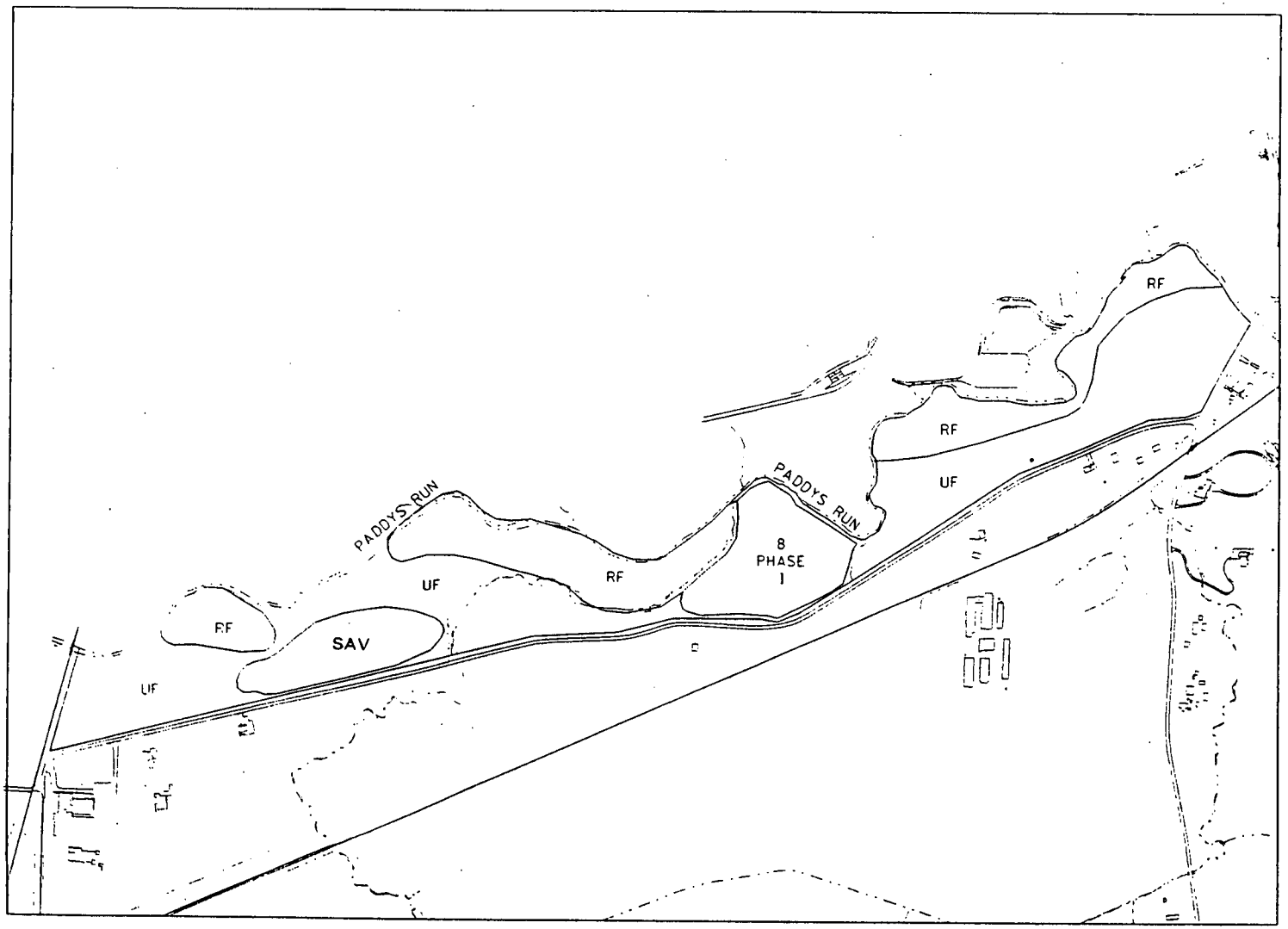

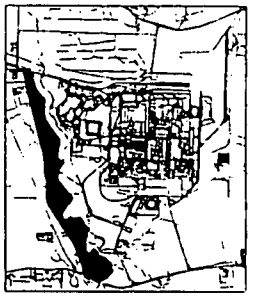

KEY PLAN

LEGEND:

..... RESTORATION PROJECT AREA

RF-RIPARIAN FOREST
TYPICAL DOMINANT TREE SPECIES
- RED MAPLE
- BOXELDER
- PIN OAK
- GREEN ASH
- SYCAMORE
- SHAGBARK HICKORY

SAV-SAVANNAH
TREE SPECIES
- RED OAK
- WHITE OAK
- CHESTNUT OAK
- SHAGBARK HICKORY
- SHELLBARK HICKORY
- TULIP POPLAR
- SUGAR MAPLE
- PRAIRIE GRASS AND FORB MIX

UF-UPLAND FOREST
TYPICAL DOMINANT TREE SPECIES
- SUGAR MAPLE
- AMERICAN BEECH
- TULIP POPLAR

SCALE

0 400 800 FEET

DRAFT

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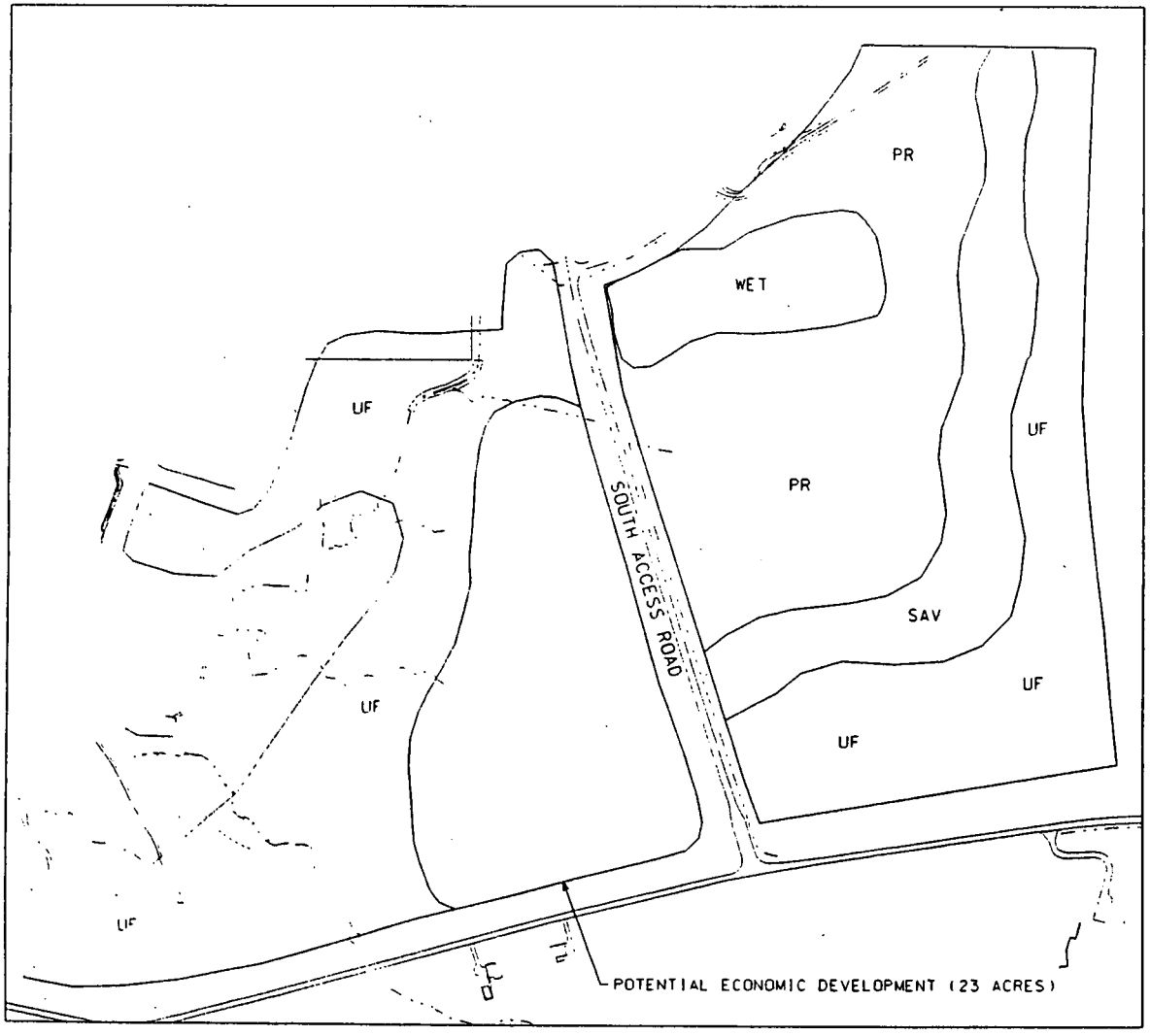
FIGURE 4-10. PHASE 2 EXPANSION OF PADDYS RUN CORRIDOR TO THE WEST



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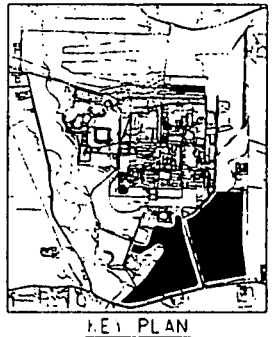
SCALE

0 300 600 FEET



KEY PLAN

LEGEND:

..... RESTORATION PROJECT AREA

WET WETLAND
- WATER PLANTAIN
- LAKE SEDGE
- SQUARESTEMMED SPIKERUSH
- FRAGRANT WATER LILY
- WATER SMARTWEED
- WIDGEONGRASS
- WILD CELERY

SAV SAVANNAH
- TREE SPECIES
  - RED OAK
  - WHITE OAK
  - CHESTNUT OAK
  - SHAGBARK HICKORY
  - SHELLBARK HICKORY
  - TULIP POPLAR
  - SUGAR MAPLE
- PRAIRIE GRASS AND FORB MIX
  - INDIAN GRASS
  - BIG BLUESTEM
  - LITTLE BLUESTEM
  - SIDE-OATS GRAMMA
  - SWITCHGRASS
  - BLACKEYED SUSAN
  - PRAIRIE CONEFLOWER
  - LANCE-LEAVED COREOPSIS
  - PURPLE CONEFLOWER
  - PURPLE PRAIRIE CLOVER

LEGEND:

PR PRAIRIE
- INDIAN GRASS
- BIG BLUESTEM
- LITTLE BLUESTEM
- SIDE-OATS GRAMMA
- SWITCHGRASS
- BLACKEYED SUSAN
- PRAIRIE CONEFLOWER
- LANCE-LEAVED COREOPSIS
- PURPLE CONEFLOWER
- PURPLE PRAIRIE CLOVER

UF UPLAND FOREST
- SUGAR MAPLE
- RED MAPLE
- AMERICAN BEECH
- TULIP POPLAR
- RED OAK, SCARLET OAK,
- SHAGBARK HICKORY

FILE NAME usr1/res/res3256/sw025b1.dgn 11:17 Aug 5-29-97 GES

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000061

FIGURE 4-11. BORROW AREA WETLAND CONSTRUCTION/ EDGE HABITAT FORMATION

5.0 MONITORING

Monitoring will be implemented to assess the progress of each restoration project. Monitoring will be performed using appropriate methods, measurements, and observations for each ecosystem identified within individual NRRDPs. Monitoring programs will be designed to identify the progress of restoration within each ecological community. Typically, standard vegetative measurement techniques will be used for monitoring (i.e., percent survival, percent cover, species diversity). Quantitative measurements may not be necessary to measure changes over time. Monitoring reports will be generated for each restoration area. These will include a collection of data, notes on field observations, and photographs.

6.0 STAKEHOLDER INVOLVEMENT

O45 Stakeholder involvement will be essential to successful development and implementation of this restoration plan. All meeting summaries generated from Natural Resource Trustee Meetings are made available to the public. Starting in June of 1998, DOE will initiate a series of workshops with interested stakeholders regarding the concept for final land-use as outlined in this NRRP. DOE-FEMP will issue this plan for a formal public review in August of 1998. Furthermore, a workshop will be held by all of the NRTs in August of 1998, to discuss the NRRP and the proposed settlement of Natural Resource issues at the FEMP in greater detail. Only after the public has been fully involved, will DOE pursue formal settlement with the other NRTs.

7.0 INSTITUTIONAL CONTROLS AND FUTURE LAND USE

Institutional controls are established in the Operable Unit 5 selected remedy as a means of ensuring continued protection of human and ecological receptors. These include:

- Continued access controls at the site during the remediation period
- Alternate water supplies to affected residential and industrial wells
- Continued federal ownership of the FEMP property
- Deed restrictions necessary to preclude residential and agricultural uses only and ensure recreational use of the remaining areas of the FEMP property
- Application of conservation easements for habitat restoration
- Enhancement of off-property areas, and the possible purchase of additional property adjacent to the FEMP.

Additionally, proper notifications, as mandated by Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), will be provided before the transfer of any federal real property known to contain, or used in the processing of, hazardous substances. These measures will minimize the potential for human exposure to contaminated soil and groundwater during the implementation of sitewide remedial actions, and to the contaminated material contained in the OSDF following completion of remedial activities at the site. Specific institutional control measures will be established during the remedial design and remedial action processes. This section will be expanded as detailed design of specific projects are completed and the details of necessary institutional controls are identified. Once finalized, this plan will function as the Institutional Control Plan and Future Land-Use Plan for the site.

The FCAB issued recommendations regarding future use of the FEMP property in March 1996. The Task Force recommended that the area of the FEMP containing the disposal facility and associated buffer zone remain under the continued ownership of the federal government. Additionally, the FCAB recommended that the remaining portions of the FEMP property be made available for the uses deemed most beneficial to the surrounding communities. The FCAB encouraged DOE to consult with the local communities to establish their preferences for future use and ownership of these areas of the site.

Consistent with these recommendations, DOE will work with the local communities during remedial design on establishing a final land use and ownership plan for the FEMP property. An institutional control plan, focused on specifying the short-term (i.e., during remedial implementation) and long-term institutional control measures to be applied at the site, will be developed during remedial design to complement this final land use plan. The following key components are identified for institutional controls and monitoring:

- Continuation of access controls at the FEMP, as necessary, during the conduct of remedial actions. Property ownership of the disposal facility and associated buffer areas will be maintained by the federal government.

- Maintenance of remaining portions of the FEMP property (outside the OSDF area) under federal ownership or control (e.g., deed restrictions) to the extent necessary to ensure the continued protection of human health commensurate with the clean-up levels established by the remedy. If portions of the FEMP property are transferred or sold at any future time, restrictions will be included in the deed, as necessary, and proper notifications will be provided as required by CERCLA.

- Maintenance of the OSDF to ensure its long-term performance and the continued protection of human health and the environment.

- Conduct of an environmental monitoring program during and following remedy implementation to assess the short- and long-term effectiveness of remedial actions.

- Provision of an alternate water supply to domestic, agricultural and industrial users relying upon groundwater from the area of the aquifer exhibiting concentrations of contaminants exceeding the FRLs. The alternate water supply will be provided until such time as the area of the aquifer impacting the user is certified to have attained the FRLs.

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ADDENDUM A

SUMMARY OF THE ECOLOGICAL CONSTITUENT OF CONCERN REVIEW

SUMMARY OF THE ECOLOGICAL CONSTITUENT OF CONCERN REVIEW

DOE must ensure that ecological receptors are not adversely impacted by residual contamination that may remain after remediation is complete. One early step towards this goal was taken with the publication of the Site-wide Ecological Risk Assessment (SERA), which was conducted as part of the Operable Unit 5 (OU5) Remedial Investigation.

The SERA considered both radiological and non-radiological risks to ecological receptors within distinct study areas at the FEMP. For radiological risks, site concentrations within each study area were used to calculate the radiological dose rates accrued by individuals of various representative species. All of these doses fell well below the target level dose of 36.5 rad/year, as established by the International Atomic Energy Agency.

For non-radiological risks, potential constituents of ecological concern (COECs) were determined for each study area by comparing existing data to literature-derived benchmark toxicity values (BTVs). The results of this effort showed that 17 soil COECs were present in one or more study areas across the FEMP. Several other COECs were identified for surface water, sediment in Paddys Run and the Great Miami River.

BTVs are not ecological cleanup levels, but rather threshold values that are protective of ecological receptors. An exceedance of a BTV indicates that further investigation may be needed, and does not necessarily indicate ecological impact. Because of this, further investigation of information developed in the SERA was to have been deferred until after all human health-driven remediation has been completed. However, as negotiations with the FEMP Natural Resource Trustees progressed, it became clear that in order to resolve all Trustee concerns, ecological impacts must be considered before remedial activities have been completed. Therefore, a second ecological risk screening was conducted, which is found in Appendix C of the Sitewide Excavation Plan (SEP).

O20 For soil, 103 potential constituents of ecological concern (COECs) were identified at the FEMP. After
O51 BTVs were established for each potential COEC, they were screened in several steps. First, all potential COECs with BTVs greater than corresponding FRLs were eliminated from further review. The remaining potential COECs were then compared against maximum sitewide soil detections. Any

parameter with a maximum concentration less than its BTV was eliminated from further evaluation. A few potential COECs were screened out when their BTV exceedances were the result of background conditions or were from locations that no longer existed. Potential COECs that remained were then screened against anticipated post-excavation soil concentrations. The results of this process were presented on maps that showed the depth below or height above excavation that a particular BTV exceedance was located (Figures C-3 through C-8). Through this process, COECs were identified in several areas that may be a concern after remedial activities have been completed. These COECs include antimony, cadmium, lead, molybdenum, silver, and a suite of polynuclear aromatic hydrocarbons (PAHs). DOE-FEMP will investigate these COECs further through evaluation of predesign, precertification, and/or certification data.

Potential surface water and sediment COECs were screened as well. Parameters with BTVs greater than corresponding FRLs were identified, along with COECs where BTV exceedances are associated with background conditions. Remaining surface water and sediment COECs will then be included in the Integrated Environmental Monitoring Plan (IEMP) sampling protocol. The surface water COECs to be sampled include barium, cadmium, and silver. For sediment, barium, cadmium, iron, lead, and zinc will be included as part of the IEMP monitoring.

Concentrations of surface water and sediment COECs were modeled for post-excavation surface water features as well. A site-specific flow and equilibrium partition model was used to determine if post-excavation soil concentrations would result in surface water and/or sediment BTV exceedances in restored wetlands and open water habitats. The result of this effort revealed that the only concern in both surface water and sediment would be associated with background soil concentrations of manganese.

ADDENDUM B

HABITAT EQUIVALENCY ANALYSIS

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Table 6 Draft HEA Analysis for the Great Miami River

Site Photographs

LIST OF ACRONYMS

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DOE	U.S. Department of Energy
FEMP	Fernald Environmental Management Project
FS	feasibility study
HEA	Habitat Equivalency Analysis
NRDA	Natural Resource Damage Assessment
NRIA	Natural Resource Impact Assessment
NRRP	Natural Resource Restoration Plan
NRTs	Natural Resource Trustees
OSDF	On-Site Disposal Facility
OU4	Operable Unit 4
RI	remedial investigation

1.0 INTRODUCTION

O21 The goal of negotiations between the Fernald Natural Resource Trustees (NRTs) is to resolve the U.S. Department of Energy's (DOE's) liability for natural resource injuries, including the settlement of the State of Ohio's 1986 claim against DOE, by implementing an on-property natural resource restoration plan. The NRTs have tentatively agreed to pursue resolution of their concerns without conducting a formal Natural Resource Damage Assessment (NRDA). Therefore, any restoration plan for the Fernald site must be justified through a process that meets at least all of the substantive aspects of the NRDA process and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

A key aspect of the natural resource trusteeship process is ensuring that restoration adequately compensates for injuries. Within an NRDA, this is accomplished by converting injuries to dollar damages, which are then spent to replace, restore, or acquire natural resources equivalent to those injured. The NRTs have agreed to pursue an alternate method to ensure that the level of natural resource restoration at the Fernald site is commensurate with the impacts that have occurred.

To accomplish this, the NRTs have tentatively agreed to pursue the use of the Habitat Equivalency Analysis (HEA) process to bridge the gap between the Natural Resource Impact Assessment (NRIA) and the Natural Resource Restoration Plan (NRRP). The NRIA provides a baseline of past and anticipated future impacts to terrestrial and surface water impacts that have occurred at the Fernald site. Based on those impacts, the NRTs have formulated the appropriate level of restoration, as defined by the evaluation in this addendum, to compensate for the agreed-upon impacts and to address all stakeholder concerns. As stated in Section 1.5 of the NRRP, groundwater impacts will be addressed separately.

2.0 HABITAT EQUIVALENCY METHODOLOGY

O22 The HEA process is one of the methods available to determine the appropriate compensation for the loss of natural resources. By using the HEA methodology, the NRTs have the flexibility to calculate the acreage of a habitat replacement project necessary to compensate for the loss of services provided by a natural resource. An example of a service loss would be the contamination of groundwater to the extent it cannot be used for drinking water or the contamination or destruction of a wetland system to the point it no longer provides the beneficial functions of a healthy wetland. The HEA process calculates compensatory restoration that accounts for interim loss of services. This restoration is in addition to any primary restoration, which is required to return a resource to baseline conditions.

Although there is a distinction made between primary and compensatory restoration projects for the purposes of compliance with regulatory requirements and implementation of the HEA process, the two may involve the same restoration activities (e.g., revegetation, creation of wetlands). However, it is important to note that there can be distinct and different projects implemented to meeting primary and compensatory restoration requirements. At the Fernald site, the intent is to propose and implement a comprehensive restoration plan (as outlined conceptually in the NRRP) to meet both primary and compensatory restoration requirements.

The ultimate goal of the HEA process is to calculate compensation based on some agreed upon level of injury for each natural resource area. This calculation will serve to demonstrate the increase in services provided by the replacement project will be of equivalent value to the public as the value of services lost due to the injury. Because detailed quantitative data is generally lacking to value the exact loss of services from a past (or future) injury, HEA calculates an equivalency between the quantity of services lost due to the injury and the quantity of services provided by the replacement projects over time.

The NRTs will negotiate the amount of yearly service loss for a particular area based upon the amount of injury that has occurred. In the case of the Fernald site, the injuries or impacts have been outlined by distinct study areas in the NRIA. Therefore, the NRTs will negotiate an appropriate level of service loss for each particular study area outlined in the NRIA. In addition, the NRTs will negotiate the appropriate level of service gain provided by the restoration projects. Based on the negotiated level of

service loss and gain, the HEA methodology will calculate the amount of compensatory restoration required (in acres) to offset of natural resource impacts or injuries. The compensatory restoration acres are calculated as explained in Section 2.1.

O4, O23 The resulting acreage will be addressed through specific restoration projects, as conceptually described in the NRRP. Roughly 850 acres are available for on-property restoration, which is estimated by taking the total site acreage (1,050 acres) and subtracting land required for the On-Site Disposal Facility (OSDF), various OU4 supplemental environmental projects, and the 23 acres designated for potential use by the Community Reuse Organization.

D2 It should be noted that utilizing the HEA process may appear to be very accurate, in reality there is a significant amount of uncertainty involved. The negotiated service levels were not quantitatively derived, but rather qualitatively set based on conservative assumptions and existing information, as discussed in the following sections. The Fernald Environmental Management Project (FEMP) NRTs agreed that the qualitative HEA process provides an order of magnitude estimate of restoration required. To illustrate this point, all HEA calculations have been rounded to the nearest 10 acres.

2.1 CALCULATIONS

Two worksheets were developed to calculate HEA acreage for each NRIA area. These worksheets provided for each area will include the columns described below. The first (left side) worksheet calculates the interim loss in services by determining *effective acre-years* lost. This is accomplished by taking the negotiated service level (column 3) for each year (column 1) and subtracting from 100 percent to get an annual percent service loss (column 4). In column 5, the average annual percent service loss is calculated by averaging the given year and the following year service losses. For instance, if year one had a service loss of 20 percent and year 2 had a service loss of 40 percent, the average annual percent service loss would be 30 percent. A discount factor of three percent is then applied in column 6 using the following equation: $1/(1+0.03)^{\text{given year} - 1997}$. This discount factor is then multiplied by the average annual percent service loss to obtain an average service loss per acre (column 7). This value is then multiplied by the total area acreage (found in the "Related Information" section at the bottom right of the various worksheets) to get an effective acres lost value for each year of impact. These annual acreage are then summed at the bottom of the worksheet to obtain a total discounted effective acre-years lost.

Service increases are then calculated. The first three columns of the service increase worksheet have similar values with respect to the percent service levels for the given years. Rather than calculating loss, however, an average percent service level change is calculated for each year. This is accomplished by again averaging the percent service change in a given year with the following year (column 4). This value is again discounted using the same discount factor equation as described above (column 5) and multiplying it by the average annual percent change to determine an effective acre-years per acre gain (column 6). These annual values are summed at the bottom of the worksheet to obtain a total gain in discounted effective acre-years per acre restored.

To determine the amount of compensatory restoration that is required, the total interim loss acre-years are divided by the total gains in effective acre-year per restoration acre in order to obtain the total amount of compensatory acreage needed. These calculations are shown below the service increases tables on each worksheet. The compensatory restoration acreage is then added to the primary restoration acreage to determine the total restoration acreage required.

2.2 CONDITIONS AND ASSUMPTIONS FOR USE

O25 In order to use HEA in the determination of compensatory restoration requirements, four conditions must be met. Each of these conditions and their applicability to the FEMP are discussed below. The use of HEA to calculate groundwater compensation will be discussed separately.

2.2.1 Values of Lost Services are Comparable to Replacement Services

Primary and compensatory restoration plans must provide services comparable to the services lost due to injuries. Restoration alternatives at the FEMP are centered around expansion, enhancement, and restoration of site habitats that have been or will be impacted due to CERCLA releases and/or remedial activities. Most of the habitats proposed in the Natural Resource Restoration Plan are habitats that have been or are presently located on FEMP property, which will provide the same services with respect to wildlife habitat, nutrient cycling, etc. Therefore, replacement services will be comparable to lost services. It should be noted that in some instances lower quality habitats will be replaced with higher quality habitats. For instance, many of the introduced grasslands located on property will be converted into deciduous woodlots. In these cases, an adjustment factor is used in the HEA calculations as an increase in service levels over 100 percent.

2.2.2 Injuries Primarily Affect Ecological Services

The use of HEA is recommended only if on-property human uses are limited and off-property human uses are difficult to quantify. This condition is met at the FEMP, where human access to the site is restricted and service losses are primarily the result of ecological impacts due to habitat loss.

2.2.3 Replacement of Habitat Services is Feasible

Service losses due to habitat impacts can be replaced with the expansion, enhancement, and restoration of representative habitats. These actions consist of standard erosion controls, grading, and revegetation, which will be detailed in the NRRP. The land for these actions is available on property, with the final land use scenario being an undeveloped park. Therefore, natural resource restoration at the FEMP will replace lost habitat services. The NRRP is conceptual at this time. As design progresses, specific restoration plans may be altered for technical reasons. Any plan revisions must still meet the restoration goals identified through the HEA process and through negotiations with the NRTs.

2.2.4 Nature of Injuries and Replacement Projects are Sufficiently Understood to Estimate HEA Parameters

Through the remedial investigation/feasibility study (RI/FS) process, volumes of information have been collected with respect to natural resource injuries and associated service losses at the FEMP. Likewise, remedial design efforts provide sufficient information to estimate service gains through restoration projects. Certain service loss and gain percentage calculations require the use of assumptions derived from existing information, current remedial design schedules, and the science of ecology. These assumptions are spelled out below.

The assumptions used to apply HEA at the FEMP can be divided into three major categories: general assumptions; assumptions associated with service losses; and assumptions associated with service gains. in addition, specific assumptions have been made for each of the areas evaluated in separate HEA calculations. These assumptions are described within the corresponding description of the area-specific HEA calculations.

2.3 GENERAL ASSUMPTIONS

The first general assumption used in the FEMP HEA calculations is that the future impact acreage identified in the NRIA is equivalent to the primary restoration project for the area in question. In other words, if no natural resource injury compensation were required, DOE would mitigate the loss of impacted habitats at a one to one ratio. This is the case for all areas evaluated at the FEMP except for the Former Production Area/Waste Storage Area, where primary restoration equals 15 acres of wetland mitigation, resulting in a 1.5 to 1.0 ratio. This is due to DOE's existing regulatory commitment for mitigation of 10 acres of wetlands that will be filled during remedial activities.

The second general assumption is the use of an annual discount rate of three percent. This rate applies to both past and future impacts.

2.4 SERVICE LOSS ASSUMPTIONS

Several assumptions are used in estimating service level impacts for each area. First, when information to the contrary is not available, service losses were assumed to have started in 1952, when full-scale operations began at the FEMP. Likewise, excavation impacts are assumed to start entirely within the first year of excavation, based on current remedial design schedules. Excavation impacts are calculated by dividing the future impact acreage (which is also the primary restoration acreage) into the total area acreage to obtain a percent service level loss. Specific details of each of these assumptions is provided in the text for each area calculated.

2.5 SERVICE GAIN ASSUMPTIONS

The assumptions used in the calculation of service level gains are as follows. First, it is assumed that recovery is complete in 20 years for all habitats restored at the site. Some habitats will recover sooner than 20 years, based on the nature of the restored habitat. Also, because existing habitats will be enhanced and/or replaced with better quality habitats through the restoration process, service gains may be estimated above 100 percent, or baseline conditions. This may still be the case even when it is acknowledged that residual contamination may remain in the soil after remediation and restoration have been completed. If it is determined that the residual contamination will not adversely effect ecological receptors and the quality of the habitat has increased, then the service level may be estimated at above 100 percent. To calculate service gains through infinity, discounted service gains are calculated and summed for 200 years.

.35 Resolving the recovery periods used in the HEA calculations are intended to estimate the point where
D3 the functional objectives of a given ecological restoration are met. Ecological succession processes may take much longer for some habitats. However, if the goal of a particular project is to establish a successional system, and secondary wildlife habitat goals are met, then the "recovery" is complete. In other words, the ecological restoration has succeeded, and further natural processes may continue.

3.0 RESULTS OF HABITAT EQUIVALENCY ANALYSIS

This section outlines the results of the HEA process for each area of the site as evaluated in the NRIA. Each area of the site is divided into a discussion of assumptions and results. The HEA worksheets for each area were based on the impacts identified in the NRIA. These impacts (both past and future) are summarized in the discussion of assumptions for each area. The discussion of assumptions also points out decisions that were made concerning the timing and severity of impacts in each area so that the HEA worksheet could be completed. The discussion of results identifies the restoration acreage that will be required to compensate for the impacts in each area. In addition, the results discussion also references the appropriate sections of the NRRP where specific restoration projects are proposed to address the required restoration acreage.

3.1 PADDYS RUN RIPARIAN CORRIDOR

O10,30 The Paddys Run Corridor encompasses approximately 98 acres along the western side of the FEMP. This area includes both riparian terrestrial habitat and aquatic habitat.

3.1.1 Assumptions

- Impacts due to contamination occurred in approximately 10 acres of the Paddys Run Corridor. Impacts are assumed to have initially began in 1953 when production started and uncontrolled runoff began to flow into Paddys Run. This increase resulted in a linear decrease in service levels to 91 percent in 1961.

O10

- Relocation of Paddys Run near the Waste Pit Area occurred in 1962 causing impact to the stream. A 16 percent reduction in services to 75 percent was estimated because the relocation involved approximately 25 percent of the portion of Paddys Run that receives flow throughout the year (Exhibit D). This accounts for impacts on both banks of Paddys Run.

- Recovery of the stream channel and adjacent revegetation was assumed to start immediately and is reflected in the HEA worksheet in the following year.

- It was assumed that full recovery of the stream occurred in approximately 9 years. The service level in 1971 is not at pre-relocation levels because vegetation recovery has not been completed.

- Full recovery of the vegetation was assumed to require 20 years as shown. The service level in 1982 is the same percentage (90 percent) that would have been present in 1962 had relocation not occurred (Exhibit G).

000081

- The installation of stormwater controls started in late 1986, limiting runoff to Paddys Run and increasing the service level one percent from 1987 on.

- Service levels were assumed to increase one percent in 1989 as a result of the Stormwater Retention Basin expansion in late 1988 and the cessation of production in 1989 (Exhibit J).

- Service levels were again assumed to increase one percent in 1992 as a result of the Waste Pit Area Stormwater Runoff controls installation.

O9.11 - In 1993, erosion controls using rip rap was installed at the inactive flyash pile which was assumed to slightly decrease service levels one percent due to minor physical impacts. The reduction was also only one percent because Removal Action 16 was implemented in 1993 as well, which further controlled runoff from the Former Production Area. The service reduction accounts for impacts to both banks of Paddys Run.

- Approximately one acre of habitat was impacted with the installation of riprap on this bank of Paddys Run in the vicinity of the K-65 Silos in 1998.

- The remediation of contaminated soil will occur in three stages, beginning in 1997 with the Southern Waste Units remedial activities and ending in 2005. Remediation will result in a significant decrease (22 percent) in the service level due to the clearing of vegetation and excavation of 34 acres of riparian corridor, which is approximately 35 percent of the entire area. The 27 percent decrease is added to the nine percent baseline decrease in 1996 to get an overall 35 percent decrease. The service reductions are staggered between 1997, 2000, and 2005 to represent the staged excavation of the corridor.

- Restoration of the corridor is assumed to begin immediately after the last stage of remediation and is reflected in the year following excavation in 2006.

- Recovery of the corridor is assumed to be complete in 20 years when the restored stream and vegetation reaches a reasonable level of maturity.

- The restoration of the corridor is assumed to improve the quality of the corridor over current conditions and thus the service level at completion will exceed 100 percent to a total of 110 percent.

3.1.2 Results

Using the impacts outlined in the NRIA, along with the assumptions outlined above, a total of 90 acres of replacement habitat would be required to compensate for impacts to the Paddys Run Corridor. Impacted areas of the existing riparian corridor and the stream will be restored at the completion of remediation. Additional restoration to compensate for the impacts to the Paddys Run Corridor will focus on the expansion and enhancement of riparian habitat adjacent to the stream. Specific projects

proposed as compensation for impacts to Paddys Run are identified in Sections 4.3, 4.4, 4.7, and 4.8 of the NRRP.

3.2 NORTHERN WOODLOT AND NORTHERN PINE PLANTATION

The Northern Woodlots include approximately 60 acres of the Northern Pine Plantation and an additional 100 acres of mixed deciduous forest including a forested wetland. The HEA worksheet for this area is outlined in Table 2 and the assumptions utilized are as follows:

3.2.1 Assumptions

- Injury was assumed to begin in 1953 as a result of airborne deposition of contaminants from production operations, causing a linear decrease in service levels to 95 percent in 1957.

- There were minor physical impacts to the area at various points in time, but these were not directly linked to a release and were not factored into HEA as a loss of service.

032 - Approximately 14 acres of the northern woodlots were cleared in 1988 for use as borrow material. This impact resulted in a four percent decrease in services for 1988 and subsequent years. Ground clearing would normally be considered a 100 percent loss. However, because baseline services are calculated according to the current 162 acres, the ground clearing for the borrow area in 1988 was not calculated on a 100 percent service loss. Instead, the impact was essentially discounted 50 percent.

- The Northern Pine Plantation was planted in 1972, but was not considered as a beneficial habitat until 1987 when the plantation reached a reasonable state of maturity. A one percent increase in service levels was included at that point (Exhibit I).

O31 - Excavation activities to support the OSDF will be initiated in 1997 with the clearing of approximately 9 acres of the Northern Pines resulting in a drop in service level to 87 percent. This service level is estimated by dividing 15 acres into the total area (162 acres). Fifteen acres were used to calculate impacts rather than 9 acres, in order to account for edle-effect service decreases. The area of the Northern Woodlots that will be impacted will be utilized for the OSDF.

- Restoration will be initiated in the year 2002 and will involve enhancing other areas of the Northern Woodlot.

- Due to the maturity of the habitat in much of the Northern Woodlot, it was assumed that only 15 years would be necessary for full recovery (i.e., maturity) of the area.

- The restoration of the woodlots is assumed to improve the quality of the woodlots over current conditions, thus the service level at completion will exceed 100 percent (to a total of 106 percent).

3.2.2 Results

Based on the acres of impacts outlined in the assumptions listed above regarding loss of services, a total of 50 acres of restoration will be required to compensate for impacts to the Northern Woodlots. The area of primary impact in the Northern Woodlot will not be available for restoration due to utilization by the OSDF. Therefore, restoration activities outlined in the NRRP in Sections 4.5 and 4.6 will focus on enhancing other areas of the Northern Woodlot.

3.3 SOUTHERN PINES AND WASTE UNITS

The Southern Pines and Waste Units encompasses approximately 66 acres south-west of the Former Production Area. Table 3 provides the HEA worksheet for the Southern Pines and Waste Units. Assumptions used in the HEA for this area are as follows:

3.3.1 Assumptions

O34
- Injury was assumed to begin in 1953 as a result of production runoff into the Pilot Plant Drainage Ditch and due to the use of the Inactive Flyash Pile and South Field as a disposal area, which caused a linear reduction in services to 85 percent in 1960 (Exhibit C). The linear decrease in percent service level to 85 percent is based on soil contamination and not habitat loss.

O34
- The initiation of the Active Flyash Pile in 1966 resulted in an ~~eight~~ 8 percent reduction in services to 77 percent. The ~~eight~~ 8 percent reduction is estimated by determining the percentage of the Southern Pines and Waste Units that the Active Flyash Pile represents (5 acres/66 acres, or 7.5 percent).

- The 80 percent service level continues until use of the Inactive Flyash Pile in 1965 is terminated and successional growth begins to take over in approximately 1970 (Exhibit E). In 1970, service levels show a linear increase to 90 percent in 1979. This represents a 15-year recovery to an old field habitat.

- The Southern Pine Plantation was planted in 1972, but was not considered a beneficial habitat until 1987, when the plantation reached a reasonable state of maturity. A two percent increase in service level was included at this point. Note that while the habitats and time frames are similar, the Southern Pine Plantation provides more benefit (as reflected in service level increases) because it represents a greater percentage of the overall area (Exhibit J).

- The clearing of several areas in the Southern Pines occurred in the 1990s resulting in additional decreases in service levels.

O13.33.34

- Excavation, soil stockpiles, and haul road impacts in 1997 result in a 64 percent service level. The 64 percent service level is obtained by calculating the percentage of habitat loss due to excavation (24 acres/66 acres, or 36 percent).

- These areas are assumed to provide beneficial habitat even though they are contaminated.

- Restoration of this area will occur in the year 2001.

- The recovery period is expected to be approximately 20 years until a reasonable level of maturity is achieved (100 percent service level).

3.3.2 Results

Using the above-listed assumptions and the acres of impact from the NRIA, 60 acres of restoration will be required to compensate for impacts to the Southern Pines and Waste Units. The NRRP references projects to be implemented for impact compensation in Sections 4.4 and 4.7.

3.4 GRASSLANDS

The Grasslands encompass approximately 235 acres in the eastern and southern portions of the FEMP. Table 4 provides the HEA worksheets for this area. The following provides the assumptions that were utilized in developing the HEA for the grassland areas.

3.4.1 Assumptions

- Production operations resulted in air deposition contaminating approximately 93 acres of grassland areas which is identified by a slight decrease in service levels to 98 percent in 1954. The reason only a two percent reduction is estimated is because of the limited habitat services the grasslands provide.

- Use of the Trap Range starting around 1960 resulted in lead contamination in an isolated portion of the grasslands which is also reflected by decreased service levels to 96 percent (Exhibit D).

- It is assumed that service levels essentially remained constant until contaminated soil was excavated along with approximately 5 acres of off property woodlot as part of Removal Action 14 in 1992. This resulted in an additional two percent reduction in services.

- A significant decrease in service levels was assumed to occur with the excavation of Area 1, Phase I in 1996. From 1996 to 2004, grassland excavations are staggered and reduced linearly to reflect the large scale excavations that will be taking place. The staggered reductions for the different phases of excavation (Area 1 Phase 1, Area 1 Phase 2, and Area 2 Phase 2) are based on qualitative estimates of the ration of a given phase to the overall acreage of the grasslands.

- In the year 2002 it is anticipated that almost all grassland areas (approximately 204 acres) will be excavated as reflected by the decrease to a 12 percent service level.

- The restoration of the grassland areas will occur where possible; however, a significant portion will be utilized for the OSDF and unavailable for restoration.

- It is assumed that restoration will occur in approximately 2005 at the time that use of the borrow area and excavation of Area 2, Phase 2 is complete.

- The recovery for the restoration of the grassland area is assumed to be approximately 5 years since portions of the area will be converted to native prairies and wetlands which are assumed to have less maturation time than an area of exclusively forest habitat. The recovery is assumed to be linear to a 110 percent service level, since restored prairies and wetlands will provide higher quality habitat than the present-day introduced grasslands.

3.4.2 Results

Based on the acres of impact identified in the NRIA coupled with the assumptions that have been made above regarding loss of services, a total of 280 acres of restoration is required to compensate for impacts to grassland areas. Restoration of the grassland areas will be focused on the borrow area, southern portions of the site and the buffer around the OSDF. Proposed restoration projects area outlined in Sections 4.9 and 4.12 in the NRRP and would focus on the establishment of a mosaic of wetland/open water, woodland and prairie habitats.

3.5 WASTE STORAGE/PRODUCTION AREA

The Waste Storage Area encompasses approximately 37 acres adjacent to the production areas. The Production Area encompasses approximately 136 acres in the center of the FEMP. Table 5 provides the HEA worksheet for these areas. The assumptions used in developing the HEA data for this area are as follows.

3.5.1 Assumptions

- The Waste Storage Area and Production Area provided very little habitat as both were disturbed as part of construction of the site (Exhibit C).
- It is assumed that both areas were impacted in their entirety due to contamination from site operations.
- A linear decrease in service level to 95 percent in 1957 is identified beginning in 1953. Decreases are not as significant due to the lack of good habitat in both areas.
- After the initial five percent decrease in service levels in the early years of production, service levels are assumed to remain constant until remediation begins in these areas.
- Remediation of the areas is assumed to impact the entire area and result in a five percent decrease in service levels starting in 1999 with a linear reduction to 89 percent service level in 2000. The 89 percent service level is calculated from the percentage of wetlands impacted (10 acres/173 acres, or six percent), which is added to the baseline five percent impact.
- The recovery of the area after remediation, is assumed to require approximately 15 years for full maturation of the habitat. Service levels are estimated to increase to 150 percent because the mitigated, contiguous wetland system will provide more quality habitat than the unmanaged, fragmented drainage ditches that encompass the majority of the 10 acres of wetlands.

3.5.2 Results

A total of 50 acres will be required to compensate for impacts given the above assumptions. Restoration of the Waste Storage/Production Area will focus on the conversion of excavated areas into wetland/open water habitat where possible, and revegetating other areas. Proposed restoration projects are outlined in Sections 4.10 and 4.11 of the NRRP.

3.6 GREAT MIAMI RIVER

The Great Miami River is the major water feature in the vicinity of the FEMP. It flows through several urban areas before joining the Ohio River. As expected, the Great Miami River receives point and nonpoint discharges from a variety of industrial, municipal, and agricultural sources. The HEA calculations for impacts to the Great Miami River were modified in that no primary restoration service gains were estimated and divided into the total loss in effective acre-years. Rather, the total interim loss was incorporated entirely into the on-property restoration acreage. The assumptions used in calculating the HEA worksheet are outlined below.

3.6.1 Assumptions

- For the purposes of calculating HEA, the total effected area of the Great Miami River was assumed to encompass 3.22 acres. This value is estimated from 2.97 acres of stream habitat and 0.25 acres of riparian habitat in the vicinity of the FEMP outfall line. The 2.97 acres of stream habitat were estimated from two sampling sites along the western shore of the Great Miami River that are surveyed by the University of Cincinnati as part of annual electrofishing surveys. The sampling sites are downstream of the FEMP outfall line (River Mile 24) and downstream of the confluence with Paddys Run (River Mile 19). The acreage estimate was obtained by taking the linear feet of each sample site and multiplying by 10 feet to estimate an area measurement.

- Service levels are estimated by assuming a one percent reduction for every 1000 kg of uranium released annually into the Great Miami River. Where actual records of annual discharge are not available, estimates were made based on historic trends.

- The 1993 service level is estimated at 91 percent based on an eight percent reduction due to the removal of contaminated riprap in the vicinity of the FEMP outfall line. 0.25 acres of riparian habitat were impacted by the riprap removal. The percentage reduction is calculated by the ratio of impacted habitat to the total area (0.25/2.97, or eight percent). The additional percent loss is due to the 1993 discharge of approximately 550 kg of uranium into the Great Miami River.

- Impacts are assumed to occur to the river until the year 2006, when all remedial actions at the FEMP will have been completed.

3.6.2 Results

The results of the HEA calculations indicate that 10 acres of restoration will be required to compensate for impacts to the Great Miami River. This restoration acreage will be added to the overall on-property restoration acreage in the NRRP.

4.0 CONCLUSIONS

The results of the HEA worksheets for each area of the site add up to a total of 540 acres of restoration required to compensate for the impacts identified in the NRIA. The NRRP outlines the proposed projects to address this required restoration acreage. Additional acreage will be restored to account for groundwater impacts, which were negotiated separately from the HEA process.

Table 1

HEA Analysis for the Paddys Run Corridor
Interim Losses due to Riparian Habitat Injury

Year	Project Status	% Service Level	% Service Loss	Avg. Annual % Loss	Discount Factor	Avg. Service Loss/Acre	Effective Acres Lost
1952		100%	0%	0.5%	3.78	1.9%	0
1953	injury begins	99%	1%	1.5%	3.67	5.5%	10
1954		98%	2%	2.5%	3.56	8.9%	10
1955		97%	3%	3.5%	3.46	12.1%	10
1956		96%	4%	4.5%	3.36	15.1%	10
1957		95%	5%	5.5%	3.26	17.9%	20
1958		94%	6%	6.5%	3.17	20.6%	20
1959		93%	7%	7.5%	3.07	23.1%	20
1960		92%	8%	8.5%	2.99	25.4%	20
1961		91%	9%	17.0%	2.90	49.3%	50
1962	stream relocation	75%	25%	25.0%	2.81	70.3%	70
1963	stream recovery begins	75%	25%	25.0%	2.73	68.3%	70
1964		75%	25%	25.0%	2.65	66.3%	60
1965		75%	25%	25.0%	2.58	64.4%	60
1966		75%	25%	24.5%	2.50	61.3%	60
1967		76%	24%	23.5%	2.43	57.0%	60
1968		77%	23%	22.5%	2.36	53.0%	50
1969		78%	22%	21.5%	2.29	49.2%	50
1970		79%	21%	20.5%	2.22	45.5%	40
1971	stream recovery complete	80%	20%	19.5%	2.16	42.1%	40
1972	vegetation recovery continues	81%	19%	18.5%	2.09	38.7%	40
1973		82%	18%	17.5%	2.03	35.6%	30
1974		83%	17%	16.5%	1.97	32.6%	30
1975		84%	16%	15.5%	1.92	29.7%	30
1976		85%	15%	14.5%	1.86	27.0%	30
1977		86%	14%	13.5%	1.81	24.4%	20
1978		87%	13%	12.5%	1.75	21.9%	20
1979		88%	12%	11.5%	1.70	19.6%	20
1980		89%	11%	11.0%	1.65	18.2%	20
1981		89%	11%	10.5%	1.60	16.8%	20
1982	vegetation recovery complete	90%	10%	10.0%	1.56	15.6%	20
1983		90%	10%	10.0%	1.51	15.1%	10
1984		90%	10%	10.0%	1.47	14.7%	10
1985		90%	10%	10.0%	1.43	14.3%	10
1986		90%	10%	9.5%	1.38	13.2%	10
1987	SWRB	91%	9%	9.0%	1.34	12.1%	10
1988	SWRB expansion	91%	9%	8.5%	1.30	11.1%	10
1989	production stops	92%	8%	8.0%	1.27	10.1%	10
1990		92%	8%	8.0%	1.23	9.8%	10
1991		92%	8%	7.5%	1.19	9.0%	10
1992	waste pits stormwater controls	93%	7%	7.5%	1.16	8.7%	10
1993	inactive flyash disposal area R A	92%	8%	8.0%	1.13	9.0%	10
1994		92%	8%	8.0%	1.09	8.7%	10
1995		92%	8%	8.0%	1.06	8.5%	10
1996		92%	8%	12.5%	1.03	12.9%	10
1997	excavation (SWU)	83%	17%	17.5%	1.00	17.5%	20
1998	Silos east bank stabilization	82%	18%	18.0%	0.97	17.5%	20
1999		82%	18%	22.0%	0.94	20.7%	20
2000	excavation (waste pits)	74%	26%	26.0%	0.92	23.8%	20
2001		74%	26%	26.0%	0.89	23.1%	20
2002		74%	26%	26.0%	0.86	22.4%	20
2003		74%	26%	26.0%	0.84	21.8%	20
2004		74%	26%	30.3%	0.81	24.8%	20
2005	excavation remaining areas	65%	35%	35.0%	0.79	27.8%	30
2006	primary restoration	65%	35%	34.5%	0.77	26.4%	30
2007	recovery begins	66%	34%	32.5%	0.74	24.2%	20
2008		69%	31%	29.5%	0.72	21.3%	20
2009		72%	28%	26.5%	0.70	18.6%	20
2010		75%	25%	23.5%	0.68	16.0%	20
2011		78%	22%	20.5%	0.66	13.6%	10
2012		81%	19%	17.5%	0.64	11.2%	10
2013		84%	16%	15.0%	0.62	9.3%	10
2014		86%	14%	13.0%	0.61	7.9%	10
2015		88%	12%	11.0%	0.59	6.5%	10
2016		90%	10%	9.0%	0.57	5.1%	10
2017		92%	8%	7.0%	0.55	3.9%	0
2018		94%	6%	5.0%	0.54	2.7%	0
2019		96%	4%	3.0%	0.52	1.6%	0
2020		98%	2%	1.0%	0.51	0.5%	0
2021		100%	0%	-1.0%	0.49	-0.5%	0
2022		102%	-2%	-3.0%	0.48	-1.4%	0
2023		104%	-4%	-5.0%	0.46	-2.3%	0
2024		106%	-6%	-7.0%	0.45	-3.2%	0
2025		108%	-8%	-9.0%	0.44	-3.9%	0
2026	recovery complete	110%	-10%	-10.0%	0.42	-4.2%	0

Total Discounted effective acre-years lost = 1510

Draft HEA Analysis for the Paddys Run Riparian Corridor
Service Increases due to Replacement Project

Year	Project Status	% Service Level Change	Avg. Annual % Change	Discount Factor	Effective Acre-Yrs/Acre
2006	primary restoration	65%	65.5%	0.77	1
2007	recovery begins	66%	67.5%	0.74	1
2008		69%	70.5%	0.72	1
2009		72%	73.5%	0.70	1
2010		75%	76.5%	0.68	1
2011		78%	79.5%	0.66	1
2012		81%	82.5%	0.64	1
2013		84%	85.0%	0.62	1
2014		86%	87.0%	0.61	1
2015		88%	89.0%	0.59	1
2016		90%	91.0%	0.57	1
2017		92%	93.0%	0.55	1
2018		94%	95.0%	0.54	1
2019		96%	97.0%	0.52	1
2020		98%	99.0%	0.51	1
2021		100%	101.0%	0.49	0
2022		102%	103.0%	0.48	0
2023		104%	105.0%	0.46	0
2024		106%	107.0%	0.45	0
2025		108%	109.0%	0.44	0
2026	recovery complete	110%	110.0%	0.42	0
2027	to infinity	110%	110.0%	na	18

Total gain in discounted effective acre-years/acre = 29

Compensatory Restoration Project:

Present discounted interim loss in effective acre-years (L) = 1510

Present discounted gain in effective acre-years/acre (G) = 29

Acres of replacement habitat required for compensation (R, R=L/G) = 53

Total restoration acreage required = 90

Related Information

Total acres of riparian habitat = 98

Acres of revegetation for the primary restoration project = 34

Annual discount rate 3.00%

Note: calculations are subject to rounding discrepancies, since impacted acres and total restoration required are rounded to the nearest 10-acre

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Table 2

HEA Analysis for the Northern Woodlots
Interim Losses due to Northern Woodlot Habitat Injury

Year	Project Status	% Service Level	% Service Loss	Avg. Annual % Loss	Discount Factor	Avg. Service Loss/Acre	Effective Acres Lost
1952		100%	0%	0.5%	3.78	1.9%	0
1953	injury begins	99%	1%	1.5%	3.67	5.5%	10
1954		98%	2%	2.5%	3.56	8.9%	10
1955		97%	3%	3.5%	3.46	12.1%	20
1956		96%	4%	4.5%	3.36	15.1%	20
1957		95%	5%	5.0%	3.26	16.3%	30
1958		95%	5%	5.0%	3.17	15.8%	30
1959		95%	5%	5.0%	3.07	15.4%	20
1960		95%	5%	5.0%	2.99	14.9%	20
1961		95%	5%	5.0%	2.90	14.5%	20
1962		95%	5%	5.0%	2.81	14.1%	20
1963		95%	5%	5.0%	2.73	13.7%	20
1964		[illegible]	[illegible]	[illegible]	2.65	13.3%	20
1965		[illegible]	[illegible]	[illegible]	2.58	12.9%	20
1966		95%	5%	5.0%	2.50	12.5%	20
1967		95%	5%	5.0%	2.43	12.1%	20
1968		95%	5%	5.0%	2.36	11.8%	20
1969		95%	5%	5.0%	2.29	11.4%	20
1970		95%	5%	5.0%	2.22	11.1%	20
1971		95%	5%	5.0%	2.16	10.8%	20
1972	north pine plantation planted	95%	5%	5.0%	2.09	10.5%	20
1973		95%	5%	5.0%	2.03	10.2%	20
1974		95%	5%	5.0%	1.97	9.9%	20
1975		95%	5%	5.0%	1.92	9.6%	20
1976		95%	5%	5.0%	1.86	9.3%	20
1977		95%	5%	5.0%	1.81	9.0%	10
1978		95%	5%	5.0%	1.75	8.8%	10
1979		95%	5%	5.0%	1.70	8.5%	10
1980		95%	5%	5.0%	1.65	8.3%	10
1981		95%	5%	5.0%	1.60	8.0%	10
1982		95%	5%	5.0%	1.56	7.8%	10
1983		95%	5%	5.0%	1.51	7.6%	10
1984		95%	5%	5.0%	1.47	7.3%	10
1985		95%	5%	5.0%	1.43	7.1%	10
1986		95%	5%	4.5%	1.38	6.2%	10
1987	NPP habitat service increase	96%	4%	6.0%	1.34	8.1%	10
1988	ground clearing for borrow area	92%	8%	8.0%	1.30	10.4%	20
1989		92%	8%	8.0%	1.27	10.1%	20
1990		92%	8%	8.0%	1.23	9.8%	20
1991		92%	8%	8.0%	1.19	9.6%	20
1992		92%	8%	8.0%	1.16	9.3%	20
1993		92%	8%	8.0%	1.13	9.0%	10
1994		92%	8%	8.0%	1.09	8.7%	10
1995		92%	8%	8.0%	1.06	8.5%	10
1996		92%	8%	12.5%	1.03	12.9%	20
1997	excavation: clearing of 15 acres	83%	17%	17.0%	1.00	17.0%	30
1998		83%	17%	17.0%	0.97	16.5%	30
1999		83%	17%	17.0%	0.94	16.0%	30
2000		83%	17%	17.0%	0.92	15.6%	30
2001		83%	17%	17.0%	0.89	15.1%	20
2002	primary restoration	83%	17%	17.0%	0.86	14.7%	20
2003	recovery begins	83%	17%	16.5%	0.84	13.8%	20
2004		84%	16%	15.5%	0.81	12.6%	20
2005		85%	15%	14.5%	0.79	11.4%	20
2006		86%	14%	13.5%	0.77	10.3%	20
2007		87%	13%	12.5%	0.74	9.3%	20
2008		88%	12%	11.0%	0.72	7.9%	10
2009		90%	10%	9.0%	0.70	6.3%	10
2010		92%	8%	7.0%	0.68	4.8%	10
2011		94%	6%	5.0%	0.66	3.3%	10
2012		96%	4%	3.0%	0.64	1.9%	0
2013		98%	2%	1.0%	0.62	0.6%	0
2014		100%	0%	-1.0%	0.61	-0.6%	0
2015		102%	-2%	-3.0%	0.59	-1.8%	0
2016		104%	-4%	-5.0%	0.57	-2.9%	0
2017	recovery complete	106%	-6%	-6.0%	0.55	-3.3%	10

Total Discounted effective acre-years lost = 1030

HEA Analysis for the Northern Woodlots
Service Increases due to Replacement Project

Year	Project Status	% Service Level Change	Avg. Annual % Change	Discount Factor	Effective Acre-Yrs/Acre
2002	primary restoration	83%	83.8%	0.86	1
2003	recovery begins	83%	84.5%	0.84	1
2004		84%	85.5%	0.81	1
2005		85%	85.5%	0.79	1
2006		86%	86.5%	0.77	1
2007		87%	87.5%	0.74	1
2008		88%	89.0%	0.72	1
2009		90%	91.0%	0.70	1
2010		92%	93.0%	0.68	1
2011		94%	95.0%	0.66	1
2012		96%	97.0%	0.64	1
2013		98%	99.0%	0.62	1
2014		100%	101.0%	[illegible]	1
2015		102%	103.0%	[illegible]	1
2016		104%	105.0%	0.57	1
2017	recovery complete	106%	106.0%	0.55	1
2018	to infinity	106%	106.0%	na	21

Total gain in discounted effective acre-years/acre = 33

Compensatory Restoration Project:

Present discounted interim loss in effective acre-years (L) = 1030

Present discounted gain in effective acre-years/acre (G) = 33

Acres of replacement habitat required for compensation (R, R=L/G) = 31

Total restoration acreage required = 50

Related Information

Total acres of north woodlot habitat = 162

Acres of revegetation for the primary restoration project = 15

Annual discount rate = 3.00%

Note: calculations are subject to rounding discrepancies, since impacted acres and total restoration required are rounded to the nearest 10-acre

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Table 3

HEA Analysis for the Southern Pines and Waste Units

Interim Losses due to Southern Pines and Waste Units Habitat Injury

Year	Project Status	% Service Level	% Service Loss	Avg. Annual % Loss	Discount Factor	Avg. Service Loss/Acre	Effective Acres Lost
1952		100%	0%	1.0%	3.78	3.8%	0
1953	injury begins	98%	2%	3.0%	3.67	11.0%	10
1954		96%	4%	5.0%	3.56	17.8%	10
1955		94%	6%	7.0%	3.46	24.2%	20
1956		92%	8%	9.0%	3.36	30.2%	20
1957		90%	10%	11.0%	3.26	35.9%	20
1958		88%	12%	13.0%	3.17	41.2%	30
1959		86%	14%	14.5%	3.07	44.6%	30
1960		85%	15%	15.0%	2.99	44.8%	30
1961		85%	15%	15.0%	2.90	43.5%	30
1962		85%	15%	15.0%	2.81	42.2%	30
1963		85%	15%	15.0%	2.73	41.0%	30
1964		85%	15%	15.0%	2.65	39.8%	30
1965	construction of disposal facilities	85%	15%	19.0%	2.58	48.9%	30
1966	active fly ash pile installed	77%	23%	23.0%	2.50	57.5%	40
1967		77%	23%	23.0%	2.43	55.8%	40
1968		77%	23%	23.0%	2.36	54.2%	40
1969		77%	23%	22.5%	2.29	51.5%	30
1970	successional growth in S W U	78%	22%	21.5%	2.22	47.8%	30
1971		79%	21%	20.5%	2.16	44.2%	30
1972	south pine plantation planted	80%	20%	19.5%	2.09	40.8%	30
1973		81%	19%	18.5%	2.03	37.6%	20
1974		82%	18%	17.5%	1.97	34.5%	20
1975		83%	17%	16.5%	1.92	31.6%	20
1976		84%	16%	15.5%	1.86	28.8%	20
1977		85%	15%	14.5%	1.81	26.2%	20
1978		86%	14%	13.5%	1.75	23.7%	20
1979		87%	13%	13.0%	1.70	22.1%	10
1980		87%	13%	13.0%	1.65	21.5%	10
1981		87%	13%	13.0%	1.60	20.9%	10
1982		87%	13%	13.0%	1.56	20.3%	10
1983		87%	13%	13.0%	1.51	19.7%	10
1984		87%	13%	13.0%	1.47	19.1%	10
1985		87%	13%	13.0%	1.43	18.5%	10
1986		87%	13%	12.0%	1.38	16.6%	10
1987	SPP habitat increase	89%	11%	11.0%	1.34	14.8%	10
1988		89%	11%	11.0%	1.30	14.4%	10
1989		89%	11%	11.0%	1.27	13.9%	10
1990		89%	11%	11.0%	1.23	13.5%	10
1991		89%	11%	12.0%	1.19	14.3%	10
1992	cleaning for Met. tower	87%	13%	13.0%	1.16	15.1%	10
1993		87%	13%	13.0%	1.13	14.6%	10
1994		87%	13%	14.0%	1.09	15.3%	10
1995	cleaning for Bldg. 45 access road	85%	15%	15.0%	1.06	15.9%	10
1996		85%	15%	25.5%	1.03	26.3%	20
1997	excavation, instal. of haul road	64%	36%	36.0%	1.00	36.0%	20
1998		64%	36%	36.0%	0.97	35.0%	20
1999		64%	36%	36.0%	0.94	33.9%	20
2000		64%	36%	36.0%	0.92	32.9%	20
2001	primary restoration	64%	36%	35.0%	0.89	31.1%	20
2002	recovery begins	66%	34%	33.0%	0.86	28.5%	20
2003		68%	32%	31.0%	0.84	26.0%	20
2004		70%	30%	29.0%	0.81	23.6%	20
2005		72%	28%	27.0%	0.79	21.3%	10
2006		74%	26%	25.0%	0.77	19.2%	10
2007		76%	24%	23.0%	0.74	17.1%	10
2008		78%	22%	21.0%	0.72	15.2%	10
2009		80%	20%	19.5%	0.70	13.7%	10
2010		81%	19%	18.5%	0.68	12.6%	10
2011		82%	18%	17.5%	0.66	11.6%	10
2012		83%	17%	16.5%	0.64	10.6%	10
2013		84%	16%	15.5%	0.62	9.7%	10
2014		85%	15%	13.5%	0.61	8.2%	10
2015		88%	12%	11.0%	0.59	6.5%	0
2016		90%	10%	9.0%	0.57	5.1%	0
2017		92%	8%	7.0%	0.55	3.9%	0
2018		94%	6%	5.0%	0.54	2.7%	0
2019		96%	4%	3.0%	0.52	1.6%	0
2020		98%	2%	1.0%	0.51	0.5%	0
2021	recovery complete	100%	0%	0.0%	0.49	0.0%	0

Total Discounted effective acre-years lost = 1130

HEA Analysis for the Southern Pines and Waste Units

Service Increases due to Replacement Project

Year	Project Status	% Service Level Change	Avg. Annual % Change	Discount Factor	Effective Acre-Yrs/Acre
2001	primary restoration	73%	73.0%	0.89	1
2002	recovery begins	73%	73.5%	0.86	1
2003		74%	74.5%	0.84	1
2004		75%	75.5%	0.81	1
2005		76%	76.5%	0.79	1
2006		77%	77.5%	0.77	1
2007		78%	78.5%	0.74	1
2008		79%	79.5%	0.72	1
2009		80%	80.5%	0.70	1
2010		81%	81.5%	0.68	1
2011		82%	82.5%	0.66	1
2012		83%	83.5%	0.64	1
2013		84%	84.5%	0.62	1
2014		85%	86.5%	0.61	1
2015		88%	89.0%	0.59	1
2016		90%	91.0%	0.57	1
2017		92%	93.0%	0.55	1
2018		94%	95.0%	0.54	1
2019		96%	97.0%	0.52	1
2020		98%	99.0%	0.51	1
2021	recovery complete	100%	100.0%	0.49	0
2022	to infinity	100%	100.0%	na	19

Total gain in discounted effective acre-years/acre = 31

Compensatory Restoration Project:

Present discounted interim loss in effective acre-years (L) = 1130

Present discounted gain in effective acre-years/acre (G) = 31

Acres of replacement habitat required for compensation (R, R=L/G) = 37

Total restoration acreage required = 60

Related information

Total acres of southern pines and waste units habitat = 66

Acres of revegetation for the primary restoration project = 22

Annual discount rate = 3.00%

Note: calculations are subject to rounding discrepancies, since impacted acres and total restoration required are rounded to the nearest 10-acre

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Table 4

HEA Analysis for the Grasslands
Interim Losses due to Grasslands Habitat Injury

Year	Project Status	% Service Level	% Service Loss	Avg. Annual % Loss	Discount Factor	Avg. Service Loss/Acre	Effective Acres Lost
1952		100%	0%	0.5%	3.78	1.9%	0
1953	injury begins	99%	1%	1.5%	3.67	5.5%	10
1954		98%	2%	2.0%	3.56	7.1%	20
1955		98%	2%	2.0%	3.46	6.9%	20
1956		98%	2%	2.0%	3.36	6.7%	20
1957		98%	2%	2.0%	3.26	6.5%	20
1958		98%	2%	2.0%	3.17	6.3%	10
1959		98%	2%	3.0%	3.07	9.2%	20
1960	use of trap range initiated	96%	4%	4.0%	2.99	11.9%	30
1961		96%	4%	4.0%	2.90	11.6%	30
1962		96%	4%	4.0%	2.81	11.3%	30
1963		96%	4%	4.0%	2.73	10.9%	30
1964		96%	4%	4.0%	2.65	10.6%	20
1965		96%	4%	4.0%	2.58	10.3%	20
1966		96%	4%	4.0%	2.50	10.0%	20
1967		96%	4%	4.0%	2.43	9.7%	20
1968		96%	4%	4.0%	2.36	9.4%	20
1969		96%	4%	4.0%	2.29	9.2%	20
1970		96%	4%	4.0%	2.22	8.9%	20
1971		96%	4%	4.0%	2.16	8.6%	20
1972		96%	4%	4.0%	2.09	8.4%	20
1973		96%	4%	4.0%	2.03	8.1%	20
1974		96%	4%	4.0%	1.97	7.9%	20
1975		96%	4%	4.0%	1.92	7.7%	20
1976		96%	4%	4.0%	1.86	7.4%	20
1977		96%	4%	4.0%	1.81	7.2%	20
1978		96%	4%	4.0%	1.75	7.0%	20
1979		96%	4%	4.0%	1.70	6.8%	20
1980		96%	4%	4.0%	1.65	6.6%	20
1981		96%	4%	4.0%	1.60	6.4%	20
1982		96%	4%	4.0%	1.56	6.2%	10
1983		96%	4%	4.0%	1.51	6.1%	10
1984		96%	4%	4.0%	1.47	5.9%	10
1985		96%	4%	4.0%	1.43	5.7%	10
1986		96%	4%	4.0%	1.38	5.5%	10
1987		96%	4%	4.0%	1.34	5.4%	10
1988		96%	4%	4.0%	1.30	5.2%	10
1989		96%	4%	4.0%	1.27	5.1%	10
1990		96%	4%	4.0%	1.23	4.9%	10
1991		96%	4%	4.5%	1.19	5.4%	10
1992	Removal Action No. 14	95%	5%	4.5%	1.16	5.2%	10
1993		96%	4%	4.0%	1.13	4.5%	10
1994		96%	4%	4.0%	1.09	4.4%	10
1995		96%	4%	20.0%	1.06	21.2%	50
1996	A1P1 excavation	64%	36%	36.0%	1.03	37.1%	90
1997		64%	36%	53.0%	1.00	53.0%	120
1998	A1P2 excavation	30%	70%	70.5%	0.97	68.4%	160
1999		29%	71%	71.5%	0.94	67.4%	160
2000		28%	72%	72.5%	0.92	66.3%	160
2001		27%	73%	79.5%	0.89	70.6%	170
2002	A2P2 excavation	14%	86%	86.5%	0.86	74.6%	180
2003		13%	87%	87.0%	0.84	72.9%	170
2004		13%	87%	87.0%	0.81	70.7%	170
2005	primary restoration	13%	87%	83.5%	0.79	65.9%	150
2006	recovery begins	20%	80%	65.0%	0.77	49.8%	120
2007		50%	50%	37.5%	0.74	27.9%	70
2008		75%	25%	12.5%	0.72	9.0%	20
2009		100%	0%	-5.0%	0.70	-3.5%	-10
2010	recovery complete	110%	-10%	-10.0%	0.68	-6.8%	-20

Total Discounted effective acre-years lost = 2490

HEA Analysis for the Grasslands
Service Increases due to Replacement Project

Year	Project Status	% Service Level Change	Avg. Annual % Change	Discount Factor	Effective Acre-Yrs/Acre
2005	primary restoration	12%	16.0%	0.79	0
2006	recovery begins	20%	35.0%	0.77	0
2007		50%	62.5%	0.74	0
2008		75%	87.5%	0.72	1
2009		100%	105.0%	0.70	1
2010	recovery complete	110%	110.0%	0.68	1
2011	to infinity	110%	110.0%	na	29

Total gain in discounted effective acre-years/acre = 32

Compensatory Restoration Project:

Present discounted interim loss in effective acre-years (L) = 2490

Present discounted gain in effective acre-years/acre (G) = 32

Acres of replacement habitat required for compensation (R, R=L/G) = 78

Total restoration acreage required = 280

Related Information

Total acres of grassland habitat = 235

Acres of revegetation for the primary restoration project = 204

Annual discount rate = 3.00%

Note: calculations are subject to rounding discrepancies, since impacted acres and total restoration required are rounded to the nearest 10-acre

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Table 5

HEA Analysis for the Waste Storage/Production Area
Interim Losses due to Production/Waste Storage Area Habitat Injury

Year	Project Status	% Service Level	% Service Loss	Avg. Annual % Loss	Discount Factor	Avg. Service Loss/Acre	Effective Acres Lost
1952		100%	0%	0.5%	3.78	1.9%	0
1953	injury begins	99%	1%	1.5%	3.67	5.5%	10
1954		98%	2%	2.5%	3.56	8.9%	20
1955		97%	3%	3.5%	3.46	12.1%	20
1956		96%	4%	4.5%	3.36	15.1%	30
1957		95%	5%	5.0%	3.26	16.3%	30
1958		95%	5%	5.0%	3.17	15.8%	30
1959		95%	5%	5.0%	3.07	15.4%	30
1960		95%	5%	5.0%	2.99	14.9%	30
1961		95%	5%	5.0%	2.90	14.5%	30
1962		95%	5%	5.0%	2.81	14.1%	20
1963		95%	5%	5.0%	2.73	13.7%	20
1964		95%	5%	5.0%	2.65	13.3%	20
1965		95%	5%	5.0%	2.58	12.9%	20
1966		95%	5%	5.0%	2.50	12.5%	20
1967		95%	5%	5.0%	2.43	12.1%	20
1968		95%	5%	5.0%	2.36	11.8%	20
1969		95%	5%	5.0%	2.29	11.4%	20
1970		95%	5%	5.0%	2.22	11.1%	20
1971		95%	5%	5.0%	2.16	10.8%	20
1972		95%	5%	5.0%	2.09	10.5%	20
1973		95%	5%	5.0%	2.03	10.2%	20
1974		95%	5%	5.0%	1.97	9.9%	20
1975		95%	5%	5.0%	1.92	9.6%	20
1976		95%	5%	5.0%	1.86	9.3%	20
1977		95%	5%	5.0%	1.81	9.0%	20
1978		95%	5%	5.0%	1.75	8.8%	20
1979		95%	5%	5.0%	1.70	8.5%	10
1980		95%	5%	5.0%	1.65	8.3%	10
1981		95%	5%	5.0%	1.60	8.0%	10
1982		95%	5%	5.0%	1.56	7.8%	10
1983		95%	5%	5.0%	1.51	7.6%	10
1984		95%	5%	5.0%	1.47	7.3%	10
1985		95%	5%	5.0%	1.43	7.1%	10
1986		95%	5%	5.0%	1.38	6.9%	10
1987		95%	5%	5.0%	1.34	6.7%	10
1988		95%	5%	5.0%	1.30	6.5%	10
1989		95%	5%	5.0%	1.27	6.3%	10
1990		95%	5%	5.0%	1.23	6.1%	10
1991		95%	5%	5.0%	1.19	6.0%	10
1992		95%	5%	5.0%	1.16	5.8%	10
1993		95%	5%	5.0%	1.13	5.6%	10
1994		95%	5%	5.0%	1.09	5.5%	10
1995		95%	5%	5.0%	1.06	5.3%	10
1996		95%	5%	5.0%	1.03	5.2%	10
1997		95%	5%	5.0%	1.00	5.0%	10
1998		95%	5%	7.5%	0.97	7.3%	10
1999	excavation	90%	10%	10.5%	0.94	9.9%	20
2000		89%	11%	11.0%	0.92	10.1%	20
2001		89%	11%	11.0%	0.89	9.8%	20
2002		89%	11%	11.0%	0.86	9.5%	20
2003		89%	11%	11.0%	0.84	9.2%	20
2004		89%	11%	11.0%	0.81	8.9%	20
2005	primary restoration	89%	11%	11.0%	0.79	8.7%	20
2006	recovery begins	89%	11%	10.5%	0.77	8.0%	10
2007		90%	10%	10.0%	0.74	7.4%	10
2008		90%	10%	10.0%	0.72	7.2%	10
2009		90%	10%	10.0%	0.70	7.0%	10
2010		90%	10%	10.0%	0.68	6.8%	10
2011		90%	10%	7.5%	0.66	5.0%	10
2012		95%	5%	5.0%	0.64	3.2%	10
2013		95%	5%	5.0%	0.62	3.1%	10
2014		95%	5%	5.0%	0.61	3.0%	10
2015		95%	5%	5.0%	0.59	2.9%	10
2016		95%	5%	2.5%	0.57	1.4%	0
2017		100%	0%	-2.5%	0.55	-1.4%	0
2018		105%	-5%	-7.5%	0.54	-4.0%	-10
2019		110%	-10%	-12.5%	0.52	-6.5%	-10
2020	recovery complete	115%	-15%	-15.0%	0.51	-7.6%	-10

Total Discounted effective acre-years lost = 980

HEA Analysis for the Waste Storage/Production Area
Service Increases due to Replacement Project

Year	Project Status	% Service Level Change	Avg. Annual % Change	Discount Factor	Effective Acre-Yrs/Acre
2005	primary restoration	89%	89.0%	0.79	1
2006	recovery begins	89%	89.5%	0.77	1
2007		90%	90.0%	0.74	1
2008		90%	90.0%	0.72	1
2009		90%	90.0%	0.70	1
2010		90%	90.0%	0.68	1
2011		90%	92.5%	0.66	1
2012		95%	95.0%	0.64	1
2013		95%	95.0%	0.62	1
2014		95%	95.0%	0.61	1
2015		95%	95.0%	0.59	1
2016		95%	97.5%	0.57	1
2017		100%	102.5%	0.55	1
2018		105%	107.5%	0.54	1
2019		110%	112.5%	0.52	1
2020	recovery complete	115%	115.0%	0.51	1
2021	to infinity	115%	100.0%	na	22

Total gain in discounted effective acre-years/acre = 32

Compensatory Restoration Project:

Present discounted interim loss in effective acre-years (L) = 980

Present discounted gain in effective acre-years/acre (G) = 32

Acres of replacement habitat required for compensation (R, R=L/G) = 30

Total restoration acreage required = 50

Related Information

Total acres of production area/waste storage area habitat = 173

Acres of revegetation for the primary restoration project = 15

Annual discount rate = 3.00%

Note: calculations are subject to rounding discrepancies, since impacted acres and total restoration required are rounded to the nearest 10-acre

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Table 6

HEA Analysis for the Great Miami River
Interim loss and resulting restoration acreage required

Year	Project Status	% Service Level	% Service Loss	Avg Annual % Loss	Discount Factor	vg. Service Loss/Acre	Effective Acres Lost
1952	kg U released from site 11	100%	0%	0 0%	3.78	0 0%	0
1953	106	100%	0%	0 0%	3 67	0 0%	0
1954	347	100%	0%	0 5%	3 56	1 8%	0
1955	657	99%	1%	1 0%	3 46	3 5%	0
1956	1485	99%	1%	2 0%	3 36	6 7%	0
1957	2595	97%	3%	3 5%	3 26	11 4%	0
1958	3641	96%	4%	5 5%	3 17	17 4%	1
1959	6388	93%	7%	5 5%	3 07	16 9%	1
1960	4445	96%	4%	4 5%	2 99	13 4%	0
1961	5386	95%	5%	4 5%	2 90	13 0%	0
1962	3543	96%	4%	4 0%	2 81	11 3%	0
1963	4466	96%	4%	7 0%	2 73	19 1%	1
1964	10304	90%	10%	7 0%	2 65	18 6%	1
1965	3630	96%	4%	4 0%	2 58	10 3%	0
1966	3640	96%	4%	3 0%	2 50	7 5%	0
1967	2305	98%	2%	2 0%	2 43	4 9%	0
1968	1855	98%	2%	2 0%	2 36	4 7%	0
1969	2290	98%	2%	2 0%	2 29	4 6%	0
1970	1914	98%	2%	2.0%	2 22	4.4%	0
1971	1637	98%	2%	1.5%	2.16	3.2%	0
1972	1140	99%	1%	1 0%	2 09	2.1%	0
1973	1126	99%	1%	1 0%	2.03	2 0%	0
1974	1066	99%	1%	1.5%	1 97	3 0%	0
1975	1852	98%	2%	1.5%	1 92	2 9%	0
1976	875	99%	1%	1.0%	1 86	1 9%	0
1977	179	99%	1%	1 0%	1 81	1 8%	0
1978	965	99%	1%	1.0%	1.75	1 8%	0
1979	880	99%	1%	1 0%	1 70	1 7%	0
1980	1175	99%	1%	1 0%	1 65	1.7%	0
1981	685	99%	1%	1 0%	1 60	1 6%	0
1982	576	99%	1%	1 0%	1 56	1 6%	0
1983	755	99%	1%	1 0%	1 51	1 5%	0
1984	564	99%	1%	1 0%	1 47	1 5%	0
1985	1054	99%	1%	1 0%	1 43	1 4%	0
1986		99%	1%	1 0%	1 38	1 4%	0
1987		99%	1%	1 0%	1.34	1 3%	0
1988	SER results 858	99%	1%	1 0%	1 30	1 3%	0
1989	841	99%	1%	1.0%	1 27	1 3%	0
1990	786	99%	1%	1.0%	1 23	1 2%	0
1991	810	99%	1%	1 0%	1 19	1 2%	0
1992	595	99%	1%	5.0%	1 16	5 8%	0
1993	~583, outfall line riprap upgrade	91%	9%	5.0%	1 13	5.6%	0
1994	460	99%	1%	1.0%	1 09	1 1%	0
1995	310	99%	1%	1 0%	1 06	1 1%	0
1996	297	99%	1%	1 0%	1 03	1 0%	0
1997	391	99%	1%	1 0%	1 00	1 0%	0
1998		99%	1%	1 0%	0 97	1 0%	0
1999		99%	1%	1 0%	0 94	0 9%	0
2000		99%	1%	1 0%	0 92	0 9%	0
2001		99%	1%	1 0%	0 89	0 9%	0
2002		99%	1%	1.0%	0.86	0.9%	0
2003		99%	1%	1 0%	0 84	0 8%	0
2004		99%	1%	0 7%	0 81	0.5%	0
2005		99%	1%	0 5%	0.79	0.4%	0
2006	remedial action complete	100%	0%	0 0%	0.77	0.0%	0

Total Discounted effective acre-years lost and restoration acreage required = 10

Effective acres lost are based on 3 22 total acres, from an estimated 2 97 acres of stream habitat and 0 25 acres of riparian habitat by the outfall line

Percent service level is estimated at a 1% reduction for every 1,000 kg uranium released into the Great Miami River from the FEMP

1993 percent service level is estimated at 91% based on an 8% reduction due to the contaminated riprap BMP (0 25/3.22) and the estimated 550 kg of uranium relaeased int the Great Miami River

Note: calculations are subject to rounding discrepancies, since impacted acres and total restoration required are rounded to the nearest 10-acre

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Exhibit
20/38)

Exhibit B (11/6/51)

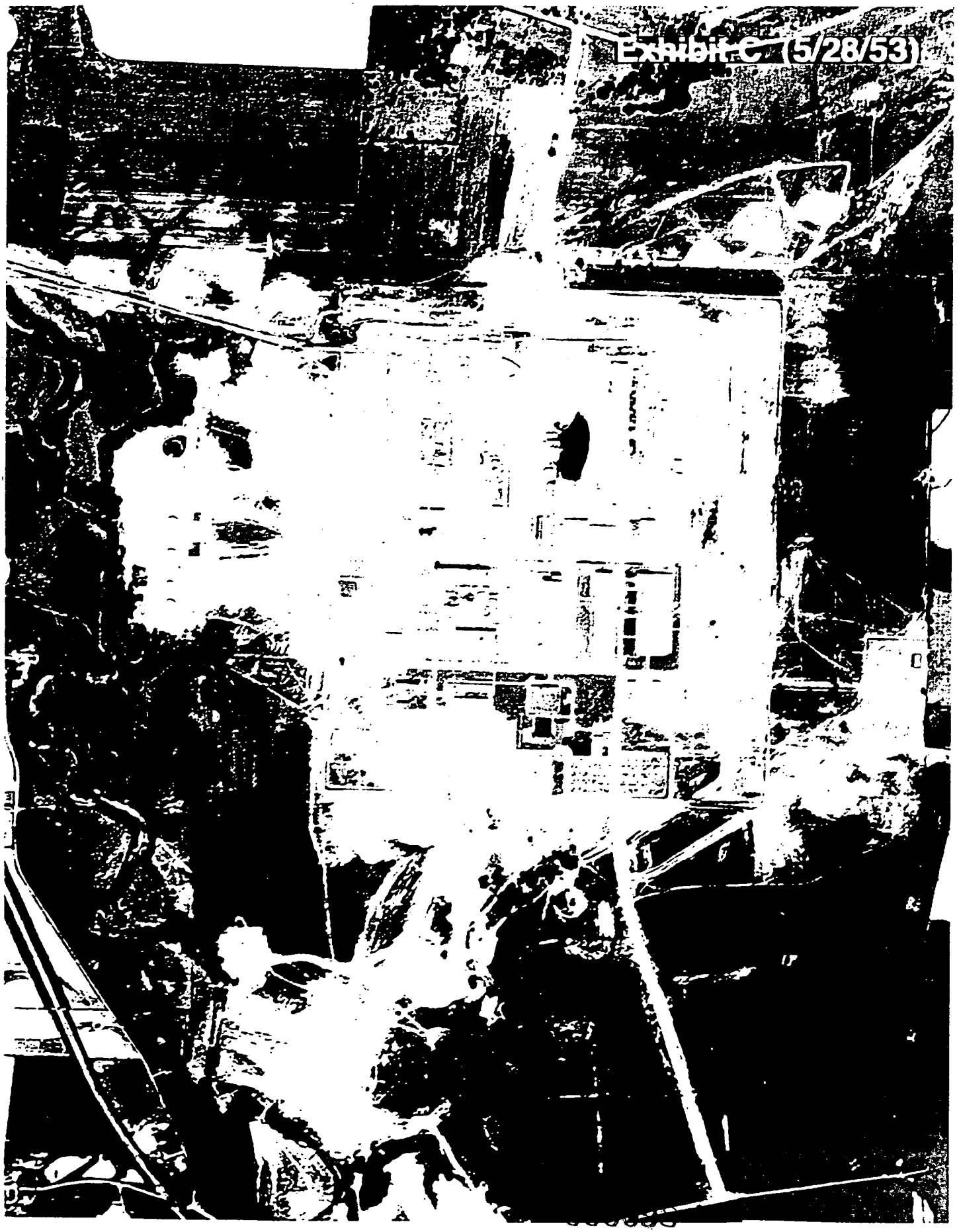
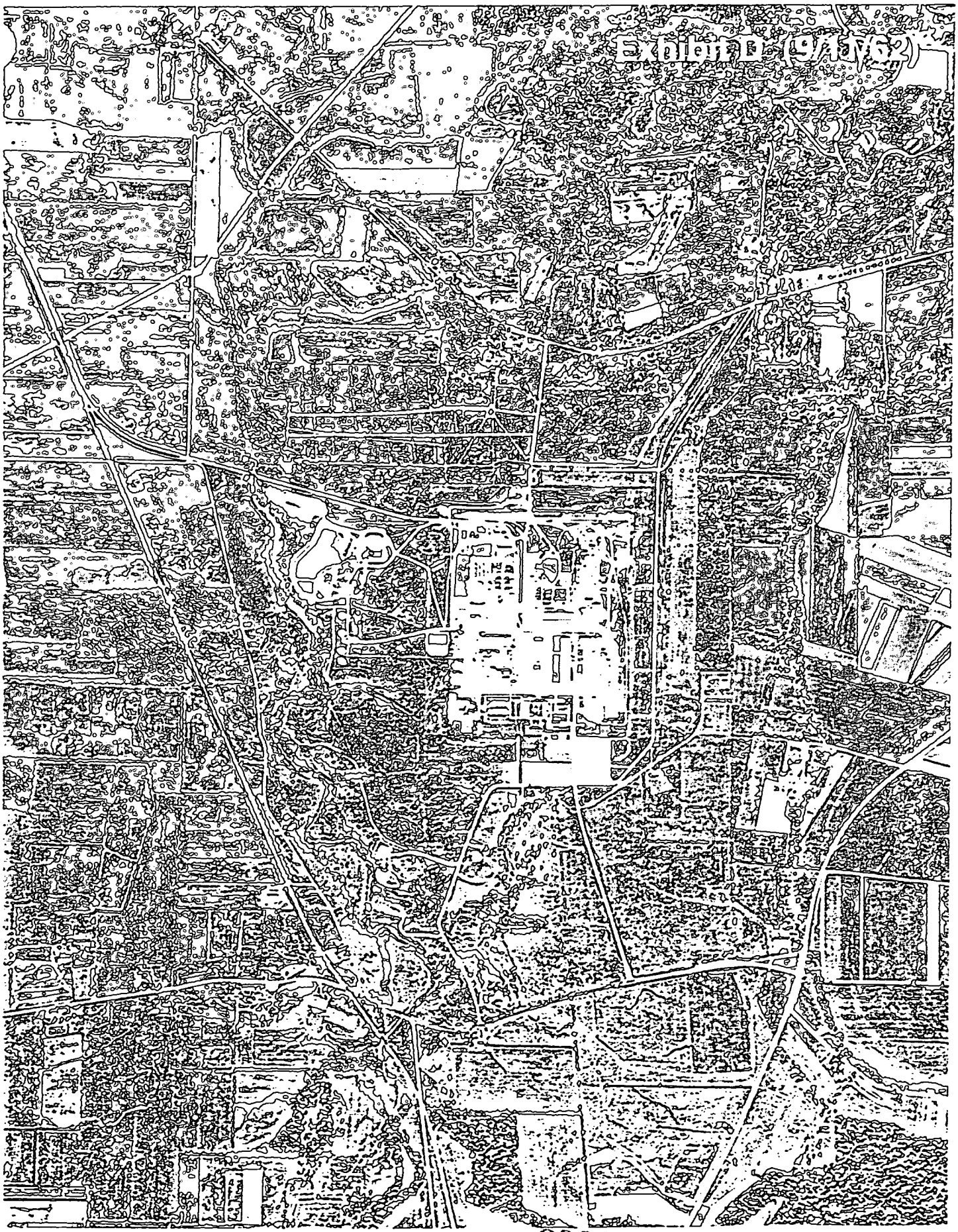


Exhibit C (5/28/53)

C.T (3/21/57)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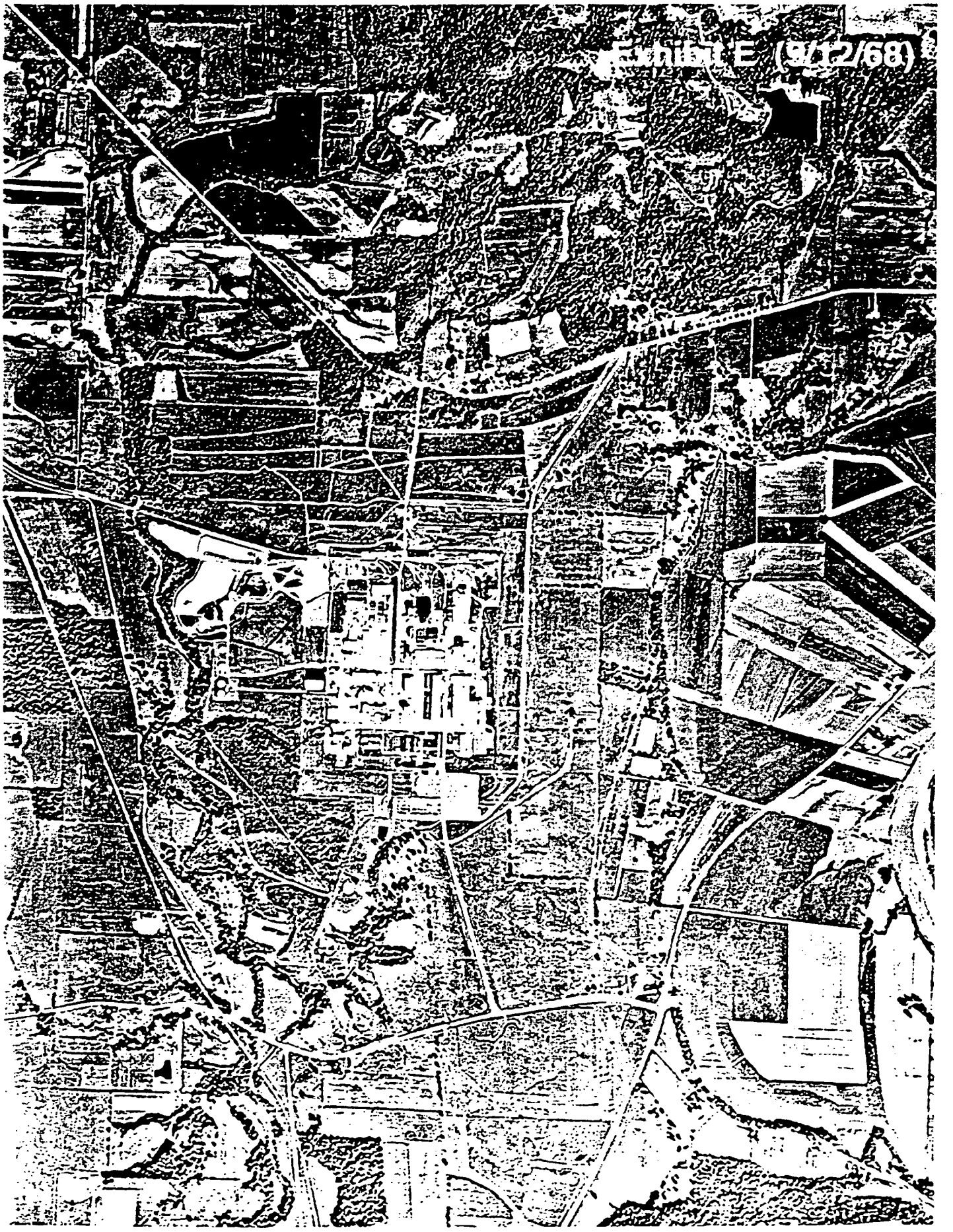

(9/2/68)

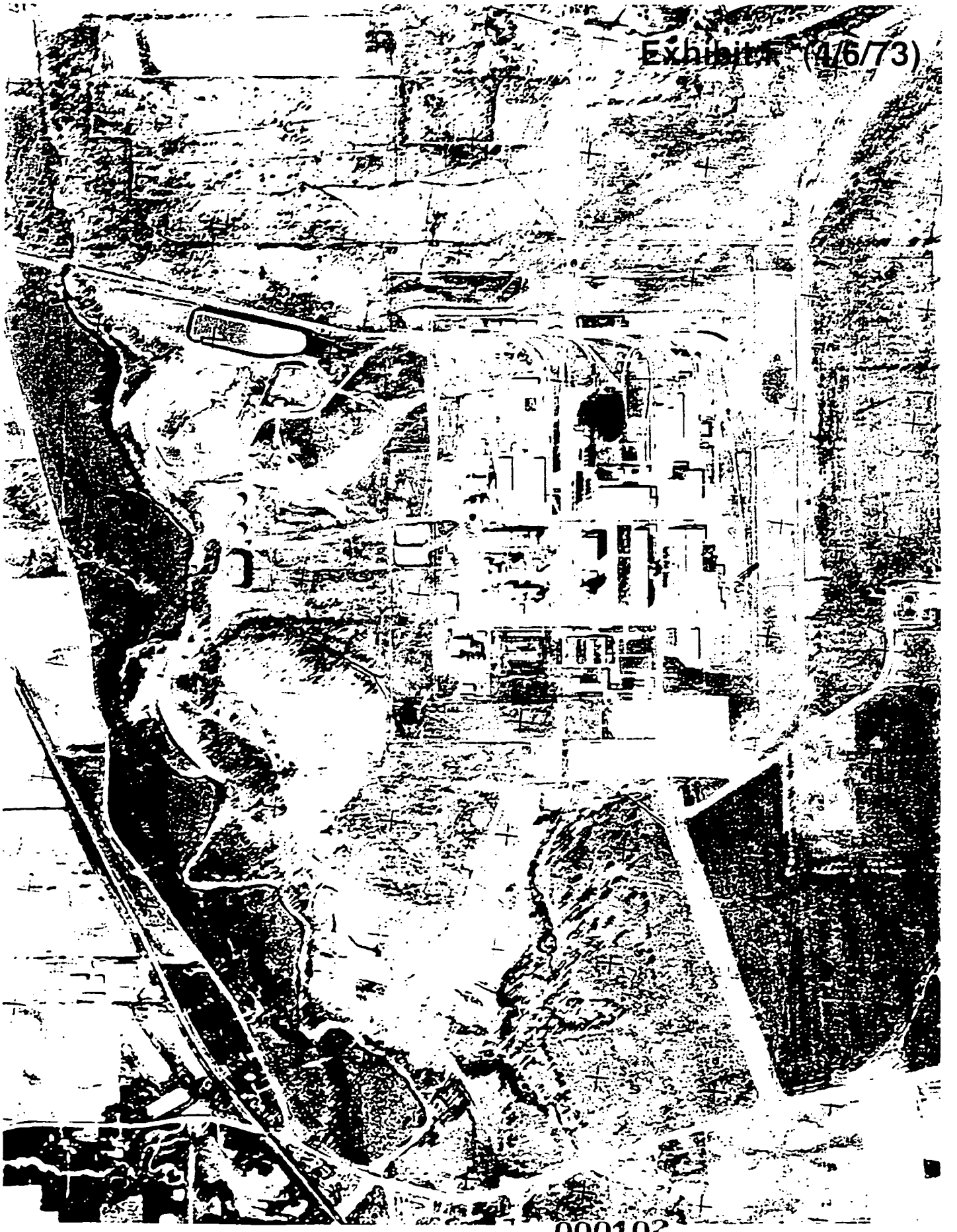
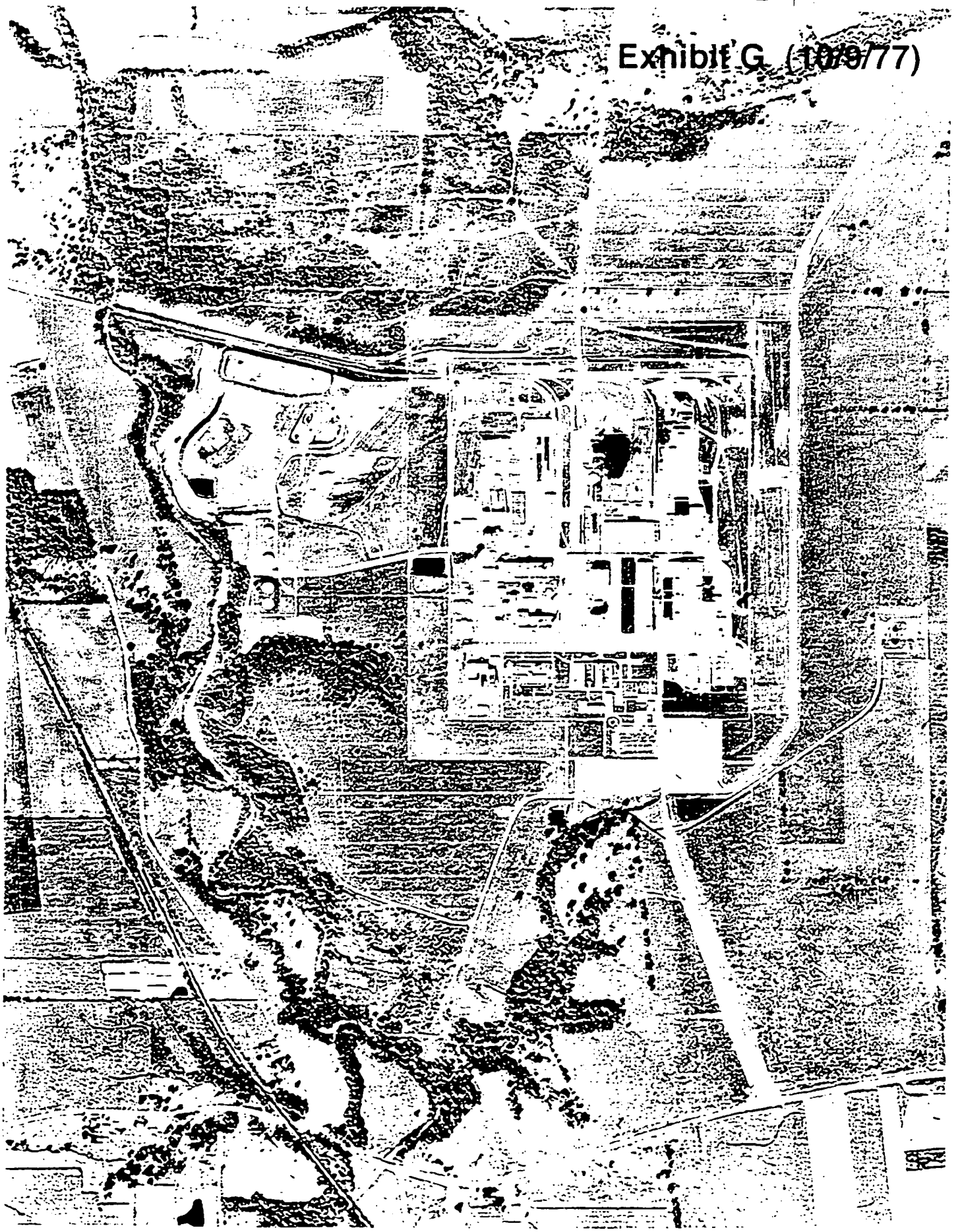
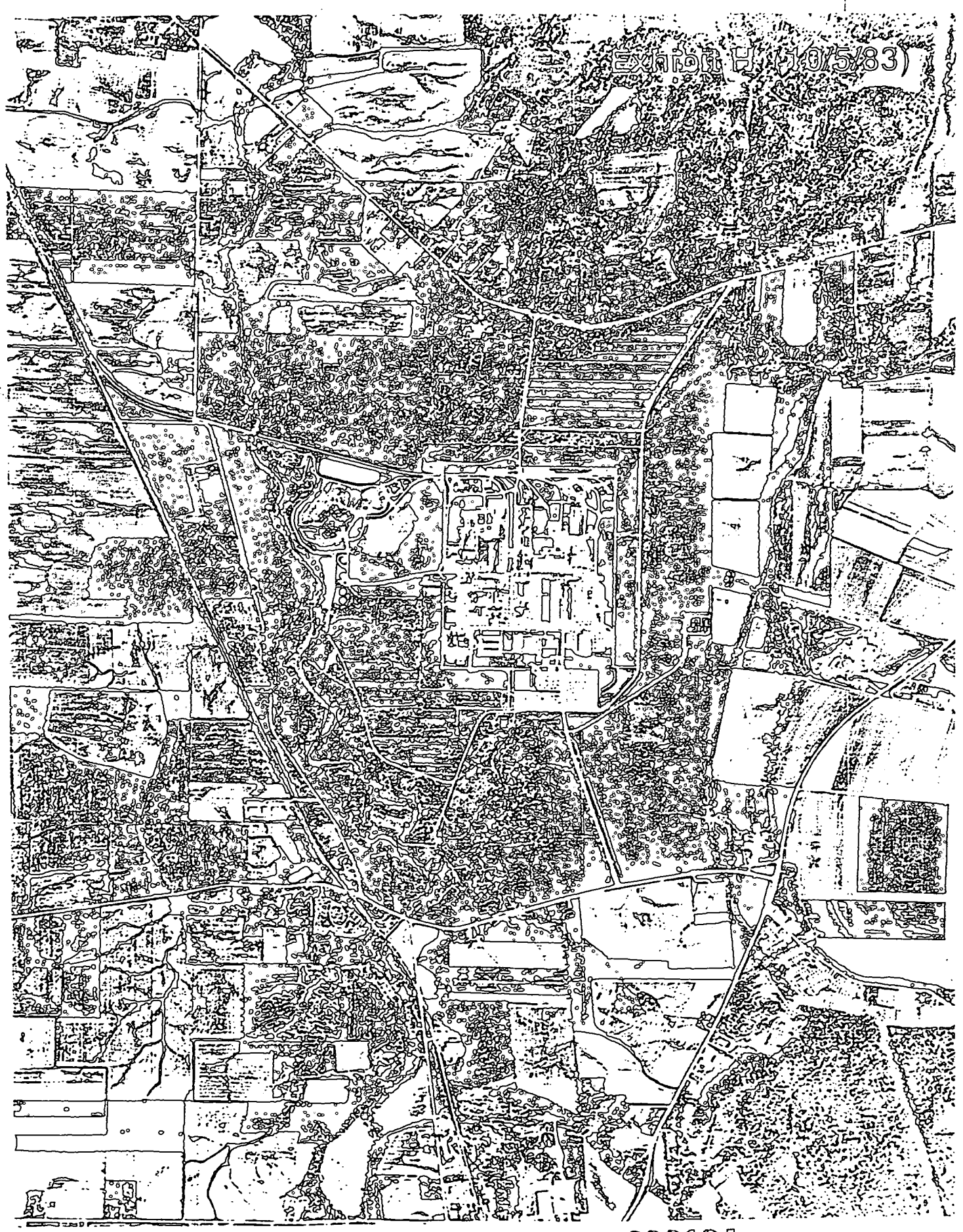


Exhibit K (4/6/73)

Exhibit G (10/9/77)

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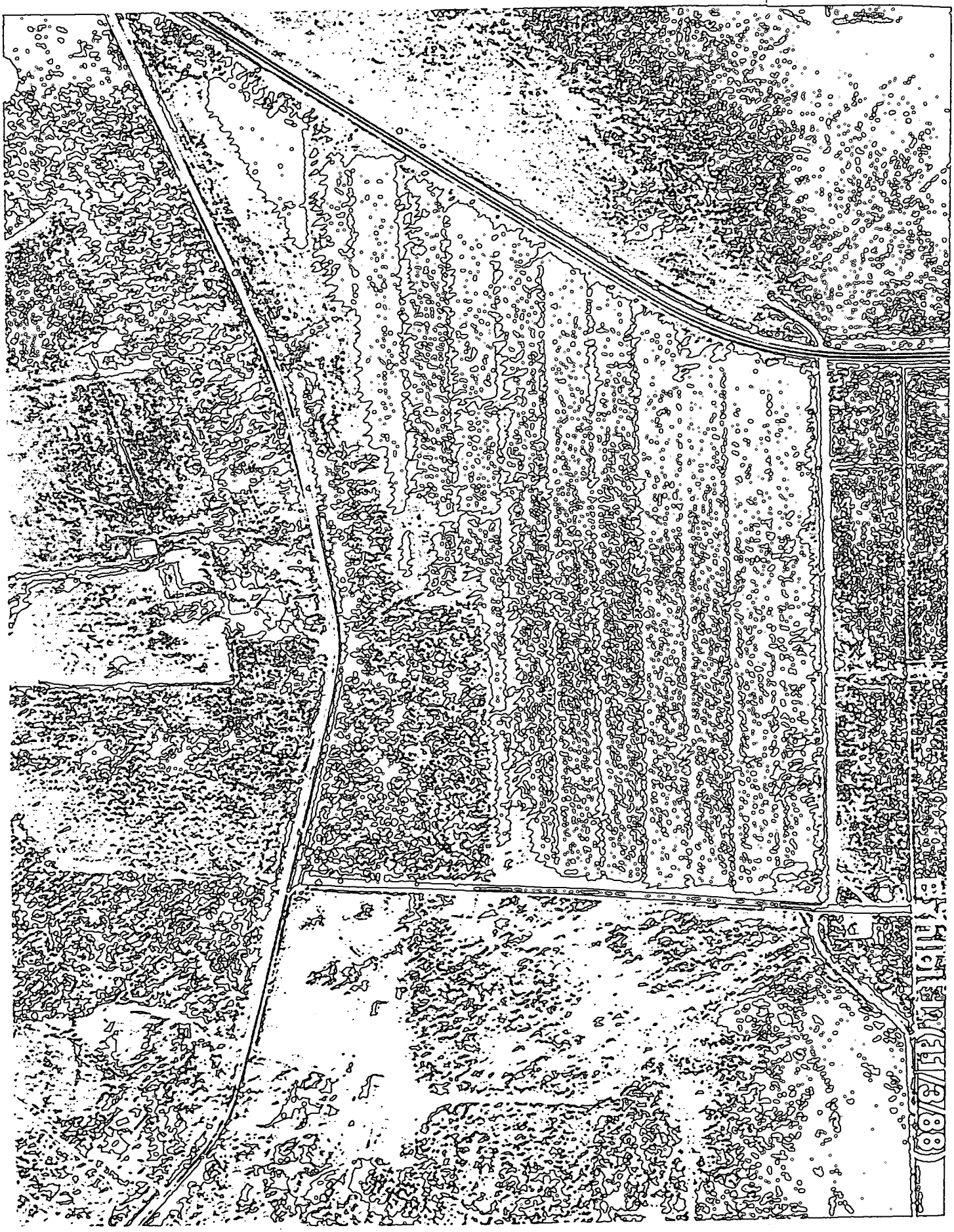

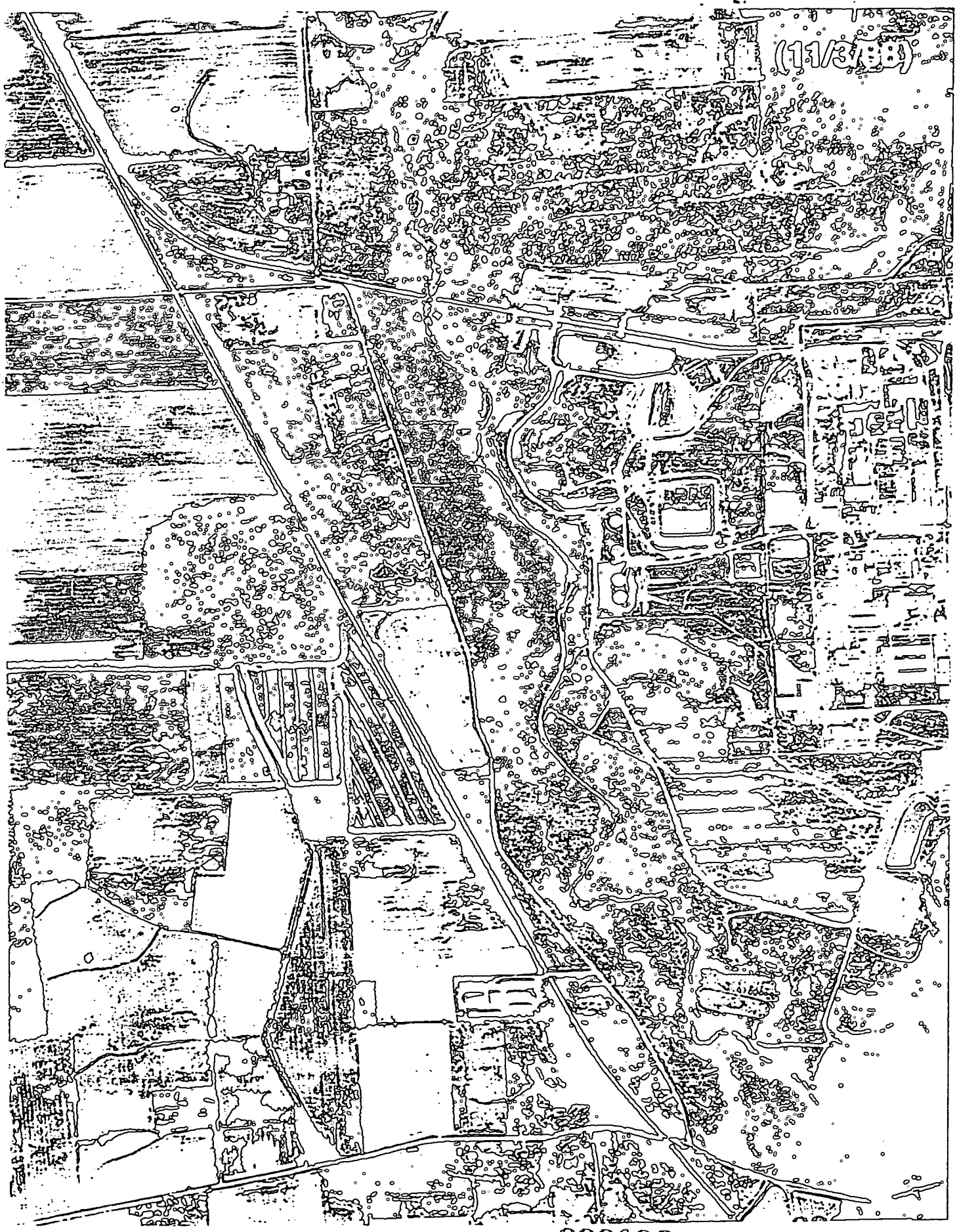

ADDENDUM C

WATER AVAILABILITY STUDY

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WATER AVAILABILITY STUDY

FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

PREPARED BY

BROWN & ROOT ENVIRONMENTAL

661 Andersen Drive

Pittsburgh, PA 15220

JULY 1, 1997

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EXECUTIVE SUMMARY

This study is intended to provide quantitative modeling results regarding the surface water routing for the four ponds under post-remediation conditions at Fernald Environmental Management Project (FEMP) site. The modeling results support the goal for natural resources restoration in the context of on-property open water/wetland habitats. As part of the site-wide restoration plan, four on-property open water areas are to be established in the former production area and its vicinity as a result of soil excavation activities. The integration of the ponds will provide open water areas for surface water habitats, and will provide sediment detention from activities such as remediation, construction, and excavation.

To ensure the engineering control and suitability of the ponds, storage routing modeling must be performed to assist understanding of the relationship of storage-stage-discharge of ponds. This engineering analysis is required to be analyzed under both normal conditions and extreme conditions. The normal conditions can be represented by considering the monthly average meteorological record, while the extreme conditions can be simulated by a storm event. The peak inflow rates generated by a storm event were modeled by using the TR55 method that is suitable for a small watershed. The characteristic storm typically considered in the TR55 method is a storm with 25-year return period and 24-hour duration.

Prior to the formulation of the routing model, the subbasin areas and drainage areas were first established. The storage routing model was then implemented secondly based on the conservation of mass, assuming that the rate of change of storage equals to the difference between the inflow and outflow. Water input to the ponds are rainfall and storm runoff. Outflow from the ponds are evaporation, infiltration loss through pond liner materials, and overflow from the weirs. The simulation time used was four years for normal conditions to reach an equilibrium state. In order for the model to be conservative for the extreme conditions, the initial storage of the ponds has incorporated the maximum storage volume predicted under normal conditions.

The routing modeling results indicated that the maximum and average depths of the ponds are constantly below the top edge of the ponds under both normal and extreme conditions. These results are based on allowing overflow when the pool level exceeds the designed overflow bottom elevation. Normally, the pool level in Pond 1 is the highest since it has a larger drainage area. Excess runoff from Pond 1 is allowed to be discharged to the Storm Sewer Outfall Ditch (SSOD). Excess water is also allowed to be drained from Pond 2 to Pond 4 through an open channel. The final outfall point for stormwater runoff routing through

Pond 1, Pond 3, and Pond 4 are the SSOD, which drains to Paddy's Run and eventually to the Great Miami River.

The maximum water depths estimated for the four ponds, when the peak inflow rates appear under the extreme conditions are approximately 19.1, 17.7, 14.1, and 25.5 feet respectively. At the same time, the average water depths estimated for the four ponds are 8.4, 10.7, 4.2, and 14.9 feet respectively. The corresponding maximum water surface acreage computed for the four ponds are 13.34, 14.0, 12.9, and 4.12 acres respectively. Also, the average water surface acreage computed for the four ponds are 13.03, 13.85, 12.0, and 4.02 acres respectively.

Based on the modeling results, it is suggested that an underground pipe be connected between Pond 1 and Pond 2. This connection will greatly improve the regulation of water storage between Pond 1 and Pond 2. This is because Pond 2 has a much larger capacity with approximately seven feet of freeboard under all conditions considered.

1.0 INTRODUCTION

This study is intended is to provide quantitative modeling results concerning the surface water routing for the four ponds under post-remediation conditions at Fernald Environmental Management Project (FEMP) site. The modeling results support the goal for natural resources restoration in the context of on-property open water/wetland habitats. These ponds are established as a result of soil remediation activities in the former production area and its vicinities within the FEMP site. The hydrologic conditions of ponds were modeled under normal climate conditions as well as storm event conditions. To achieve the goal of restoring natural resources, a comprehensive site-wide restoration plan is in the process of being implemented when excavation of contaminated soil at FEMP site is completed. As part of the restoration plan, four on-property ponds are to be established in the southern portion of the former production area. The integration of ponds will provide open water areas for surface water habitats, and will provide sediment detention from activities such as remediation, construction, and excavation.

1.1 SITE BACKGROUND

The U.S. Department of Energy's (DOE) FEMP site occupies 1,050 acres in rural southwestern Ohio, approximately 18 miles northwest of downtown Cincinnati, Ohio. The DOE's Fernald facility produced high-purity uranium metal products in support of the U.S. defense program from 1953 to 1989. Production was ceased in 1989, after the United States Environmental Protection Agency (USEPA) placed the sites on the National Priority List for remediation. Subsequently, the remedial efforts were initiated under the Comprehensive Environmental Response Compensation, and Liabilities Act (CERCLA).

The FEMP site is bounded by Paddys Run on the west, Willey Road to the south, and route 126 to the north. It is located at approximately 39°18' 06 " north latitude and 84°42' 30" west longitude. The site lies within the Great Miami River Drainage basin, with the Great Miami River flowing approximately 1.5 miles to the east.

For the remediation of contaminated soil in the shallow subsurface, it will be necessary to conduct site-wide soil excavation. This excavation plan will require the removal of approximately 20 feet of the contaminated soil delineated in the former production area and adjacent areas. The soils designated for remediation are mainly the gray clay at the base of the glacial overburden layer.

1.2 OBJECTIVES AND SCOPE

The primary purpose of the four on-property ponds is to restore the natural resources of surface water, and promote the land use for a natural park. To ensure the proper engineering control, storage routing modeling must be performed in assisting the understanding of the relationship of storage-stage-discharge of ponds. This engineering analysis is required for analyzing under both normal conditions and storm event conditions.

As indicated in the conceptual final land use, the developed park will be composed of a portion of open water surface areas, enhanced forest, and vegetated woodland adjacent to the open water areas (Figure 1-2). Based on the post-excavation site-wide grading map, the ponds will serve the purposes of runoff control through storage and routing the excess peak flow (Figure 1-1). The ponds will also provide open water space for surface water habitats. More specific objectives of the open water areas are:

- Controlling and storage of surface water runoff for the post-remediation conditions.
- Regulate the excess runoff during a storm event.
- Provide detention basins of sediment from soil remediation activities.
- Collecting the excess perched water near the former production area

1.3 OVERVIEW OF THE TECHNICAL PROCEDURES

The general technical steps for this pond modeling are briefly outlined as below:

- Investigation of the surface features for the post-excavation conditions.
- Delineation of the pond boundaries
- Delineation of outline of the pond water surface at 5-foot contour increments.
- Determination of subbasins that contribute surface runoff to the four pond areas.
- Estimation of drainage area for each individual pond.
- Determination of stage and storage relationship.

<u>Under Normal Conditions</u>

- Estimation of monthly mean rainfall depth.
- Estimation of monthly mean stormwater runoff depth.
- Estimation of monthly mean infiltration rates.
- Estimation of monthly mean evaporation rates.
- Assembling the reservoir routing model based on one month interval.

- Implementing the reservoir routing model with the four ponds linked together.

Under Extreme Conditions

Technical Release 55 (TR55) method was used to calculate the peak rate of discharge and hydrographs for floodwater ponds at FEMP site.

- Implementation of a conceptual model for subbasins and channels in relation to the watershed drainage path.
- Computation of peak inflow to the ponds generated by a 25-year frequency and 24-hour duration storm event.
- Generation of tabular hydrograph.
- Assembling the reservoir routing model based on six minutes time interval.
- Designing the hydraulic connections (discharging channel, and overflow weirs) between the ponds.
- Implementing the flood routing model with the four ponds linked together.
- Sizing of the discharging channel.
- Determination of the adequacy in hydraulic design and planning based on the modeling results.

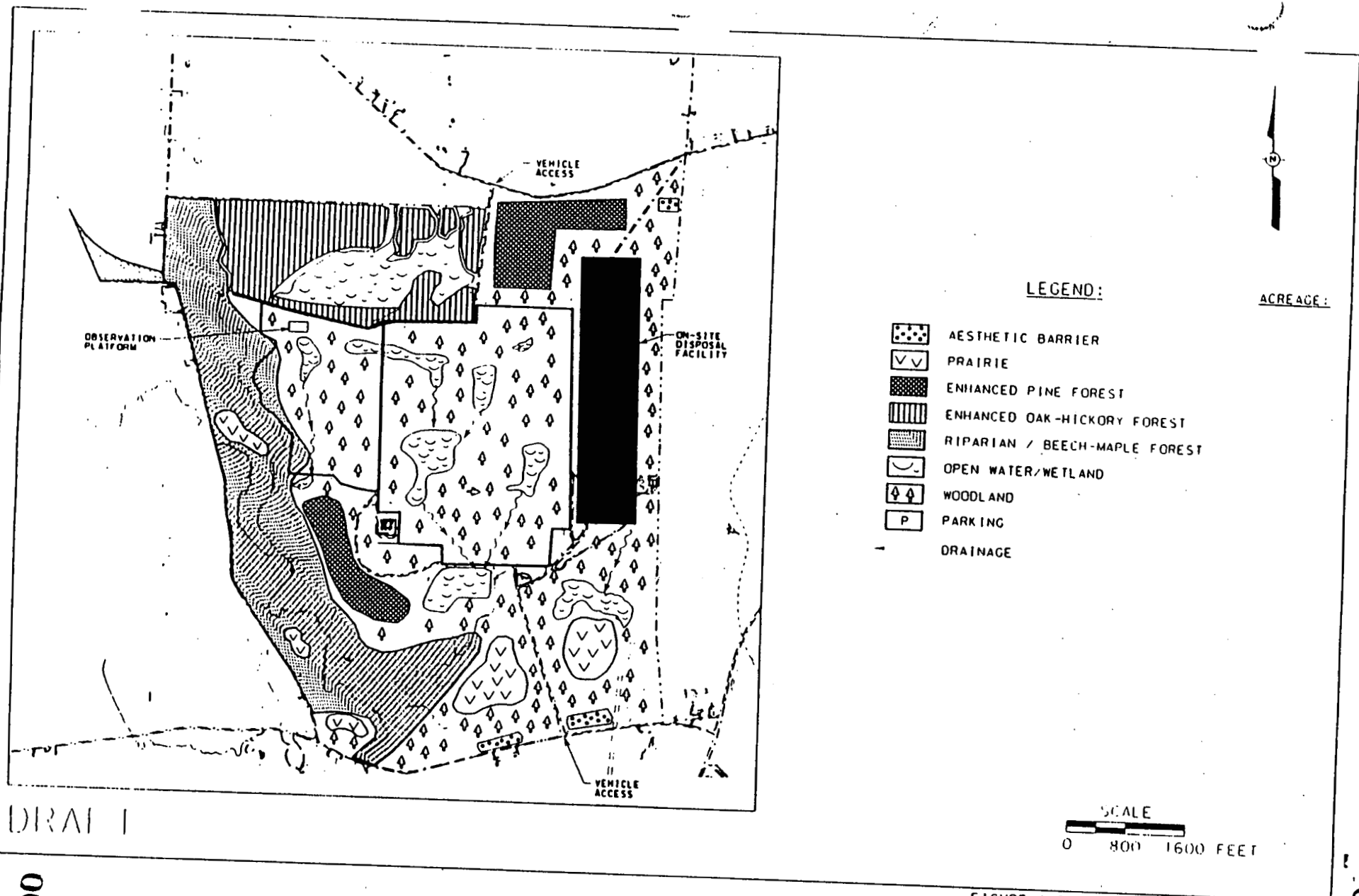

FIGURE 1-2. CONCEPTUAL FINAL LAND-USE

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2.0 CONCEPTUAL MODEL DEVELOPMENT

This section presents the conceptual model and technical approach used for developing pond routing, in relation to pond storage and pond stage.

2.1 SURFACE FEATURES AT POST-EXCAVATION CONDITIONS

In developing the pond routing model, the post-remediation site surface conditions are used. Figure 1-1 presents the projected post-excavation topographic map. The existing topography is mainly level in the former production area with the remainder of the site gently sloping throughout. The elevations range from a high point of approximately 700 feet MSL within the northeastern reaches of the site, to a low point of 550 feet MSL within the Paddys Run corridor at the southwestern corner of the site. Surface slopes associated with on-site stream channels are severe.

For the projected post-excavation conditions, Pond 1 is established in the northeast of FEMP, and also east of the former production area. Pond 2 is developed west of Pond 1. Pond 3 is at the south side of FEMP, and was designated as the soil borrow area for the construction of On Site Disposal Facility (OSDF) and other structures. Pond 3 lies on a steep hills, therefore, its storage capacity is quite limited. However, Pond 3 is for temporary runoff storage purpose. Stormwater in Pond 3 can be freely overflowed to the SSOD. Pond 4 is also designated as a stormwater retention pond, and is west of Pond 3.

Soil Excavation Zones

The proposed soil excavation areas are mainly within the on-property areas, excluding the northern portion of the FEMP site, these areas include:

- The Former Production Area
- Waste Storage/management Areas
- Existing Stockpiles
- Shallow excavation of Impacted, On-property Areas
- Pipeline excavation outside of the Former Production Area

In addition to the soil excavation, OSDF will be constructed at the eastern border for containing the processed low-level radionuclide waste. Construction of the OSDF will require some road and traffic changes. Hence, only the existing topography in the northern portion of the FEMP site remains unchanged since this area is not designated in the boundary of soil remediation.

The excavation of the soil during remediation will change the runoff characteristics of some of the remediated areas. As indicated in figure 1-1, the soil excavation activities occur mainly in the former production area and its vicinities. The change of runoff characteristics in this area are a result of the remediation activities. Prior to the remediation, much of the production area is covered with buildings and pavement. During remediation these structures will be removed, followed by soil excavation, interim grading, establishment of vegetation, and other necessary restoration requirements. Therefore, the surface features at the post-remediation condition will be altered, when compared to the current conditions. The post-remediation site surface conditions are used for reflecting the changes such as runoff curve numbers, and drainage paths.

Subsurface Features in the Excavation Zones

The subsurface soils designated for remediation at the vicinity of FEMP consist of mainly impermeable gray clay at the base of the glacial overburden. Within this shallow excavation zone, the perched groundwater table elevation is generally high. It ranges from 574 to 576 feet in the area of Pond 1 and 2, and is approximately 570 feet in the vicinity of Pond 4 (retention pond) and Pond 3 (borrow area). The contaminated perched groundwater is located in the weathered portion of the overburden which contains fractures.

2.2 SUBBASIN AND DRAINAGE AREAS

The FEMP property can be divided into several subbasins based on drainage divides to allow for the analysis of separate areas of the FEMP containing different surface conditions and stormwater drainage systems. As shown in Figures 1-1, the drainage basin that contributes to each individual pond consists of multiple subbasins. The physical configuration of these subbasins are important in the estimation of runoff volume as well as the routing of inflow hydrograph. Since the configuration and location of the subbasins will directly affect the time of concentration and also the travel time, and subsequently determine the peak inflow rates for a storm event.

Table 2-1 presents the areas of the subbasins that contribute runoff to each individual pond. The total drainage area is also calculated in Table 2-1. As indicated in Table 2-1, the drainage area of Pond 1 consists of subbasins A, B, O, and L. The drainage area of Pond 2 is composed of subbasins N and M. The drainage area of Pond 3 encompasses subbasins C, E, F, and H. Pond 3 will collect runoff generated from the east portion of the OSDF (subbasin C) along with runoff from adjacent subbasin areas E and F, and finally drains through a culvert pipe to Pond 3. Runoff collected in subbasins K and J discharges to

Pond 4. Based on the post-excavation topographic map, the runoff collected from subbasins D, I, and G, which are located south of the OSDF, drains to SSOD.

The subbasin configurations in the OSDF area that are referred to in this study compared the peak discharge for pre-development conditions with the post-development conditions (Parsons, 1997). As stated in this study, a rerouting of drainage from the north and west areas of the OSDF draining into the OU1 Railyard channels has been considered.

2.3 STAGE AND STORAGE RELATIONSHIP

In general, the stage-storage relationship depends on the local topography at the site of the storage structures. At the FEMP site, the stage-storage relationship was derived as a discrete function (i.e. a set of points). The water surface areas within contour lines of the site can be plannimetered with five feet contours. Thus, the storage in a depth increment of five feet can be calculated by the product of the average area and the depth increment. Then, the total volume of storage is the summation of all the storage increments. The data presented in Table 2-2 were used to generate the stage-storage relationship for the routing modeling. Figure 2-2 presents the surface water area at stages for every five feet of increment of elevation. Figure 2-3 presents the stage-storage relationship of the four ponds. As indicated in Figure 2-3, Pond 2 has the highest storage, while Pond 3 has the lowest storage when compared at the same stage among the four ponds.

2.4 CONTROLLING FACTORS

The peak inflow rates and the maximum depths of the ponds are controlled by factors such as meteorological data, hydrological parameters as well as the surface features and subsurface soil stratum properties of the watersheds. These three major controlling factors are summarized in this section.

Meteorological data

The Meteorological data that affect the modeling results are:

- Monthly mean rainfall depth under the normal conditions
- Rainfall depth from a 25-year and 24-hour storm, and storm type under extreme conditions
- Air and water surface Temperature that will affect the saturated vapor pressure
- Relative humidity
- Wind speed
- Percentage of possible sunshine
- Net radiation

Hydrological data

The hydrological data that affect the modeling results are:

- Subbasin configuration in the watershed.
- Natural drainage channel length and size.
- Vegetation cover conditions upstream of the ponds
- Curve number corresponding to site soil group
- Drainage path slope.
- Time of concentration

Surface and subsurface features

The surface and subsurface features that affect the modeling results are:

- Final site-wide grading features.
- Thickness of pond liner
- Hydraulic conductivity of pond liner materials.
- Stage-storage relationship of individual pond.

2.5 STORAGE ROUTING MODEL

When planning pond development conditions, the routing process considerations take precedence. Storage routing refers to the process of estimating the passage of a storm or flood hydrograph through a pond or reservoir. The routing model is based on conservation of mass, which assumes that the rates of change of storage equals to the difference between the inflow and outflow. In comparison to other hydrological problems, storage routing is relatively complex. There are a number of variables involved, including :

- Input hydrograph (monthly mean rainfall and runoff depth)
- Output hydrograph (monthly mean pond evaporation and leakage from the pond liner)
- The stage-storage volume relationship
- The storage-water surface area relationship
- The stage-discharge relationship
- The designed peak discharge rates allowed through the pond

The drainage area is determined from the topographic map. It is assumed that the change of pond area will not change the drainage area for the routing process. The detailed storage routing equations are presented in Section 3.0.

2.6 POND INFLOW MODEL

As shown in Figure 2-1, the inflow term consists of two terms: runoff from the drainage area and rainfall directly into the pond. The monthly mean rainfall depth and runoff depth were used in the calculation under the normal conditions. The peak inflow rates were estimated using the TR55 method for extreme conditions. A brief overview of the TR55 method is provided in Section 5.0.

2.6.1 Monthly Average Rainfall and Runoff

The monthly mean precipitation was taken from database of National Oceanic and Atmospheric Administration (NOAA) (NOAA, 1986). The data are statistics from hourly precipitation data for Cincinnati, Ohio. The monthly runoff was calculated by using Hydrologic Evaluation of Landfill Performance (HELP) model based on the monthly mean precipitation data from NOAA. In HELP calculations, it is assumed that the ground surface will be compacted during the interim grading operation. Appendix A presents the monthly runoff depth calculations (HELP model).

2.7 POND OUTFLOW MODEL

The outflow components considered in the model were evaporation from the open water surface, infiltration loss from the pond liner materials, and overflow rates from the weirs when the stage exceeds the overflow bottom elevation (Figure 2-1).

2.7.1 Monthly Evaporation Model

The evaporation rate was estimated using Penman equation based on meteorological data from climate station within the study region, since direct evaporation data is not available. The Penman equation was developed for estimating evaporation from open water surface (McCUEN, 1989). In Penman's model, the following parameters are considered: air and water surface temperature, relative humidity, saturated vapor pressure, wind velocity, amount of radiation absorbed, outward flow of long-wave radiation, percent of possible sunshine etc. The detailed evaporation model equations are presented in Section 3.0.

2.7.2 Monthly Infiltration Model

The amount of infiltration through the pond liner material has incorporated the data presented in the infiltration zone model in the Feasibility Study Report (FS Report) (DOE, 1995). Based on Figures 2-4 and 2-5 originally presented in Appendix F of FS, bottom liner material is mainly the gray clay located at the base of the glacial overburden layer. Part of the Pond 1 liner materials consist of the unsaturated Great Miami Aquifer material. The gray clay is a clay-rich glacial till deposit, with an average porosity of 0.20. The reported hydraulic conductivity for gray clay is 7.23×10^{-7} cm/sec. The thickness of the liner was assumed to be 3 feet. The infiltration rates were estimated by Darcy's Law , which states that the infiltrated velocity is the product of the hydraulic conductivity of the pond liner and the vertical gradient of water depth inside the pond through the bottom liner. The infiltration equation is presented in Section 3.0.

2.8 POND LINER MATERIAL

As indicated in figures 2-4 and 2-5, the soil excavation in the Pond 2 area is in Infiltration Zone V, and will reach the formation of gray clay layer near the bottom of the overburden layer. This means the liner material for Pond 2 will be a natural gray clay material with a permeability of about 10^{-7} cm/sec. However, the soil excavation in the pond 1 area is in Infiltration Zone II & III, which reaches the unsaturated Great Miami Aquifer. The unsaturated Great Miami Aquifer is generally sandy material with a permeability range 10^{-2} to 10^{-3} cm/sec. Therefore, the liner material for Pond 1 requires replacement with either a lower permeability clay soil or a synthetic liner. Replacing the sandy soil will facilitate the minimum leakage of water through the liner materials.

2.9 HYDRAULIC CONNECTION PLAN

The hydraulic connections are necessary for regulating the storage in the ponds and to maintain open water space for surface water habitats. This design plan utilizes outlet facilities such as weirs and open channels for the conveyance of water between ponds or discharging to SSOD. In the hydraulic connection plan, excessive water from Pond 1 can be drained through an open channel to SSOD. Excessive water from Pond 2 will first be conveyed through an open channel to Pond 4 (retention pond), and then either store in Pond 4 or overflow to SSOD when the pool level in Pond 4 exceeds the weir bottom elevation. The excessive water in Pond 3 will simply overflow through a weir to SSOD.

2.10 POND DAILY OVERFLOW AND OUTFLOW DISCHARGE

It is assumed that overflow will take place in a pond when the surface water elevation in the pond is higher than a certain elevation (pond overflow elevation). Therefore, in the routing process, if the pond surface water is higher than the pond overflow elevation, the pond water will overflow until the pond surface water is just at or below the pond overflow elevation. Also, the daily overflow rate was estimated by dividing the total amount of overflow in a month by 30 days.

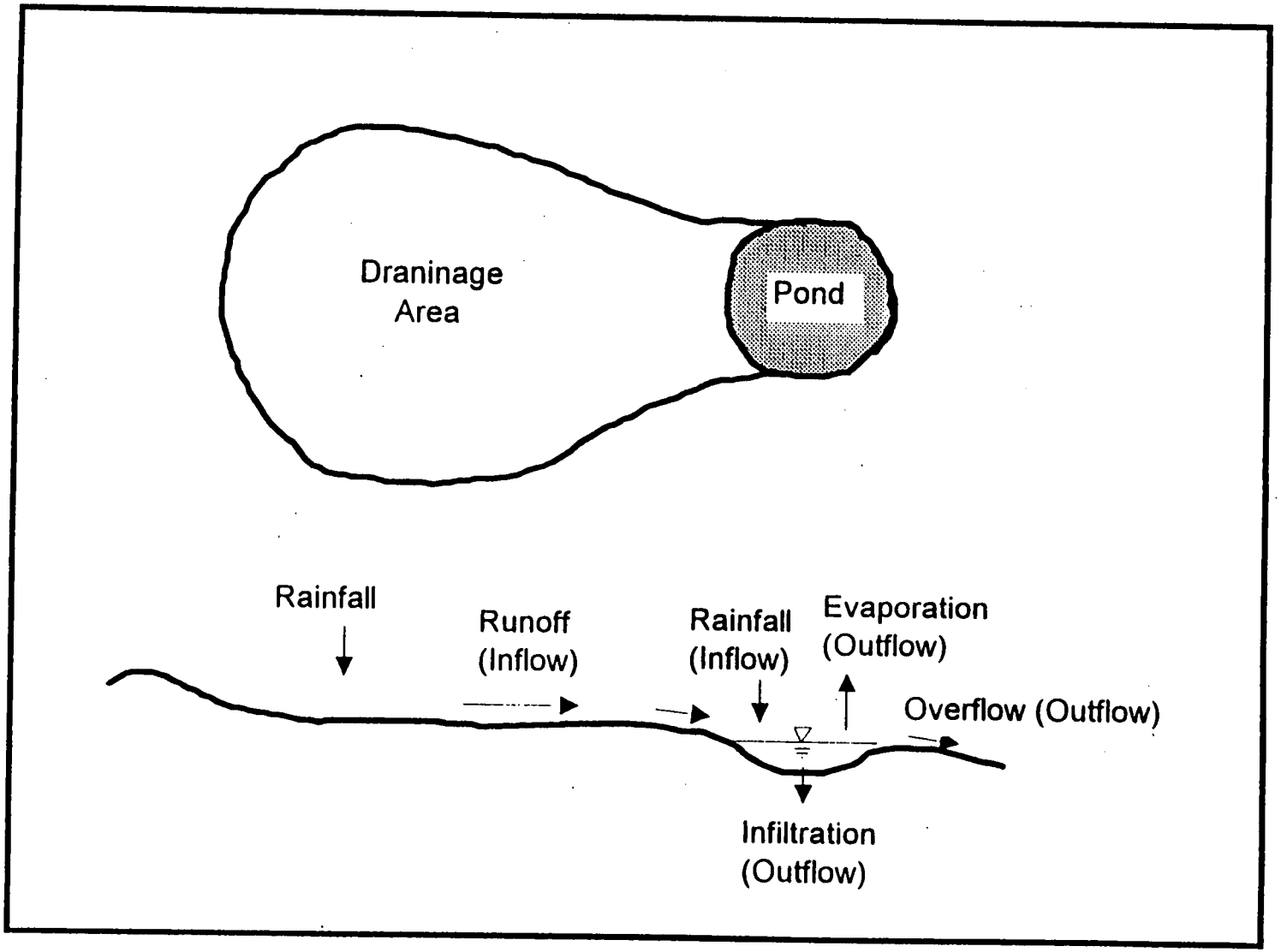

Figure 2-1 Conceptual Pond Routing Model

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FIG2-2 Chart 1

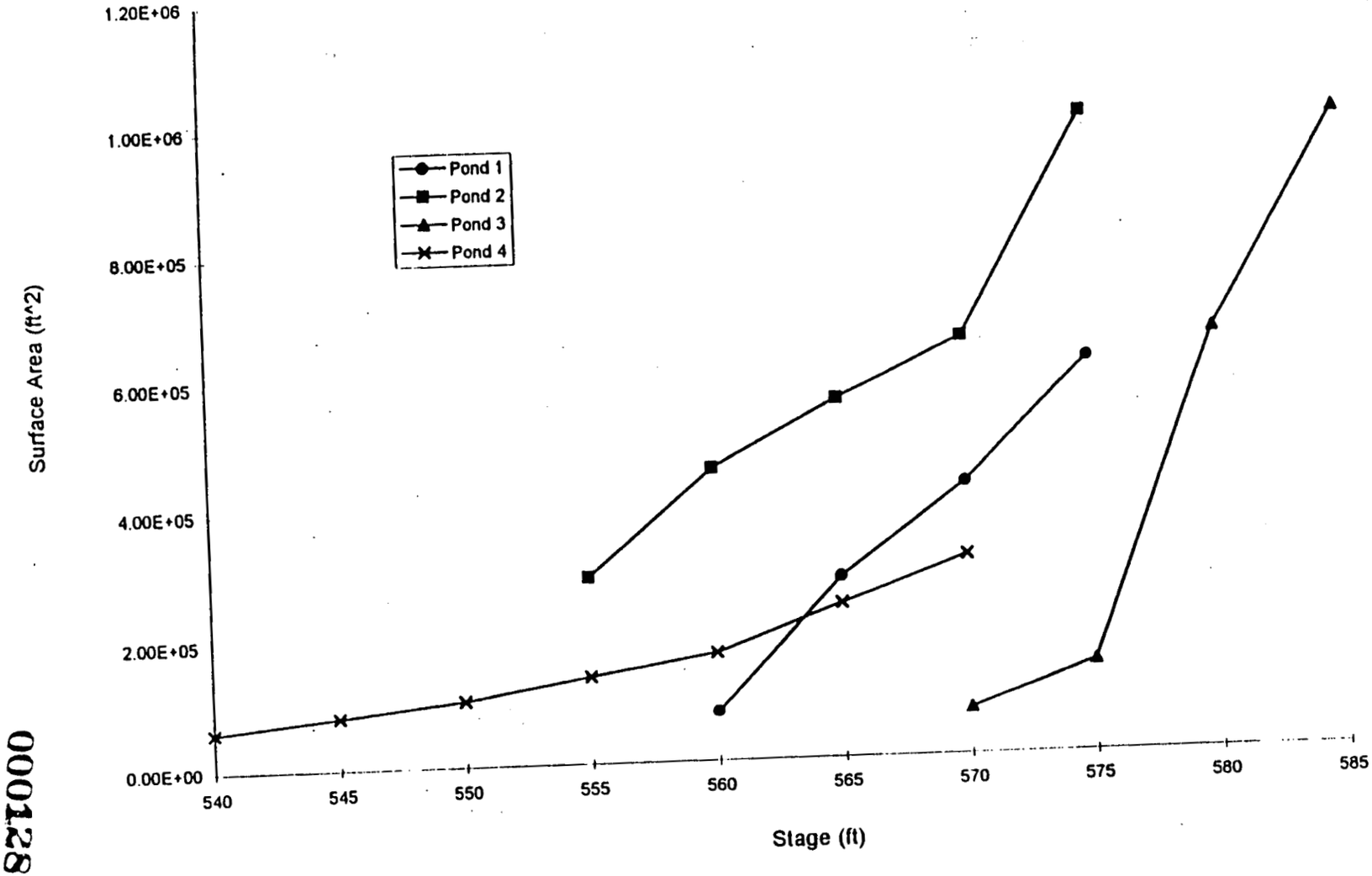

Figure 2-2 Stage and Water Surface Area Relationships

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FIG2-2 Chart 9

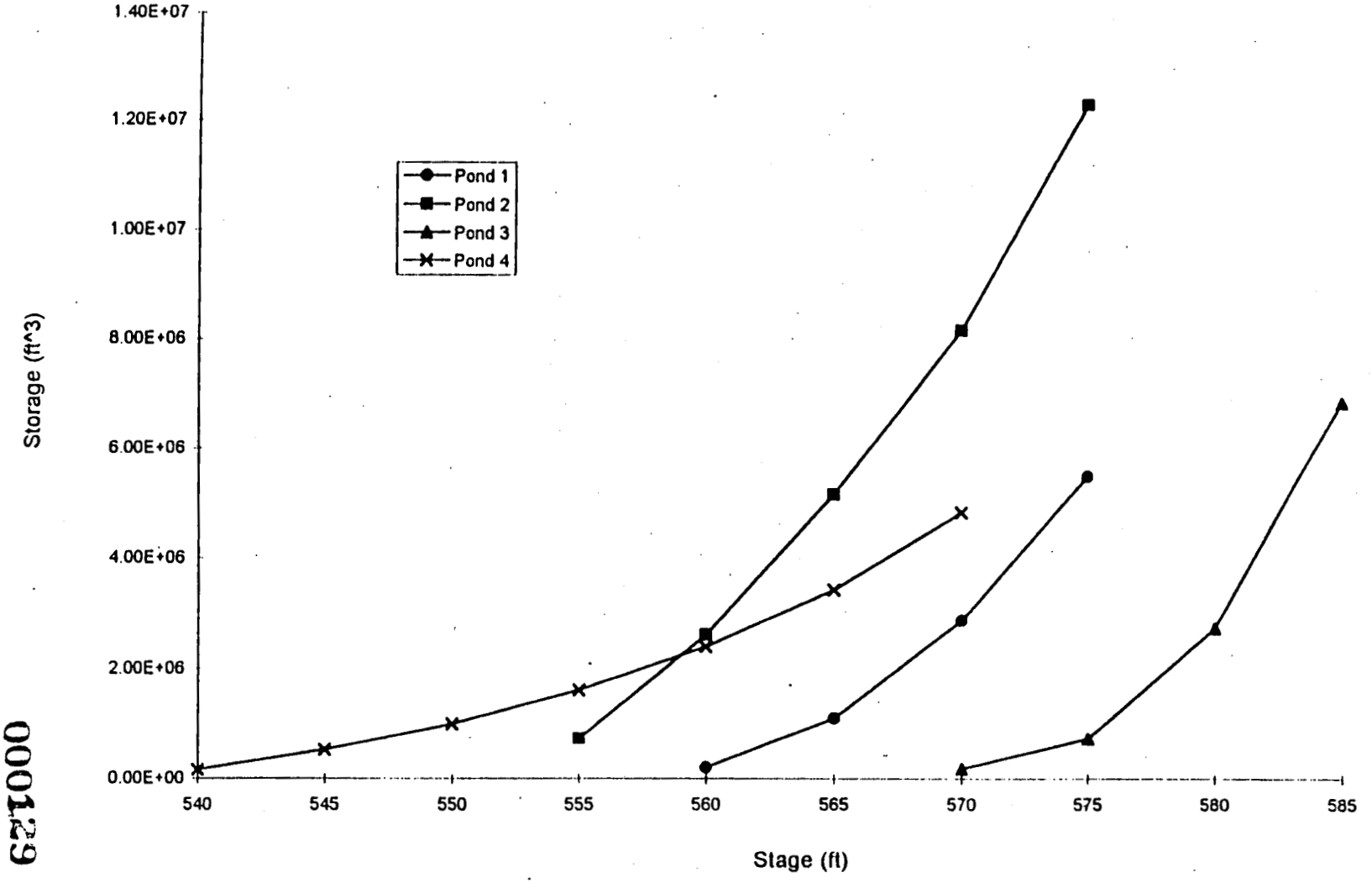

Figure 2-3 Stage and Storage Relationships

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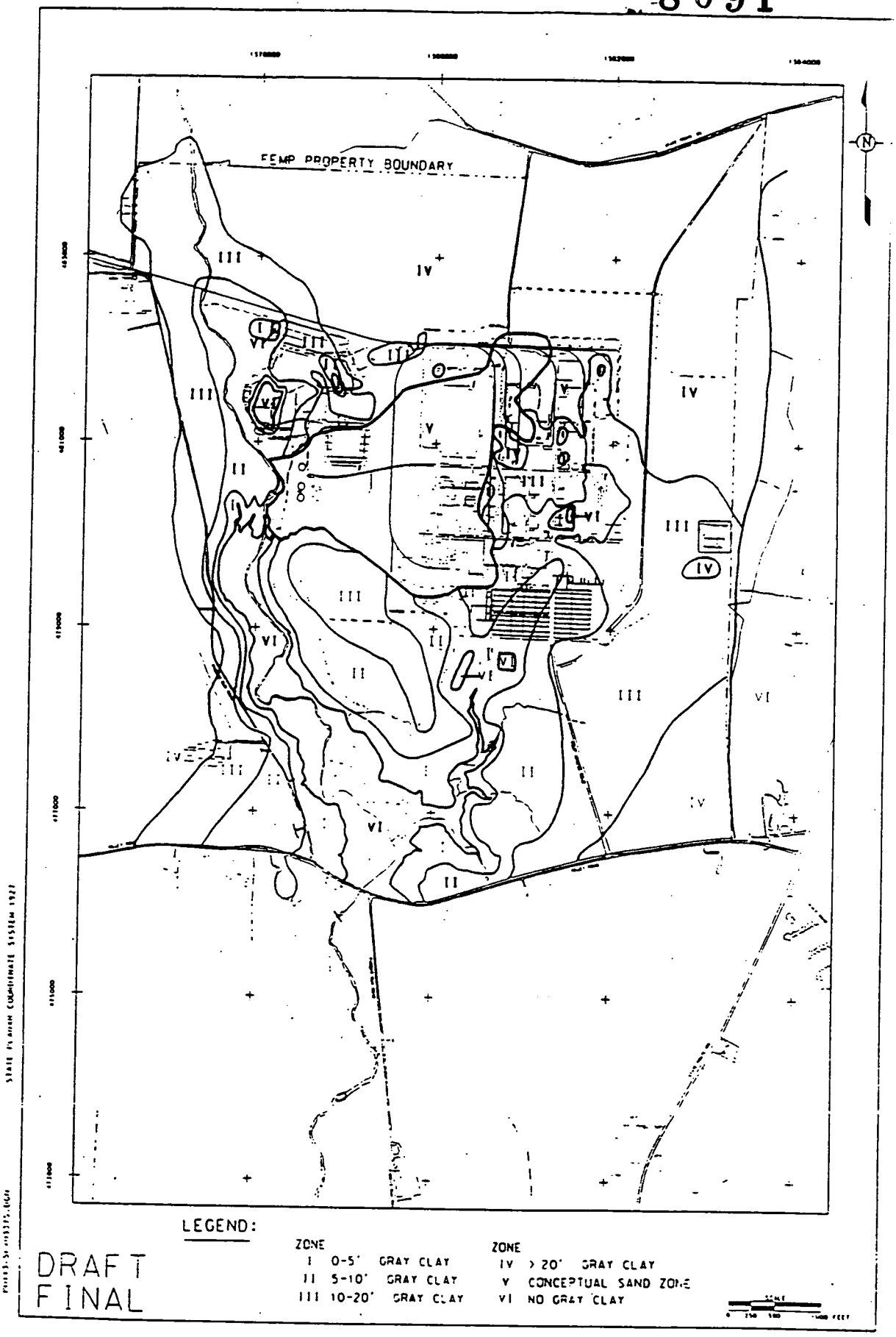
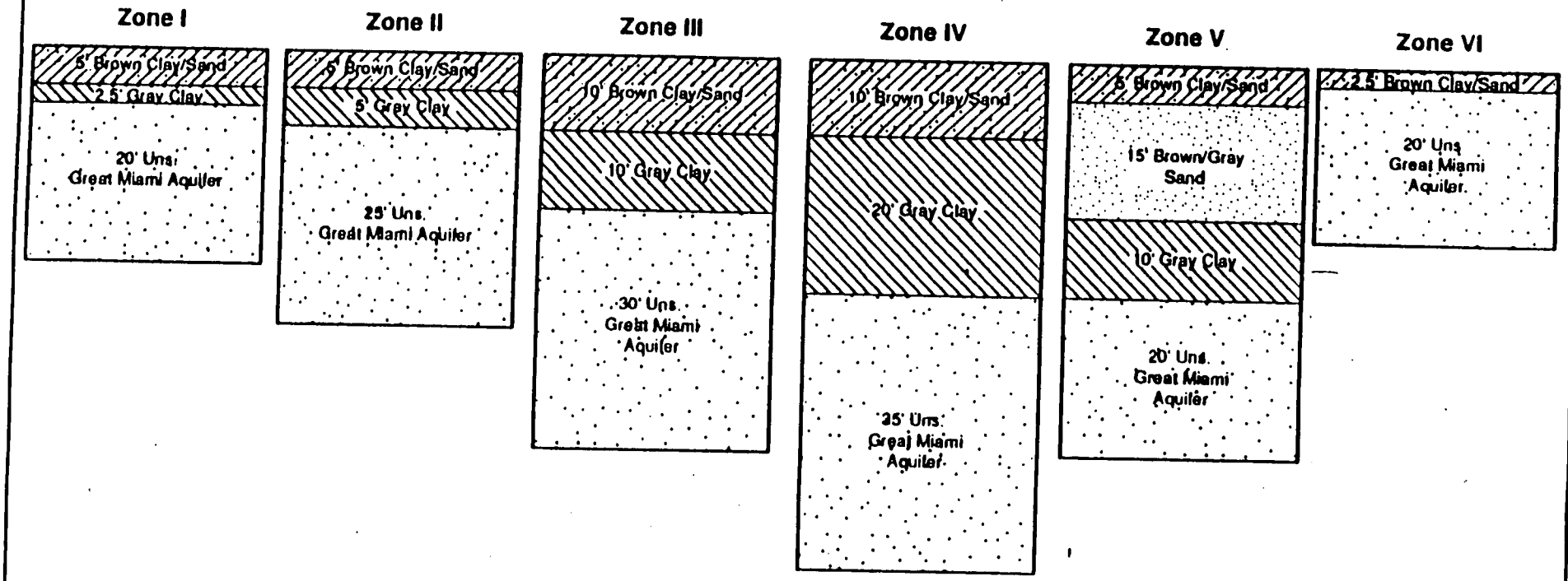


FIGURE 2-4 INFILTRATION ZONES



FORMATION	Kv (cm/sec)	POROSITY	DATA SOURCE
Gray Clay	7.23E -07	0.20	Kv from GO/UGMAS model calibration, = 0.4 of geometric mean of slug test results
Brown/Gray Sand	1.10E -04	0.30	Harmonic mean of Kh from slug tests divided by 10
Brown Clay/Sand	7.04E -05	0.30	Harmonic mean of Kh from slug tests
Uns. GMA	1.59E -02	0.30	Kv from SWIFT Model Calibration

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FIGURE 2- 5 GENERALIZED CROSS SECTIONS

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TABLE 2-1
POND SUBBASIN AREAS AND DRAINAGE AREAS
FEMP - POST EXCAVATION CONDITION

	Subbasin			Drainage Area
	Subareas	ft^2	acres	acres
POND 1 (Northeast of FEMP)	A	1150200	26.4	127.4
	B	310500	7.1	
	O	2236500	51.3	
	L	1853100	42.5	
POND 2 (Northwest of FEMP)	N	2255400	51.8	109.1
	M	2498400	57.4	
POND 3 (Southeast of FEMP)	C	1588500	36.5	104.0
	E	311850	7.2	
	F	1003500	23.0	
	H	1624500	37.3	
POND 4 Retention Pond	K	378000	8.7	49.3
	J	1768500	40.6	
		Total Drainage Area for Pond		389.8

Note: Based on the post-excavation topographic map, the runoff collected from subbasins D, I, and G that are located south of the OSDF drains to SSOD.

TABLE 2-2

POND WATER SURFACE AREA AT DIFFERENT STAGES

Surface Elevation (ft) / Pond Surface Area (ft^2) / Pond	540	550	555	560	565	570	575	580	585	Pond Drainage Area (ft^2)
POND 1 (southeast side)				7.88E+04	2.85E+05	4.25E+05	6.17E+05			5.55E+06
POND 2 (south side)			2.94E+05	4.56E+05	5.59E+05	6.54E+05	1.00E+06			4.75E+06
POND 3 (south end)						7.32E+04	1.45E+05	6.58E+05	9.99E+05	4.53E+06
POND 4 (Retention POND)	6.30E+04	1.06E+05	1.39E+05	1.72E+05	2.43E+05	3.14E+05				2.15E+06

Note: 1 acre = 43560 ft^2

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TABLE 2-3

STAGE AND STORAGE RELATIONSHIPS

Pond Storage (ft^3) / Pond \ Surface Elevation (ft)	540	550	555	560	565	570	575	580	585
POND 1 (southeast side)				1.97E+05	1.11E+06	2.88E+06	5.49E+06		
POND 2 (south side)			7.36E+05	2.61E+06	5.15E+06	8.18E+06	1.23E+07		
POND 3 (south end)						1.83E+05	7.28E+05	2.74E+06	6.88E+06
POND 4 (Retention POND)	1.58E+05	1.00E+06	1.61E+06	2.39E+06	3.43E+06	4.82E+06			

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Pond I A

Checked by:
Date :

TABLE 2-4
MONTHLY AVERAGE EVAPORATION RATES
POND ROUTING MODELING - FEMP

Input parameters

Sigma = 1 2E-07
Latitude = N 39 1 °
Reflection Coeff r = 0 12
Emplirical r (0 05-0 12)

Psychrometric Const (alpha) = 0 485 mm Hg/°C
Delta = $(e_s - e_a^*)/(To-Ta)$

Month	Temp °F	Temp °C	Temp T	Relative Humidity R_h %	Saturation Vapor Pressure e_s mm Hg (1)	Actual Vapor Pressure e mm Hg (2)	Wind Speed at 2m V m/s	Short Wave Radiation Flux Ra g-cal/cm²/day (3)	% of Possible Sunshine n/D	Radiation Absorbed RI g-cal/cm²/day	Outward flow of Longwave Radiation Rb g-cal/cm²/day	Net Radiation Rn=RI-Rb g-cal/cm²/day	Hv g-cal/cm² (4)	Evaporation Rates E mm/day (5)	Water Surface Temp Tw °C (6)	Delta	Evaporation in Air Eao mm/day	Evaporation at Water Surface Hw mm/day	Evaporation at Water Surface Hw in/month
Jan	28 9	-1 72	271 28	0 725	4 046	2 93	4 78	370 29	0.38	127	109	18	596 9	0.31	-2 20	2.33	1.10	0 45	0 527
Feb.	32 1	0 06	273 06	0 7025	4 562	3 20	4 65	549 57	0.42	198	116	82	596.0	1.37	0.00	24.43	1 31	1.37	1 620
Mar	41 6	5 44	278.44	0 6725	6 74	4 53	4 96	670 11	0.49	262	128	134	593.2	2.26	0.00	0.41	2.26	2 26	2 673
Apr.	53 5	11 94	284 94	0 64	10 478	6 71	4 78	850 02	0.56	359	136	223	589.8	3.78	2.00	0.38	3 74	3 78	4 437
May	63	17.22	290 22	0 675	14 728	9 94	3 89	929.19	0 6	409	129	280	587.0	4.77	5.00	0.39	3.92	4 30	5 076
June	71 4	21 69	294 69	0 6925	19 688	13 63	3 53	998 57	0 65	461	119	342	584.6	5.86	8.00	0.44	4 54	5 16	6 098
July	75 4	24 11	297 11	0 715	22 513	16 10	3 17	939 69	0 67	442	109	334	583.5	5.72	9 00	0.42	4 37	5 00	5 905
Aug	74 1	23 39	296 39	0 73	21.567	15 74	3 04	844 98	0.65	390	108	283	583.8	4.84	8.00	0.38	3.82	4 27	5.039
Sept.	67 5	19 72	292 72	0 7325	17 232	12.62	3 31	725 17	0.66	338	124	215	585.7	3.66	5.00	0.31	3.26	3 42	4.036
Oct.	55 3	12 94	285 94	0 7025	11.182	7 86	3 62	537.54	0.5	213	120	93	589.3	1.58	1.00	0.28	2 55	2 20	2 593
Nov	43 4	6 33	279 33	0 7175	7 172	5 15	4 29	409.11	0.36	137	103	34	592.7	0.57	0.00	0.32	1.82	1 32	1.558
Dec	33 8	1 00	274 00	0 7425	4 92	3 65	4 56	330 65	0.32	105	98	7	595.5	0.12	0.00	1 27	1 20	0 42	0 494

Annual total (in) 40 05

Notes:
Weather data are mean monthly data for Cincinnati, Ohio, National Oceanic and Atmospheric Administration (NOAA), Part I Eastern Region, 1987.
The amount of evaporation from open water surface was computed with Penman equation presented in McCUEN, 1989.
(1) From Table 14-1, Mc CUEN, 1989
(2) $e = e_s * R_h$
(3) From Table 14-3, Mc CUEN, 1989
(4) Hv = 596 - 0 52*Tc
(5) E = 1-*Rn/Hv
(6) Water surface temperature was estimated based on the ambient temperature

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3.0 CONCEPTUAL MODEL FORMULATIONS

The analytical implementations of the conceptual model presented in Section 2.0 are described in this section. The general technical rational and basic equations that account for the routing processes is presented first. Then, the inflow and outflow components such as rainfall, runoff, evaporation, and infiltration are described based on site-specific information. Finally, the pond overflow equation and sizing of the discharging channels are described.

3.1 STORAGE ROUTING MODEL EQUATION

As described in the conceptual model, storage routing is the process of estimating the passage of a storm or flood hydrograph through a retention facility. For the purpose of developing routing model through the retention pond, the mass balance which states the difference between inflow and outflow equals to the pond storage change can be expressed as (see Figure 2-1)

$$I(t) - O(t) = \frac{dS_p(t)}{dt} \tag{1}$$

where

I(t) is the inflow into the pond per unit time,

O(t) is the outflow from the pond per unit time,

$S_p(t)$ is the pond storage at time t, and

t is the time.

If the month is used as the unit time, and finite difference is applied to Eq. (1), The mass balance equation can be written as:

$$I(i) - O(i) = S_p(i+1) - S_p(i) \tag{2}$$

Or

$$S_p(i+1) = S_p(i) + I(i) - O(i) \tag{3}$$

where

I(i) is the total inflow into the pond in the month i,

O(i) is the total outflow from the pond in the month i,

$S_p(i+1)$ is the pond storage at the end of month i+1, and

$S_p(i)$ is the pond storage at the end of month i.

The pond storage at the end of month i+1 can be calculated from Eq. (3) by assigning the pond storage at the end of month i (initial pond storage) and inflow and outflow in month i.

3.2 INLOW COMPONENTS : RAINFALL AND RUNOFF

As shown in Figure 2-1, the inflow term I(i) consists of two terms: runoff from the drainage area and rainfall directly into the pond. It can be expressed as:

$$I(i) = ROF(i) \times A_d + RAIN(i) \times A_p \tag{4}$$

where

ROF (i) is the runoff per unit area in month i,

RAIN (i) is the rainfall per unit area in month i,

A_d is drainage area, and

A_p is the pond surface water area at stage of H.

The monthly average rainfall depth and runoff were used in the calculations.

It is also assumed that the change of pond surface water area will not change the drainage area. Surface water area of pond (A_p) is the function of the stage for a specific pond:

$$A_p = f_{Ap}(H(i)) \tag{5}$$

Where H(i) is the pond surface water elevation in month i.

Substituting equation (5) into equation (4) will yield the following equation

$$I(i) = ROF(i) \times A_d + RAIN(i) \times f_{Ap}(H) \tag{6}$$

The monthly average rainfall was obtained from the database of the National Oceanic and Atmospheric Administration (NOAA). The recorded length obtained for the monthly mean rainfall from NOAA is approximately 30 years.

The monthly runoff was calculated by using HELP model based on the monthly rainfall data from NOAA. Appendix A presents the monthly runoff depth calculations (HELP model). The drainage area (Ad) is determined from the topographic map.

3.3 OUTFLOW COMPONENTS :EVAPORATION, INFILTRATION AND OVERFLOW

The outflow components considered in the model were evaporation from the open water surface and infiltration (see Figure 2-1). Equation (7) describes their relationship.

$$O(i) = Hw(i) \times A_P + Inf(i) \times A_P + \text{Pond Overflow} \qquad (7)$$

where

O(i) is the total loss of the water in the month (i)

Hw(i) is the evaporation rate (per unit area) in month i, and

Inf(i) is the infiltration rate (per unit area) to subsurface in month i.

Evaporation rate E will be directly incorporated into Equation (7), if pan evaporation data are available. The evaporation rate was estimated using the Penman equation based on meteorological data from the climate station of Cincinnati, Ohio, since pan evaporation data is not available. The following two subsections present the evaporation and infiltration model.

3.3.1 Evaporation Simulation

The Penman equation was used for estimating evaporation from open water surface. Penman proposed the following simplified energy balance equation (McCUEN, 1989):

$$H_W = \frac{\Delta E + \alpha\ E_{\alpha 0}}{\Delta + \alpha} \qquad (8)$$

Where

Hw = evaporation from water surface (mm/day),

E_{w0} =0.35 (e_s-e) (0.2+0.55V),

e=e_sxR_h,

R_h is the relative humidity,,

e is the vapor pressure at air temperature,

e_s is the saturated vapor pressure, and is a function of temperature.

V is the wind velocity at 2 meter high, and

α is the psychometric constant, the typical value is 0.485 mm Hg/°C

$$\Delta = \frac{e_0 - e_a^*}{T_0 - T_a} \tag{9}$$

Δ is the slope of the saturated vapor pressure curve at mean temperature,

T_0 and T_a are temperature of the water surface and air, respectively,

e_0 is the vapor pressure of the water surface, and e_a^* is the saturation vapor pressure at T_a.

$$E = 10\frac{R_n}{H_v} \tag{10a}$$

$$R_n = R_I - R_B \tag{10b}$$

R_n is the net radiation in units of g-cal/cm^2-day,

R_I is the amount of radiation absorbed, and is a function of short-wave radiation function,

R_B is the outward flow of long-wave radiation.

R_I and R_B can be expressed as below:

$$R_I = R_A(1-r)(a+b\frac{n}{D}) \tag{10c}$$

$$R_B = \sigma T_a^4(0.47-0.077\sqrt{e})(0.2+0.8\frac{n}{D}) \tag{10d}$$

$$H_V = 596 - 0.52T \tag{10e}$$

Where

r is the reflection coefficient,

a and b are empirical coefficients that are location dependent,

n/D is the fraction of possible sunshine,

R_A is the Angot's values of short-wave radiation flux in units of g-cal/cm^2/day, and is a function of the latitude and the month of the year,

σ =117.7 x 10^9 g-cal/cm^2/day

H_v is in unit of g-cal/cm^3,

T is the temperature, in ^{0}C.

3.3.2 Infiltration Simulation

The amount of infiltration through the pond liner material has incorporated the data presented in the infiltration zone model in the Feasibility Study Report (FS Report) (DOE, 1995). Based on the Figures F-1 and F-2 in Appendix F of FS, bottom liner material is mainly the gray clay located at the base of the glacial overburden layer. Part of Pond 1 liner materials is the unsaturated Great Miami Aquifer material. The gray clay is a clay-rich glacial till deposit, with an average porosity of 0.20. The reported hydraulic conductivity for gray clay is 7.23 x 10^{-7} cm/sec. The thickness of the liner was assumed to be 3 feet.

The infiltration rates will follow Darcy's Law, and can be described as below:

$$Inf(i) = K\frac{H(i) - H_{GW}(i)}{TH} \qquad (11)$$

where

K is the hydraulic conductivity of the pond liner,

H (I) is the water surface elevation of the pond in month I,

H_{GW}(I) is the higher value between liner bottom elevation and groundwater elevation, and

TH is the pond liner thickness.

Eq.(11) indicates that if Inf(i) is positive, flow is from surface water in the pond to groundwater, if Inf(i) is negative, flow is from groundwater to surface water.

3.3.3 Pond Overflow

It is assumed that overflow will take place in a pond when the surface water elevation in the pond is higher than a certain elevation (pond overflow elevation). For normal conditions, the daily overflow rates were estimated by dividing the total amount of overflow in a month by 30 days. For extreme conditions, if the pond surface water is higher than the pond overflow elevation, then water will overflow until the pond stage is just at or below the pond overflow elevation. The overflow equation is stated as follow:

$$Q = 3.3LH^{1.5} \tag{12}$$

where

Q is the flow rates in ft^3/sec.

L is the weir width in feet.

H is the water depth above the weir bottom in feet.

3.4 STORAGE ROUTING COMPUTATION PROCEDURES

Substituting the Equations of (6), (7), (8) and (11) into Equation (3) will yield following routing equation:

$$\begin{aligned} S_P(i+1) = {} & S_P(i) + ROF(i) \times A_d + RAIN \times f_{Ap}(H(i)) \\ & - Hw(i) \times f_{Ap}(H(i)) - K\frac{H(i) - H_{GW(i)}}{TH} f_{Ap}(H(i)) - Overflow \end{aligned} \tag{13}$$

Equation (13) can be used to calculate the pond storage $S_p(i+1)$ starting from month i. For example, the computation starts from month 0 (i=0) to calculate the pond storage term $S_p(1)$ at month 1. The $S_p(0)$ is given as the initial condition. The runoff (ROF), rainfall (RAIN), H(i), and Hw(i) in month 0 will be calculated explicitly. The pond storage Sp(1) at month 1 can then be calculated , since the terms on the right side of Equation (13) are all known.

3.5 SIZING OF CONNECTION CHANNELS

The hydraulic connections are necessary for regulation of the pond storage, maintaining minimum depth and open water space for surface water habitats. The current hydraulic connection plan utilizes outlet facilities such as weirs and open channels for the conveyance of water between ponds or discharging to SSOD. As stated in Section 2.0, the connection plan requires two discharging channels. The first channel drains excessive water from Pond 1 to SSOD. The second channel discharges the excessive water from Pond 2 to Pond 4 (the retention pond).

Sizing the discharging channel is based on outflow rates through the outlet weirs. The outflow rates were determined from the routing model under the extreme conditions. A grass lined trapezoidal channel with side slope of 1V:1H is proposed. Manning's equation is used for estimating the depth of water in the channel, assuming a width for the channel. This computation was performed using FLOWMASTER, a sizing program for channels and pipes (Haestad, 1990).

4.0 POND MODELING RESULTS UNDER NORMAL CONDITIONS

This section presents the storage routing modeling results under normal conditions. The normal conditions are represented by considering the monthly average meteorological data. As stated in Section 2.0, monthly mean data of rainfall depth, temperature, the fraction of possible sunshine, relative humidity, and wind speed were used for developing the monthly routing model. The conceptual routing model as presented in section 2.0 is the basis for calculating the storage and passage of runoff generated by a normal rainfall event. The routing equation described in Section 3.0 defines the water budget of a watershed. The water balance is a physical analysis of the drainage basin based on the conservation of mass, which assumes that the rates of change of storage is equal to the difference between the inflow and outflow. Inflow parameters considered in the normal climate conditions are monthly rainfall and runoff. The monthly mean rainfall data source is based on data available from NOAA. Runoff depths were calculated using the HELP model. Outflow parameters considered are evaporation from the pond surface and infiltration through the liner material. The simulation time selected was four years and represents the normal conditions in order to reach an equilibrium state. Tables C-1 through C-4 in Appendix C present the detailed monthly calculations for a period of four years. The following sections present the results of the routing model by considering the monthly average meteorological record.

4-1 INPUT PARAMETERS

The input data to the routing model used for the normal conditions are briefly summarized in this subsection.

Drainage Area. The drainage areas are the total of each individual subbasin, and each subbasin is plannimetered based on the enlarged scale of the post-excavation topographic map. The drainage area for the four ponds are estimated as 127.4,109.1,104, and 49.3 acres respectively. Table 2-1 presents the subbasin areas and their total drainage areas.

Pond Bottom Elevations. Bottom elevations of the four ponds are designed at 555, 550, 565, and 535 feet respectively (Appendix C).

Monthly Mean Rainfall. The monthly mean precipitation was based on the database from NOAA (NOAA, 1986). They are presented within EXCEL calculation tables in Appendix C.

Monthly Mean Runoff. The monthly mean runoff was calculated by using the HELP model based on the monthly mean precipitation data from NOAA. The monthly mean runoff depths were presented in Appendix C.

Evaporation Model Input Parameters. In Penman's model, the following monthly mean input parameters are considered: air and water surface temperature, relative humidity, saturated vapor pressure, wind velocity, short-wave radiation flux, and percent of possible sunshine. (NOAA, 1987). Other input parameters that are not time dependent are the latitude, reflection coefficient, and psychrometric constant. The input data are presented in Table 2-4.

Pond Liner Hydraulic Conductivity. A Hydraulic Conductivity of 7.23×10^{-7} cm/sec for natural gray clay as shown in Figure 2-5 was used for modeling. As discussed in Section 2.0, the liner materials for Pond 1 requires replacement with materials that have similar hydraulic conductivity in the range of 10^{-6} to 10^{-7} cm/sec.

Thickness of Pond Liner. The thickness of pond liner is proposed as three feet for the four ponds.

Pond Overflow Elevations. Overflow elevations of the four ponds are designed as 573, 573, 578, and 560 feet respectively.

Groundwater Elevation. The typical groundwater elevation in the pond areas is reported as 520 feet.

4.2 POND INFLOW AND OUTFLOW HYDROGRAPH

Figures 4-9, 4-13, 4-17, and 4-21 present inflow and outflow hydrographs for the four ponds respectively. As shown in these figures, the total inflow volume on a monthly basis are generally higher in the first part of the year, and are lower for the months between May and November for the four ponds. Table 4-1 presents the maximum inflow rates and maximum outflow rates for the four ponds. As indicated in Table 4-1 and Figures 4-9, 4-13, 4-17, and 4-21, Pond 1 will receive the highest runoff in April among the four ponds, and also has nearly the highest outflow rates.

TABLE 4-1

MAXIMUM INFLOW RATES AND MAXIMUM OUTFLOW RATES UNDER NORMAL CONDITIONS

	Maximum Inflow Rates (ft^3/month)	Maximum Outflow Rates (ft^3/month)
POND 1 (Northeast of FEMP)	1.1×10^6	8.71×10^5
POND 2 (Northwest of FEMP)	9.81×10^5	6.19×10^6
POND 3 (Southeast of FEMP)	9.06×10^5	8.13×10^5
POND 4 (Retention Pond)	4.20×10^5	2.36×10^5

4.3 POND MONTHLY STORAGE VARIATIONS

Figures 4-10, 4-14, 4-18, and 4-22 present monthly pond storage variations for the four ponds respectively. As shown in these figures, the storage volume on a monthly basis are generally higher in the first part of the year, and decrease from April or May to the end of the year for the four ponds. Also, the storage variations experienced within each pond are about the same in order of magnitude. Table 4-2 presents the maximum and minimum pond storages for each pond under normal conditions. Table 4-3 presents the monthly pond storage variations under normal conditions.

TABLE 4-2

MAXIMUM AND MINIMUM POND STORAGE UNDER NORMAL CONDITIONS

	Maximum Storage (ft^3)	Minimum Storage (ft^3)
POND 1 (Northeast of FEMP)	$4.45X10^6$	$3.05X10^6$
POND 2 (Northwest of FEMP)	$6.19X10^6$	$4.74X10^6$
POND 3 (Southeast of FEMP)	$1.93X10^6$	$1.25X10^6$
POND 4 (Retention Pond)	$2.55X10^6$	$2.12X10^6$

4.4 POND MONTHLY STAGE VARIATIONS

Figures 4-11, 4-15, 4-19, and 4-23 present monthly pond stage variations for the four ponds respectively. Figures 4-1 through 4-8 present the pond water surface outlines with maximum and minimum storage for the four ponds. As indicated in the figures, stage variations in Pond 1 is relatively high when compared to the other ponds. This is due to the relatively smaller pond storage capacity, however, Pond 1 has a higher volume of runoff generated by a larger drainage area. Table 4-4 presents the stage changes for each pond. As indicated in the table, Pond 2 has the largest freeboard (about 7 to 8 feet) below the top edge of the pond. For this reason, Pond 2 collects less runoff, and will be excavated in a relatively large area during the soil remediation. Pond 3 serves as a temporary stormwater detention basin. Stormwater in Pond 3 can be overflowed to the SSOD. Of the four ponds, Pond 4 is the smallest one. Pond 4 also has a much lower rate of inflow, and can be functioned as an intermediate retention basin. As indicated in Table 4-4, difference in pond freeboard between Pond 1 and Pond 2 is approximately 6 feet. It would be more efficient for the purpose of storage routing, if a hydraulic connection is installed between Pond 1 and Pond 2.

Table 4-5 presents the monthly stage variations for each pond. As can be seen in Table 4-5, stage variations in Pond 3 (ranged from 576.3 to 578 feet) is the greatest among the four ponds in the same month. Pond 1 (ranged from 570.3 to 573 feet) has the second highest pool level. As mentioned in

Table 4-3 Monthly Storage Variations Under Normal Conditions

Month	Pond Water Storage (ft^3)			
	Pond 1	Pond 2	Pond 3	Pond 4
Jan	3.08E+06	4.75E+06	1.31E+06	2.13E+06
Feb	3.63E+06	5.23E+06	1.80E+06	2.34E+06
Mar	4.45E+06	5.96E+06	1.93E+06	2.55E+06
Apr	4.45E+06	6.19E+06	1.60E+06	2.54E+06
May	4.01E+06	5.96E+06	1.51E+06	2.46E+06
Jun	3.83E+06	5.75E+06	1.45E+06	2.40E+06
Jul	3.64E+06	5.52E+06	1.39E+06	2.34E+06
Aug	3.63E+06	5.44E+06	1.46E+06	2.33E+06
Sep	3.43E+06	5.20E+06	1.37E+06	2.26E+06
Oct	3.26E+06	4.99E+06	1.31E+06	2.20E+06
Nov	3.11E+06	4.81E+06	1.25E+06	2.14E+06
Dec	3.05E+06	4.74E+06	1.25E+06	2.12E+06

Section 2.0, Pond 3 serves as temporary runoff control, therefore, the higher stage is maintained for a short period of time. The stages simulated for Pond 1 would remain for a certain amount of time until the pool level exceeds the outlet elevation of 573 feet, then overflows to SSOD.

TABLE 4-4

MAXIMUM AND MINIMUM POND STAGE UNDER NORMAL CONDITIONS

	Pond Stage		Pond Top Edge Elevation (feet)
	Maximum (feet)	Minimum (feet)	
POND 1 (Northeast of FEMP)	573.0	570.32	575
POND 2 (Northwest of FEMP)	566.71	564.19	575
POND 3 (Southeast of FEMP)	578.0	576.29	580
POND 4 (Retention Pond)	560.0	556.9	575

Note: The maximum stage occurs in April, while the minimum stage occurs in December.

4.5 POND DAILY OVERFLOW RATE

Figures 4-12, 4-16, 4-20, and 4-24 present daily overflow rates for the four ponds respectively. As shown in these figures, the daily overflow rate occurs normally in April in response to the higher inflow rates. In general, the daily overflow rates are determined by the bottom elevation of pond outlets facilities. Table 4-6 presents the maximum daily overflow rates and bottom elevations of pond outlets for each pond under normal conditions. As indicated in table 4-6, the daily overflow rate is zero for Pond 2, since the pool level in Pond 2 has never reached the designed overflow elevation of 573 feet.

Table 4-5 Monthly Stage Variations Under Normal Conditions

Month	Pond Surface Water Elevation (ft)			
	Pond 1	Pond 2	Pond 3	Pond 4
Jan	570.4	564.2	576.5	557.0
Feb	571.4	565.1	577.7	558.5
Mar	573.0	566.3	578.0	560.0
Apr	573.0	566.7	577.2	559.9
May	572.2	566.3	577.0	559.4
Jun	571.8	566.0	576.8	558.9
Jul	571.5	565.6	576.6	558.5
Aug	571.4	565.5	576.8	558.5
Sep	571.1	565.1	576.6	558.0
Oct	570.7	564.7	576.5	557.5
Nov	570.4	564.3	576.3	557.1
Dec	570.3	564.2	576.3	556.9

TABLE 4-6

MAXIMUM DAILY OVERFLOW RATE UNDER NORMAL CONDITIONS

	Daily Overflow Rate (ft^3/day)	Pond Outlet Elevations (feet)
POND 1 (Northeast of FEMP)	$7.46X10^3$	573
POND 2 (Northwest of FEMP)	0	573
POND 3 (Southeast of FEMP)	$2.09X10^4$	578
POND 4 (Retention Pond)	$4.22X10^3$	560

4.6 MAXIMUM AND AVERAGE DEPTH OF THE PONDS

The maximum depth was computed as the difference between the water surface elevation and the pond bottom elevation. The average depth was determined by dividing the storage by the surface water area. Table 4-8 presents the maximum and average water depths under normal conditions. As indicated in Table 4-8, the highest maximum and average depths generally occur in April. The highest maximum water depths estimated for the four ponds are 18, 16.7, 13, and 25 feet respectively. The highest average water depths estimated for the four ponds are 8.2, 10.5, 4.5, and 14.8 feet respectively.

Table 4-7 Maximum and Average Depth Under Normal Conditions

Month	Pond 1		Pond 2		Pond 3		Pond 4	
	Maximum Depth (ft)	Average Depth (ft)	Maximum Depth (ft)	Average Depth (ft)	Maximum Depth (ft)	Average Depth (ft)	Maximum Depth (ft)	Average Depth (ft)
Jan	15.38	7.00	14.22	8.75	11.31	4.49	20.87	13.64
Feb	16.43	7.55	15.13	9.31	12.49	4.31	22.30	14.08
Mar	18.00	8.22	16.33	10.20	13.00	4.26	24.65	14.71
Apr	18.00	8.22	16.71	10.46	12.33	4.33	25.00	14.79
May	17.16	7.88	16.34	10.20	12.07	4.36	24.00	14.55
Jun	16.82	7.73	15.99	9.95	11.87	4.39	23.44	14.40
Jul	16.46	7.57	15.60	9.67	11.67	4.42	22.89	14.25
Aug	16.43	7.55	15.47	9.57	11.81	4.40	22.79	14.22
Sep	16.06	7.37	15.08	9.27	11.57	4.44	22.21	14.06
Oct	15.73	7.19	14.69	9.03	11.38	4.47	21.68	13.90
Nov	15.43	7.03	14.33	8.82	11.20	4.51	21.18	13.74
Dec	15.32	6.96	14.19	8.73	11.18	4.52	20.92	13.65

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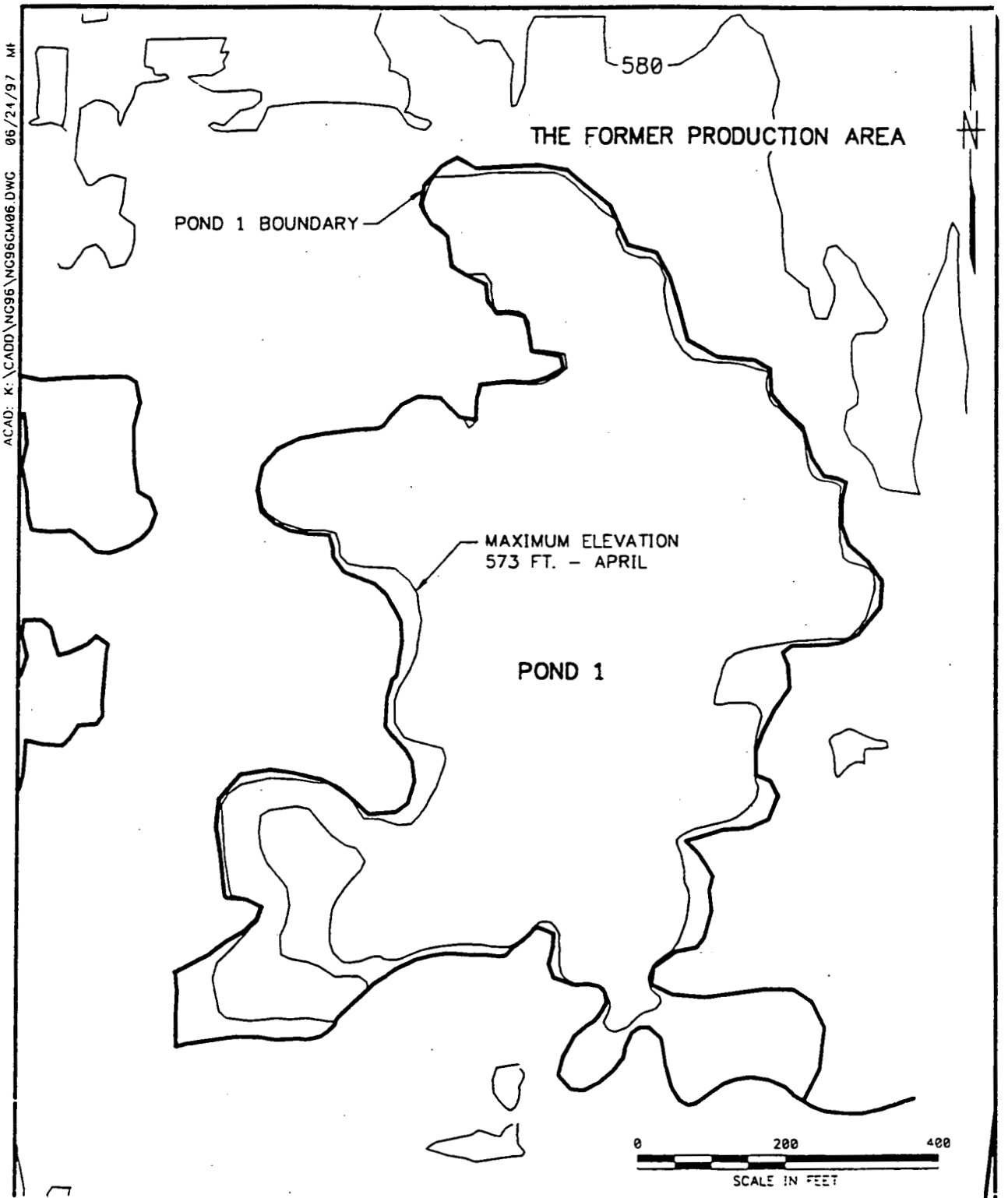

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CHECKED BY DATE	POND 1 WATER SURFACE OUTLINE UNDER NORMAL CONDITION MAXIMUM ELEVATION FEMP	APPROVED BY	DATE
COST/SCHED-AREA		APPROVED BY	DATE
SCALE AS NOTED		DRAWING NO. FIGURE 4-1	REV. 0

FORM CADD NO. SOUTH_AV.DWG - REV 0 - 02/07/97

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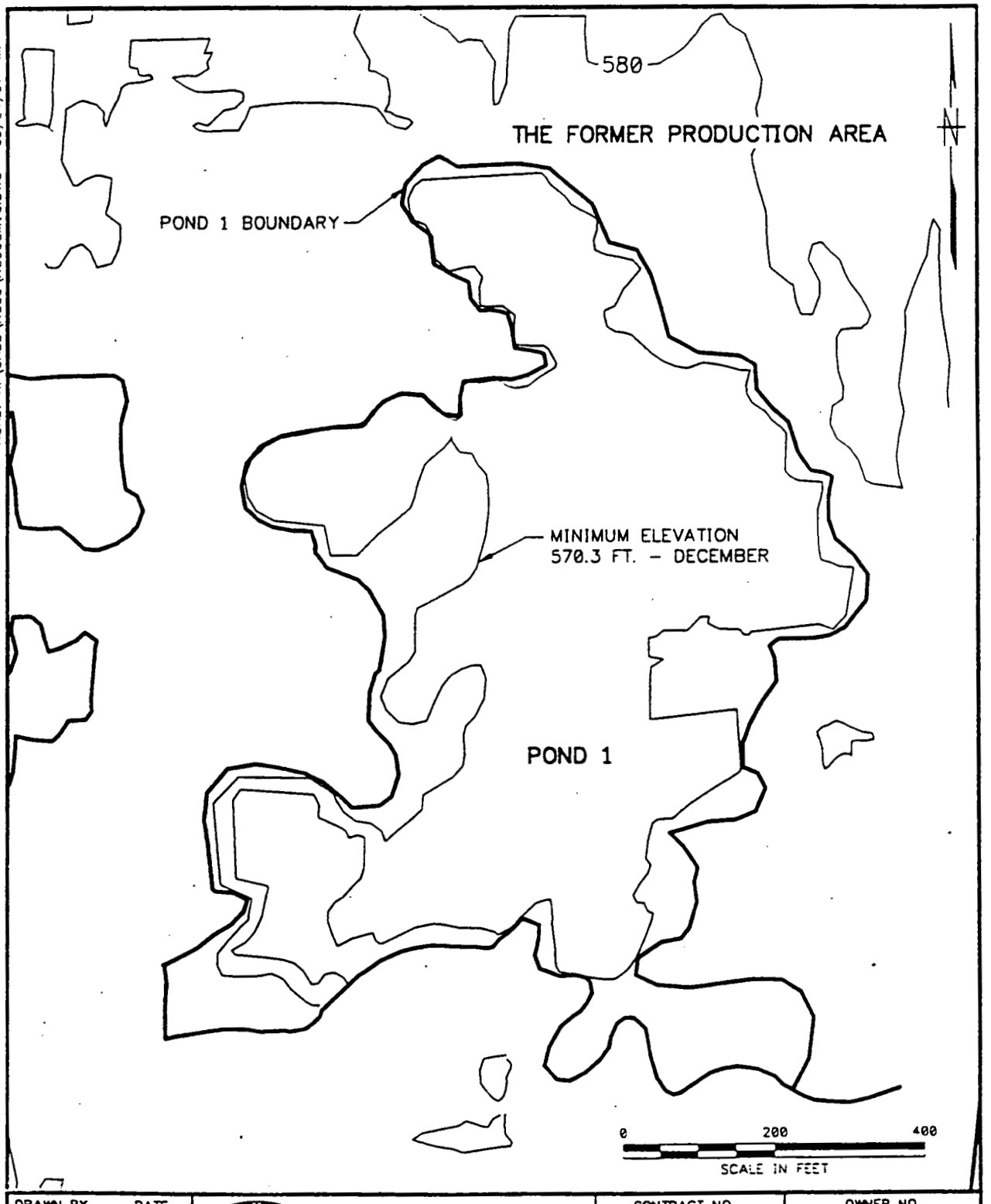

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COST/SCHED-AREA		APPROVED BY	DATE
SCALE AS NOTED		DRAWING NO. FIGURE 4-2	REV. 0

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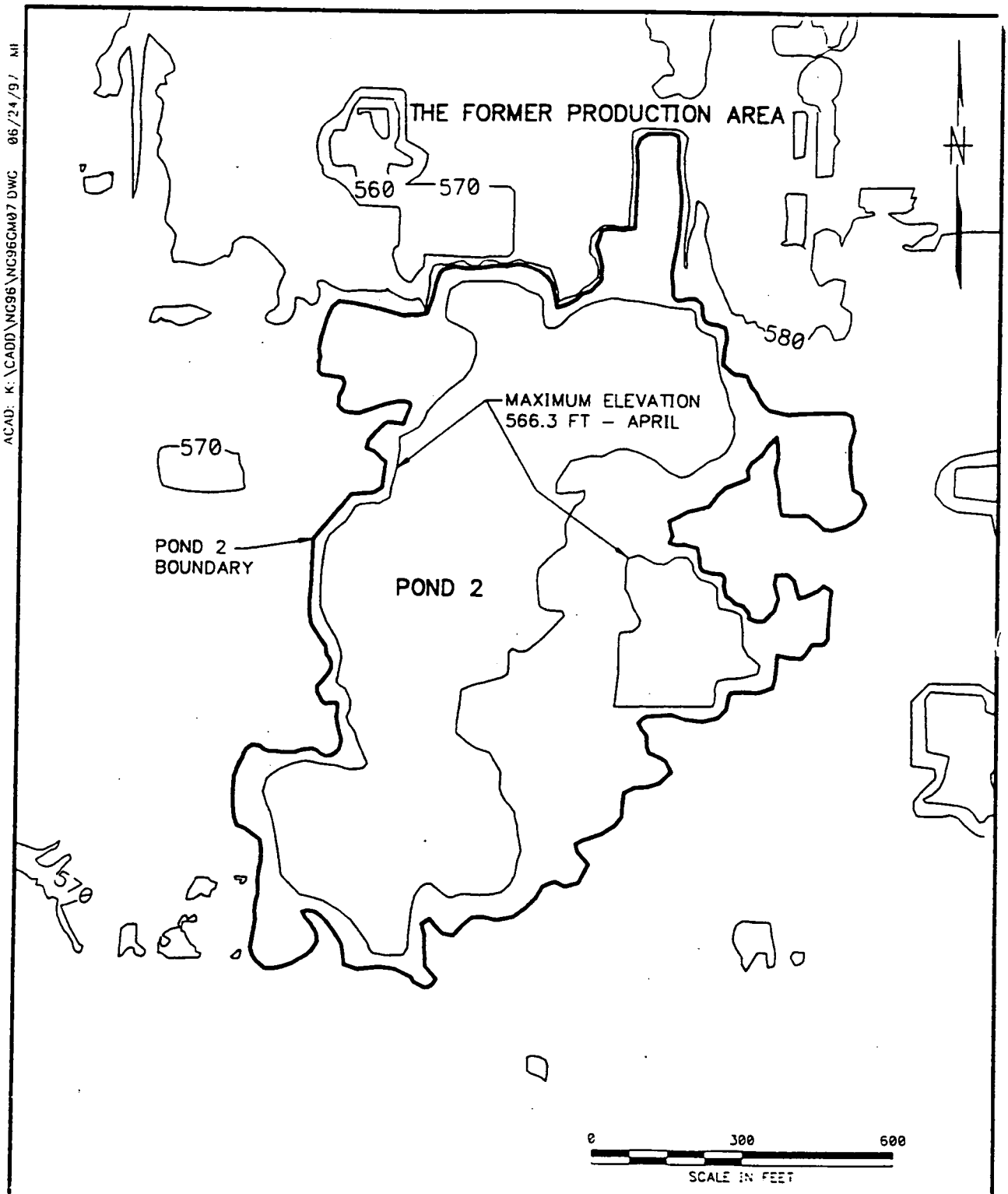

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DRAWN BY DLT DATE 6/13/97	Brown & Root Environmental	CONTRACT NO. NG96	OWNER NO.
CHECKED BY DATE	POND 2 WATER SURFACE OUTLINE UNDER NORMAL CONDITION MAXIMUM ELEVATION FEMP	APPROVED BY	DATE
COST/SCHED-AREA		APPROVED BY	DATE
SCALE AS NOTED		DRAWING NO. FIGURE 4-3	REV. 0

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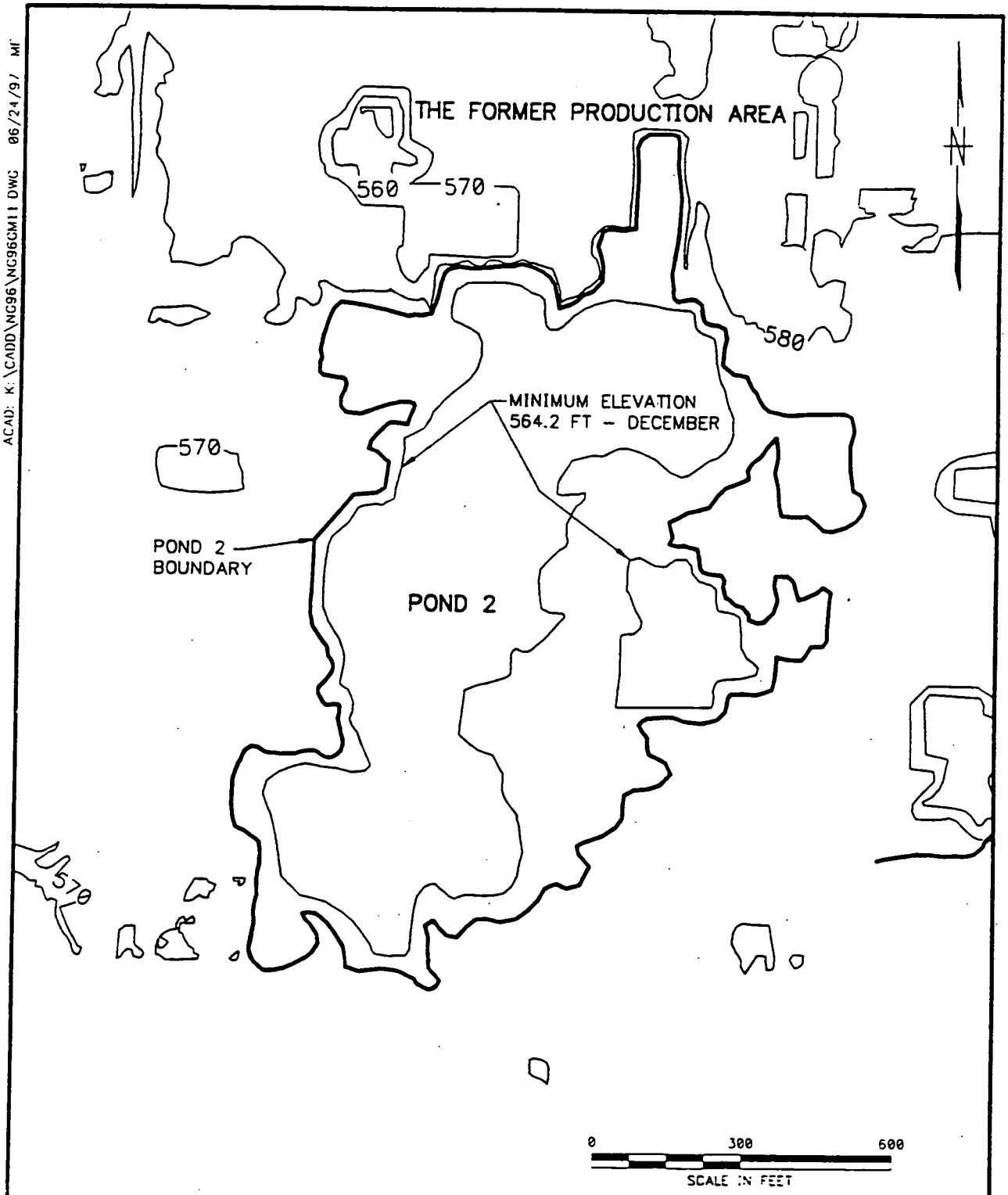

DRAWN BY DLT DATE 6/13/97	Brown & Root Environmental	CONTRACT NO. NG96	OWNER NO.
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COST/SCHED-AREA		APPROVED BY	DATE
SCALE AS NOTED		DRAWING NO. FIGURE 4-4	REV. 0

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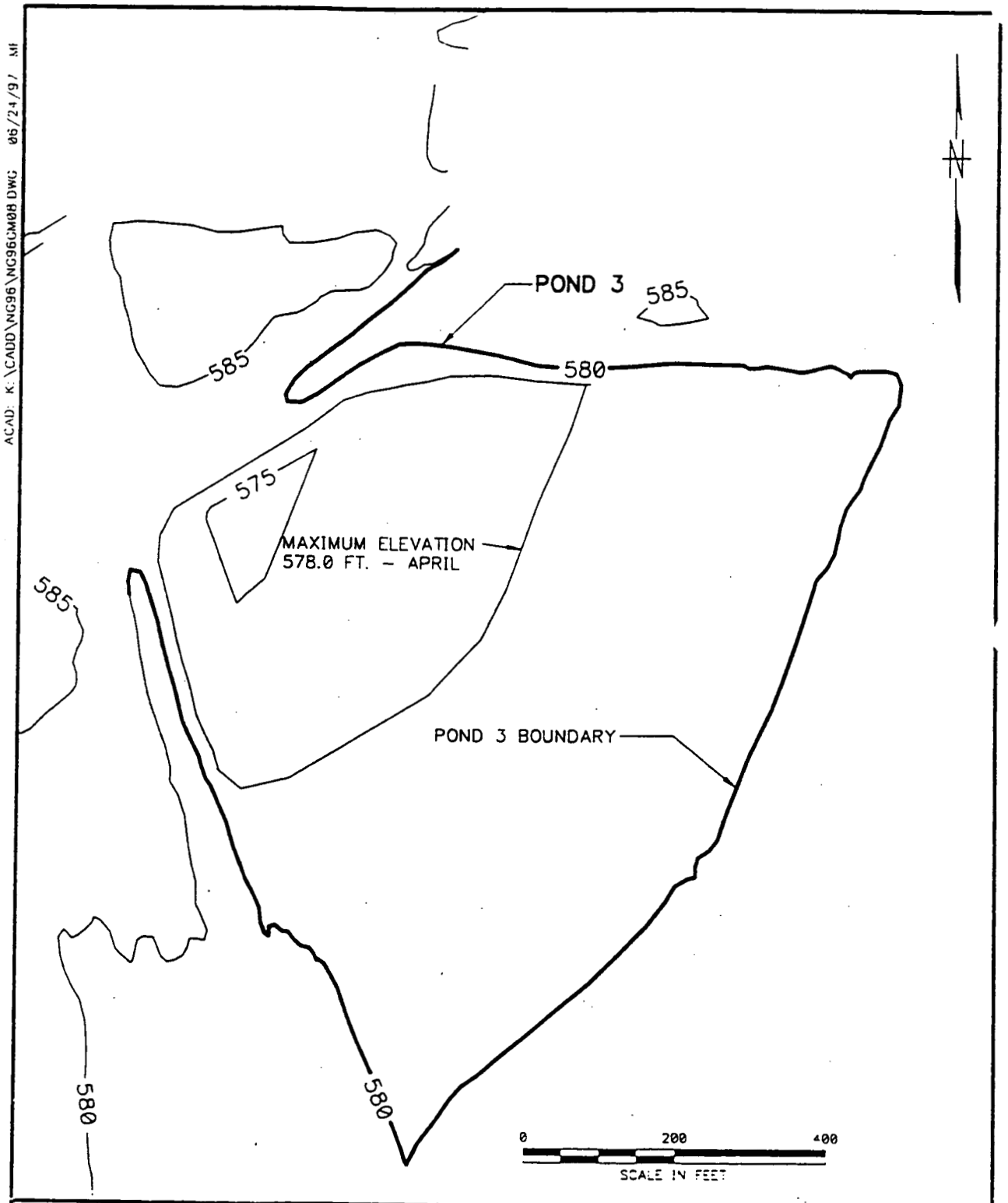

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CHECKED BY DATE	POND 3 WATER SURFACE OUTLINE UNDER NORMAL CONDITION MAXIMUM ELEVATION FEMP	APPROVED BY	DATE
COST/SCHED-AREA		APPROVED BY	DATE
SCALE AS NOTED		DRAWING NO. FIGURE 4-5	REV. 0

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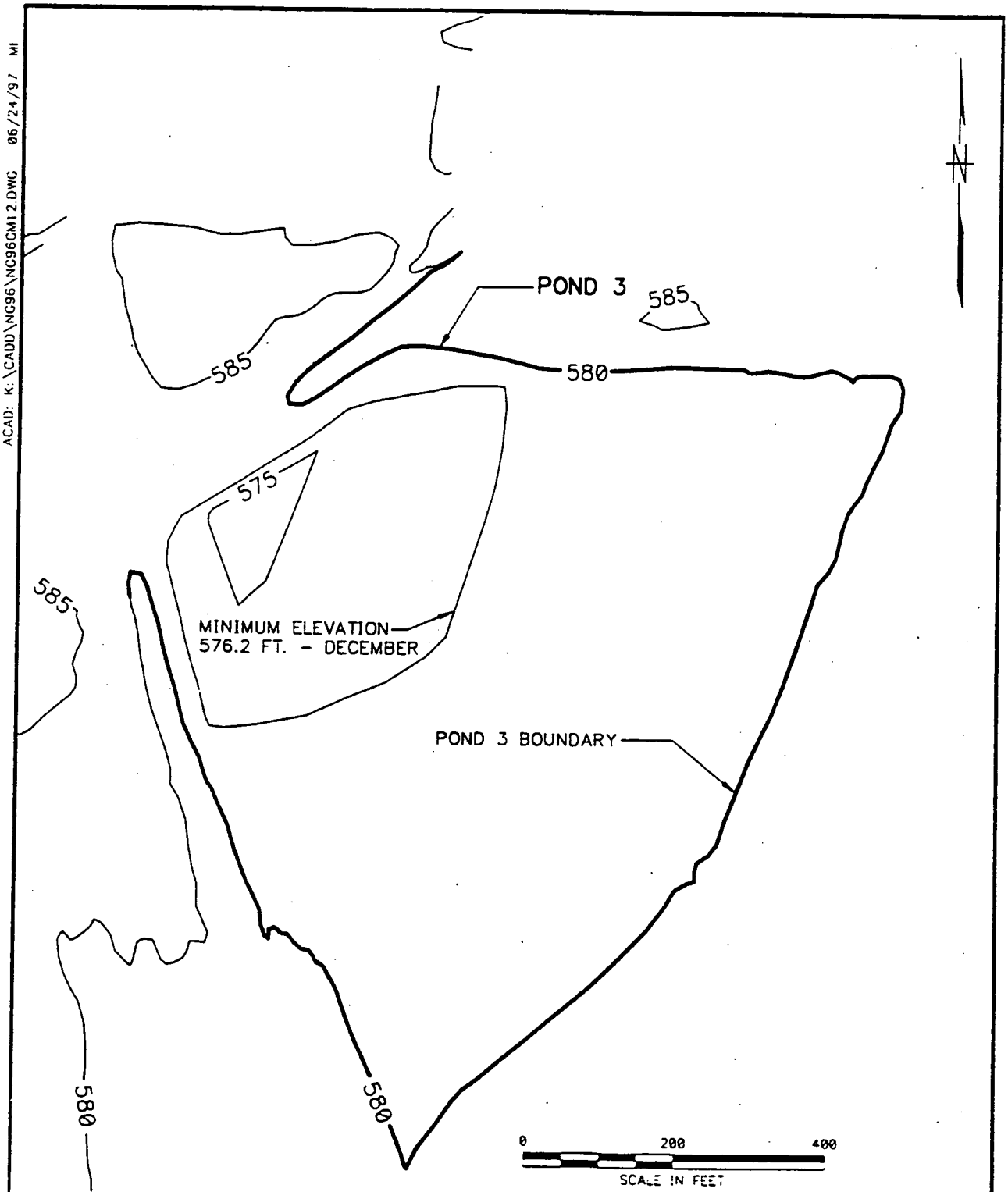

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CHECKED BY DATE	POND 3 WATER SURFACE OUTLINE UNDER NORMAL CONDITION MINIMUM ELEVATION FEMP	APPROVED BY	DATE
COST/SCHED-AREA		APPROVED BY	DATE
SCALE AS NOTED		DRAWING NO. FIGURE 4-6	REV. 0

FORM CADD NO. SOUTH_AV.DWG - REV 0 - 02/07/97

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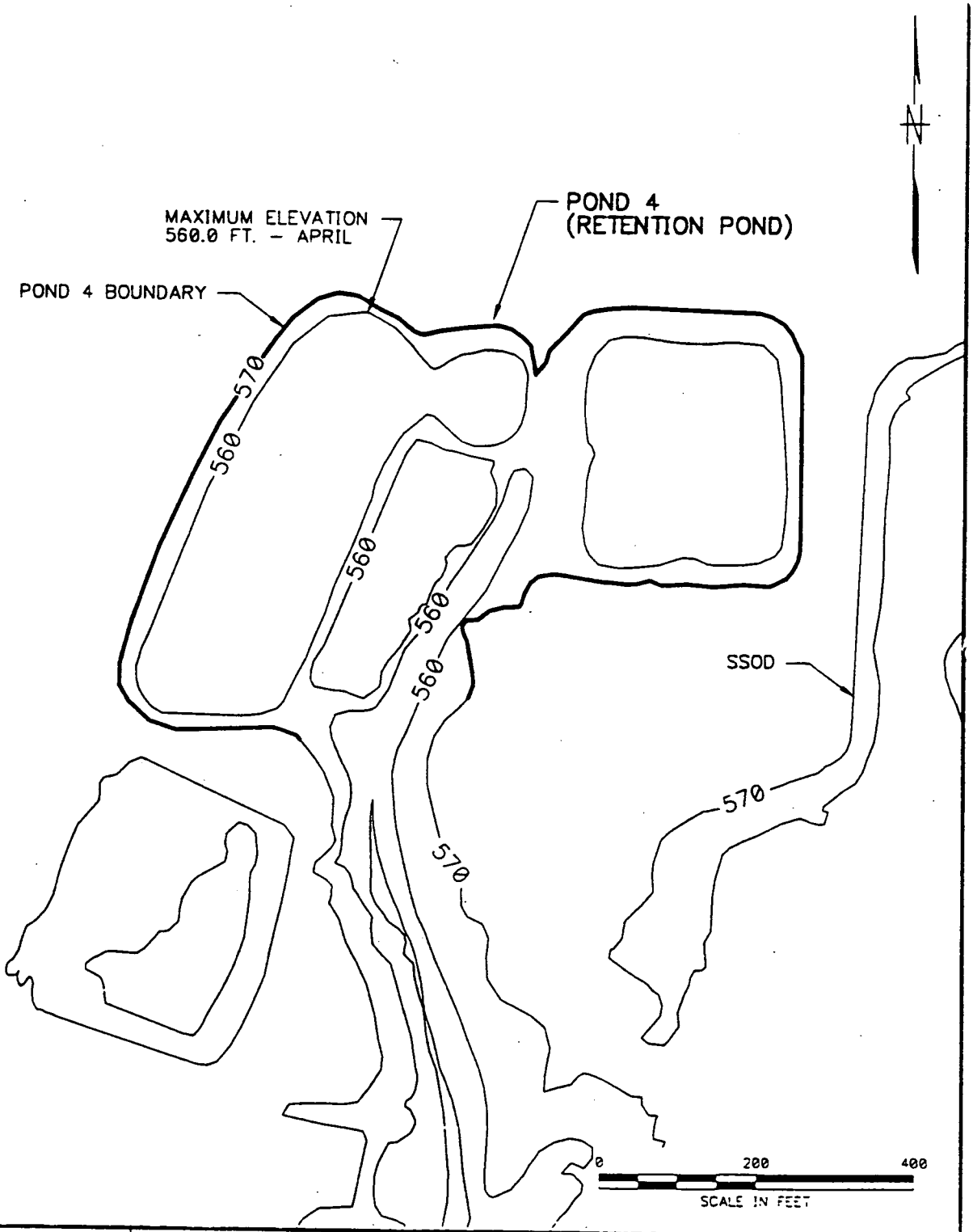

DRAWN BY GMF DATE 6/16/97	Brown & Root Environmental	CONTRACT NO. NG96	OWNER NO.
CHECKED BY DATE	POND 4 WATER SURFACE OUTLINE UNDER NORMAL CONDITION MAXIMUM ELEVATION FEMP	APPROVED BY	DATE
COST/SCHED-AREA		APPROVED BY	DATE
SCALE AS NOTED		DRAWING NO. FIGURE 4-7	REV. 0

FORM CADD NO. SOUTH_AV.DWG - REV 0 - 02/07/97

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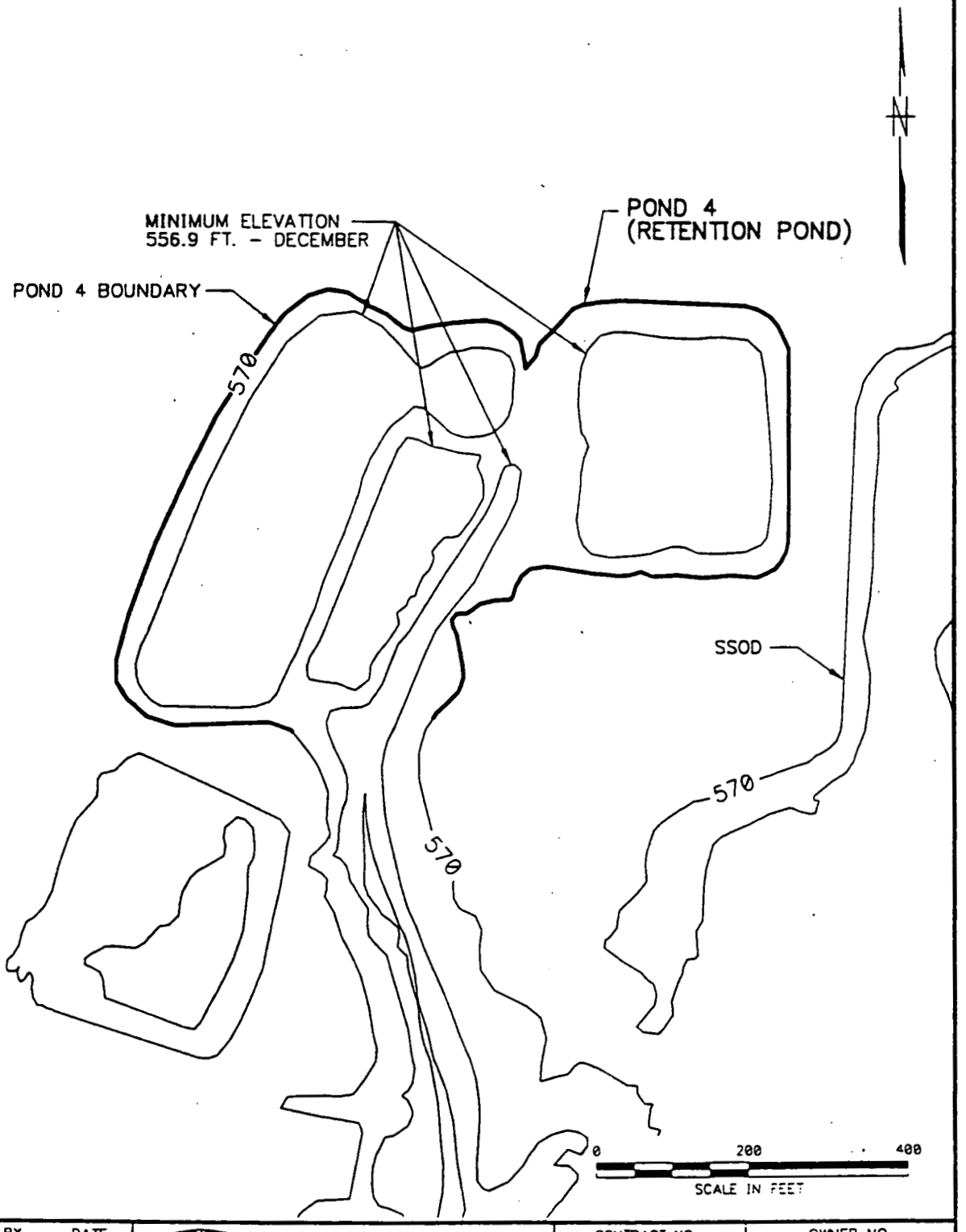

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COST/SCHED-AREA		APPROVED BY	DATE
SCALE AS NOTED		DRAWING NO. FIGURE 4-8	REV. 0

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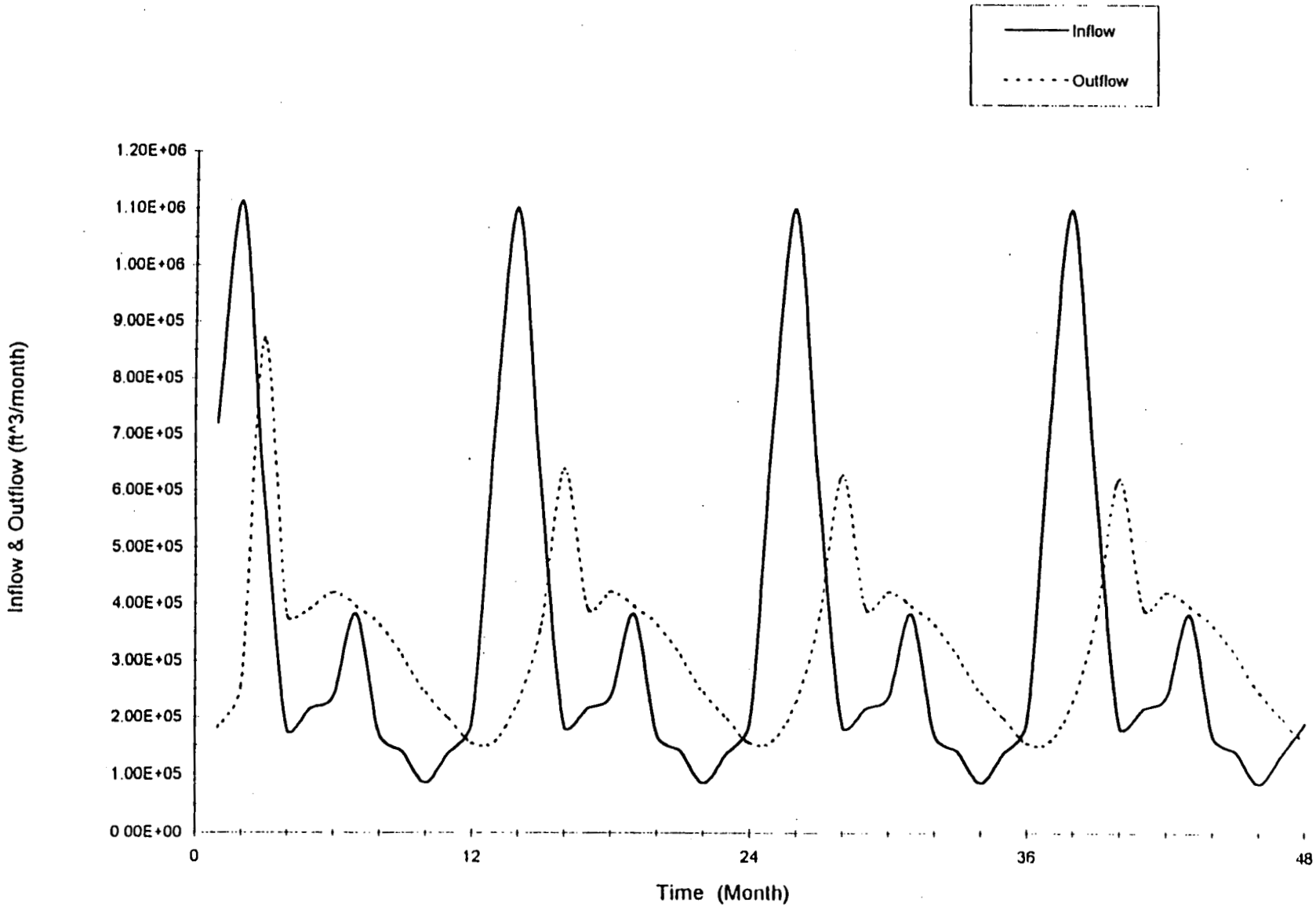

Figure 4-9 Monthly Inflow And Outflow Rates of Pond 1

000160

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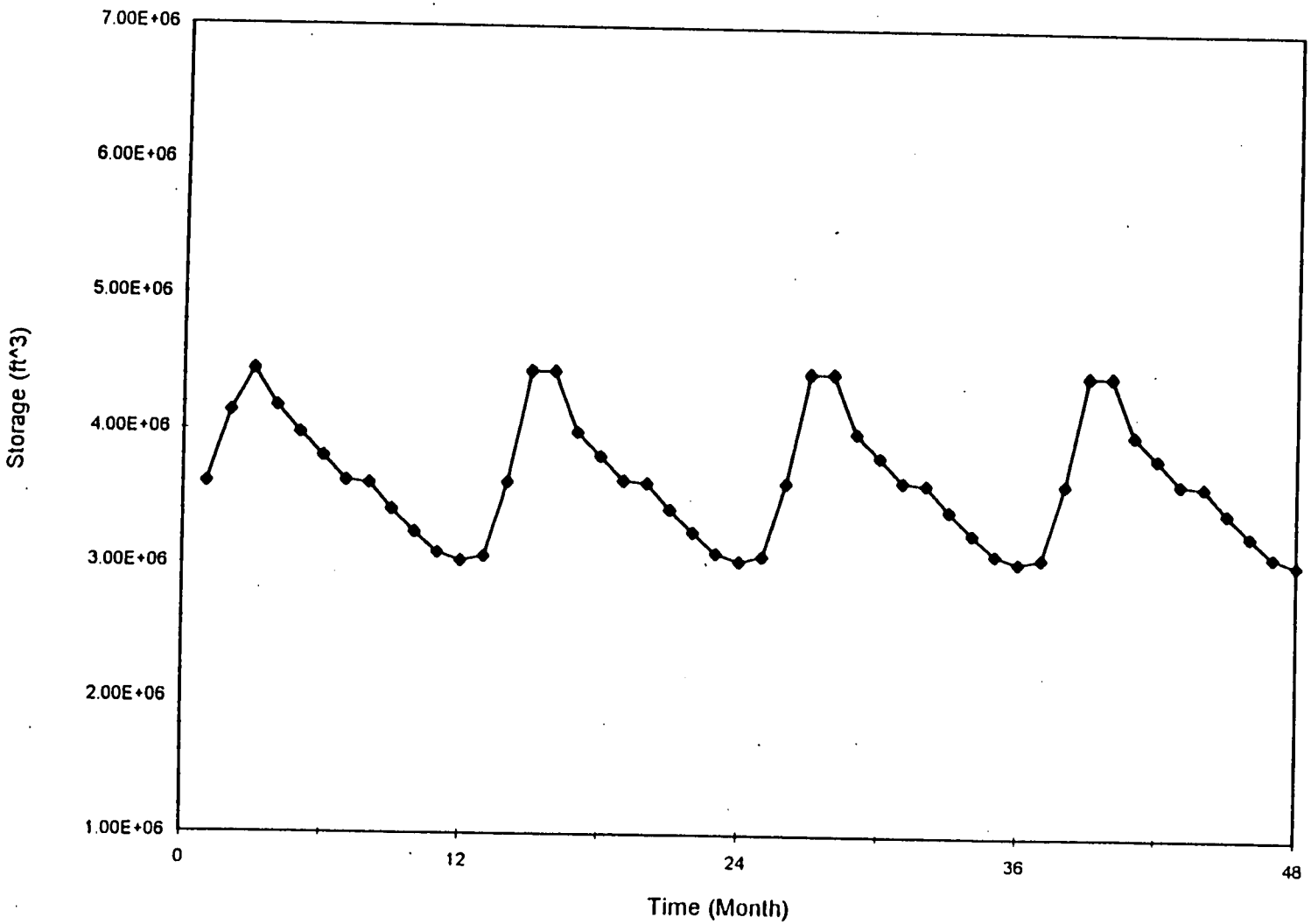

Figure 4-10 Monthly Storage Variations of Pond 1

000161

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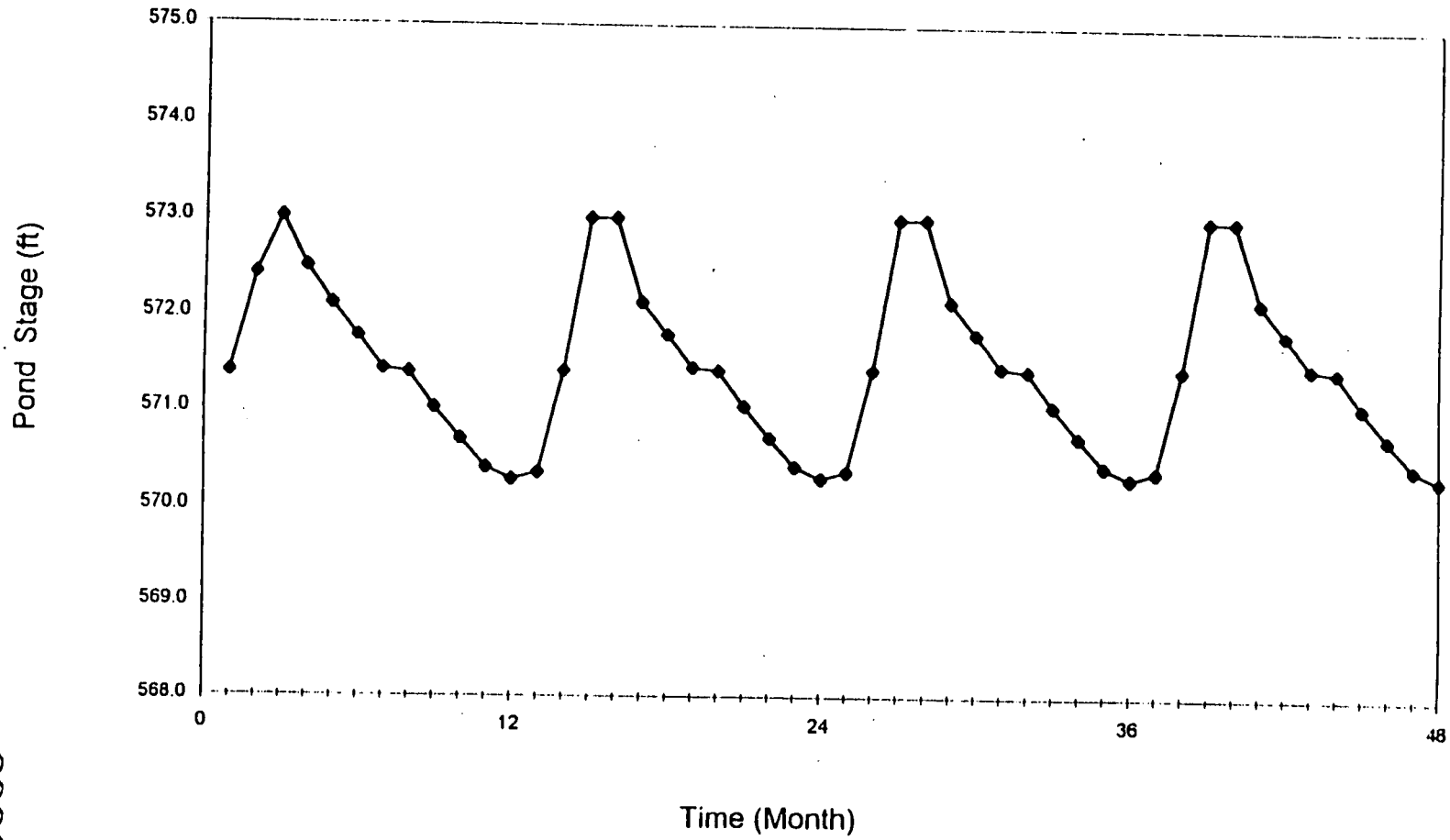

Figure 4-11 Monthly Stage Variations of Pond 1

0001162

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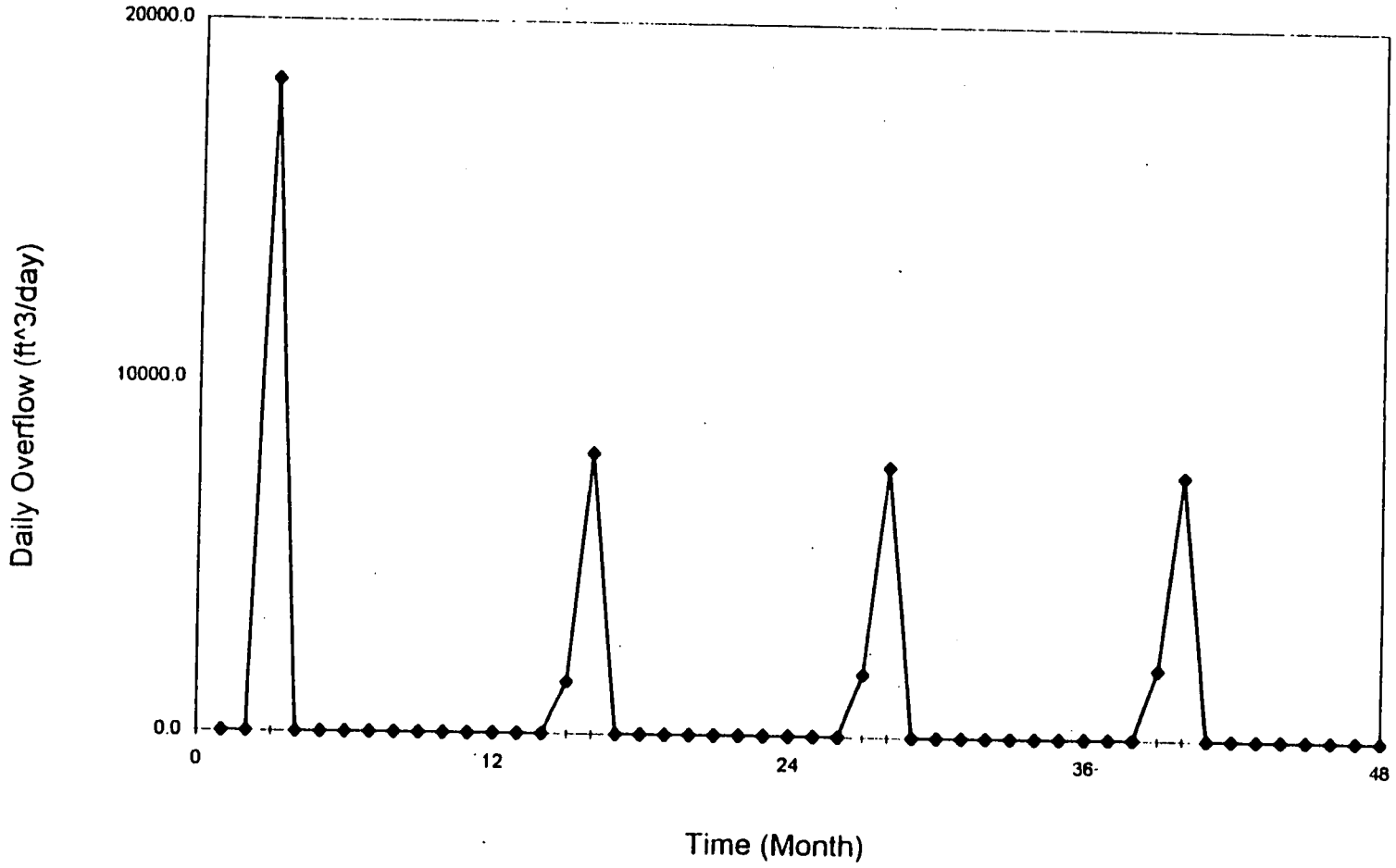

Figure 4-12 Daily Overflow Rates of Pond 1

000163

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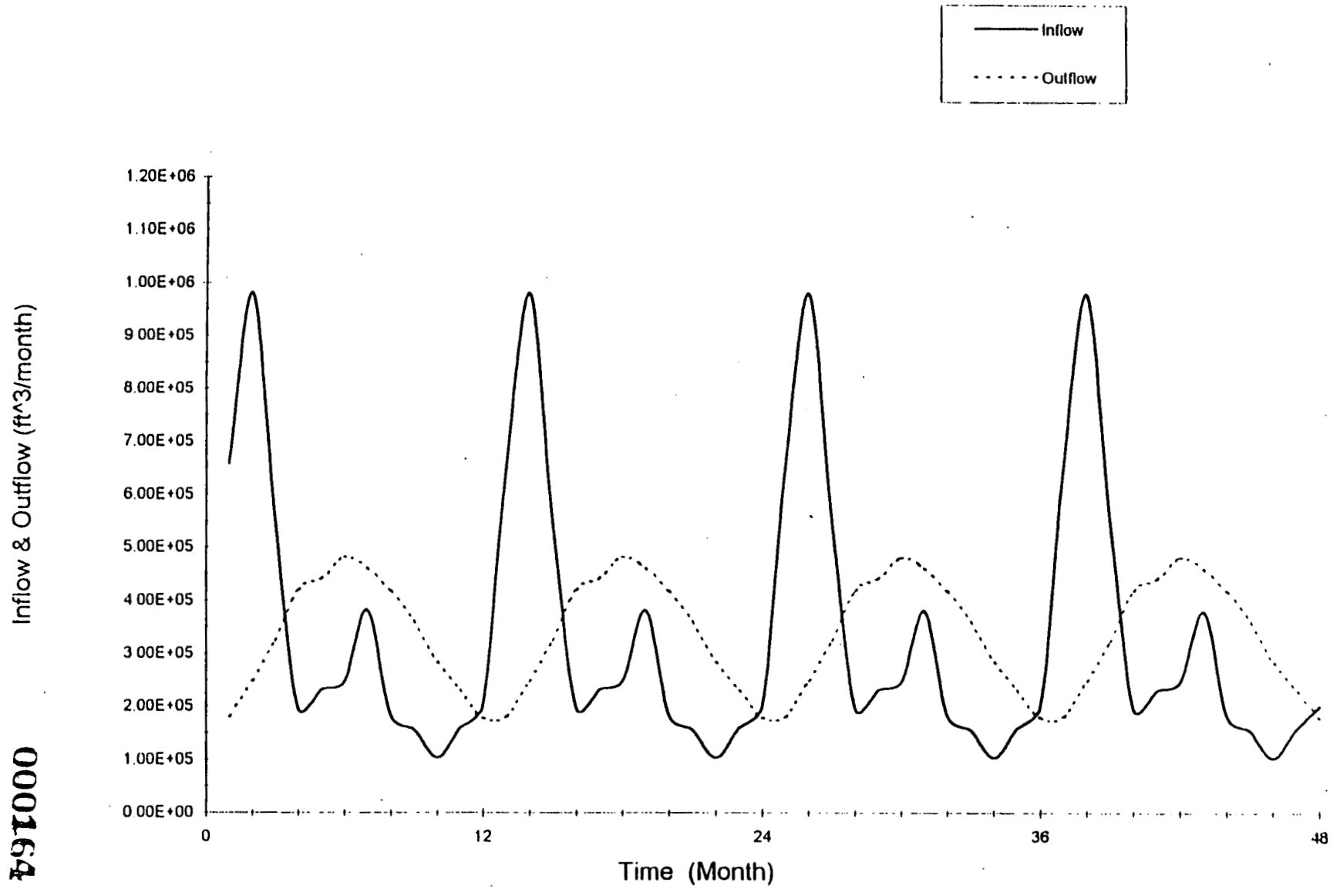

Figure 4-13 Monthly Inflow And Outflow Rates of Pond 2

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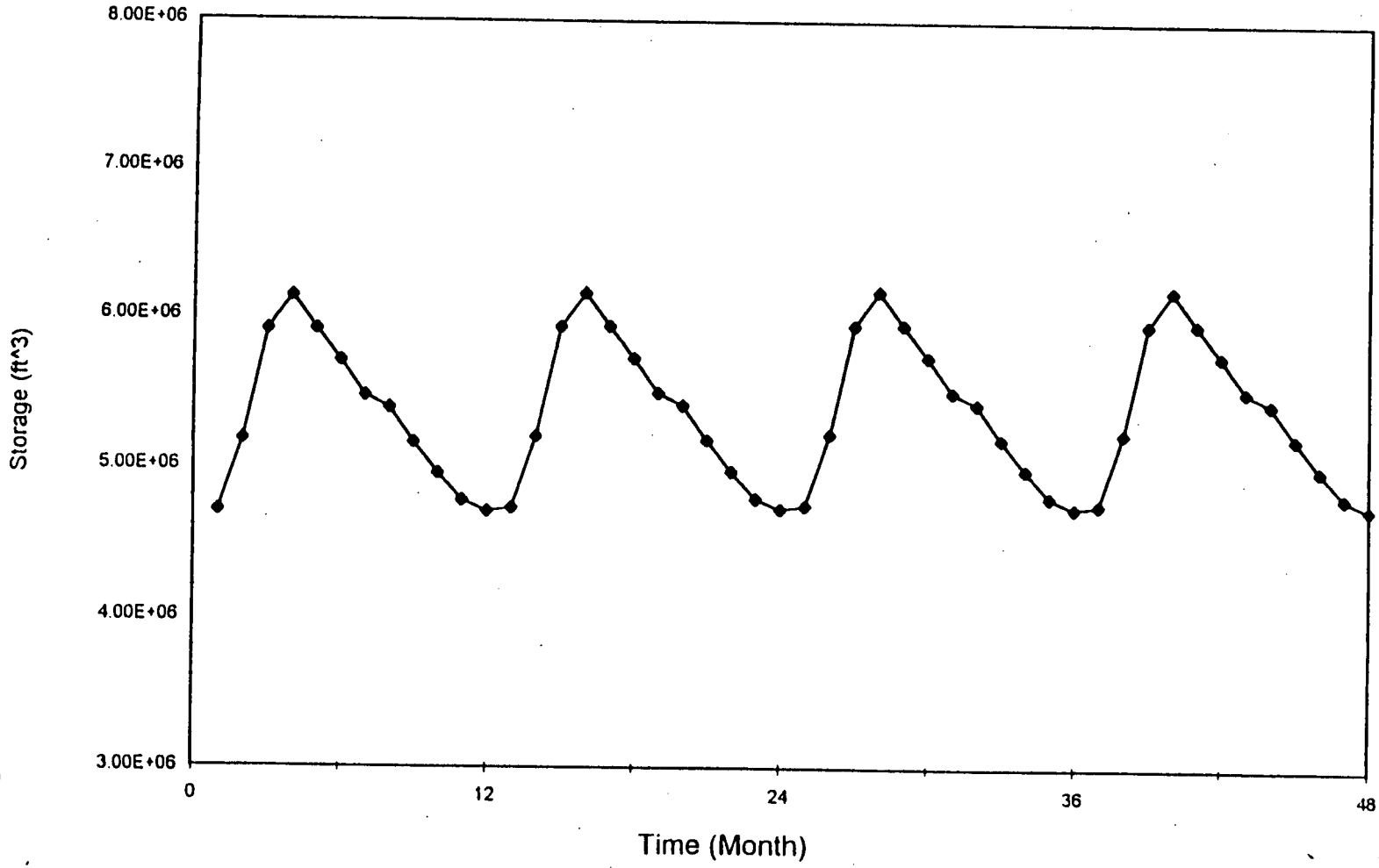

Figure 4-14 Monthly Storage Variations of Pond 2

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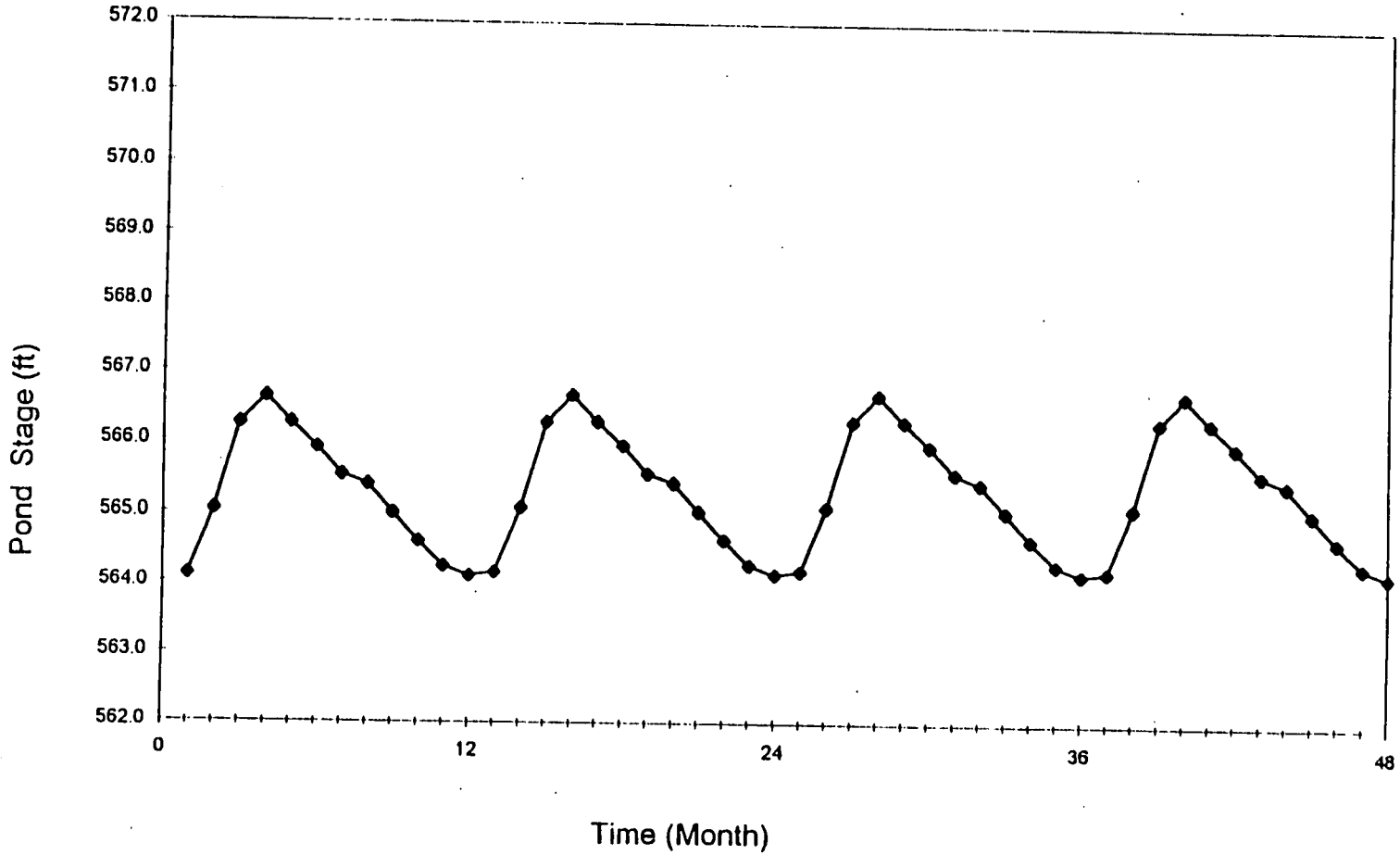

Figure 4-15 Monthly Stage Variations of Pond 2

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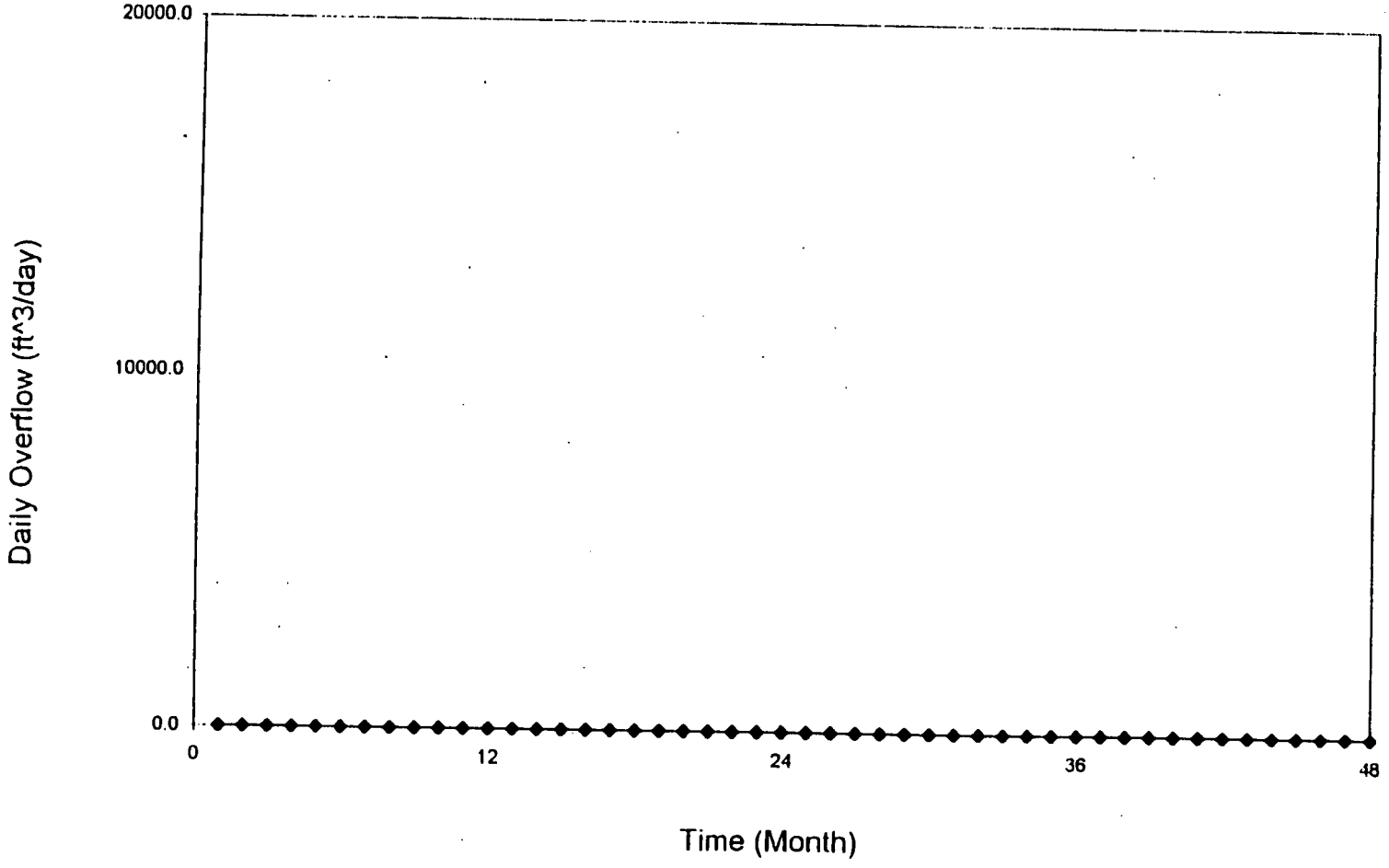

Figure 4-16 Daily Overflow Rates of Pond 2

000167

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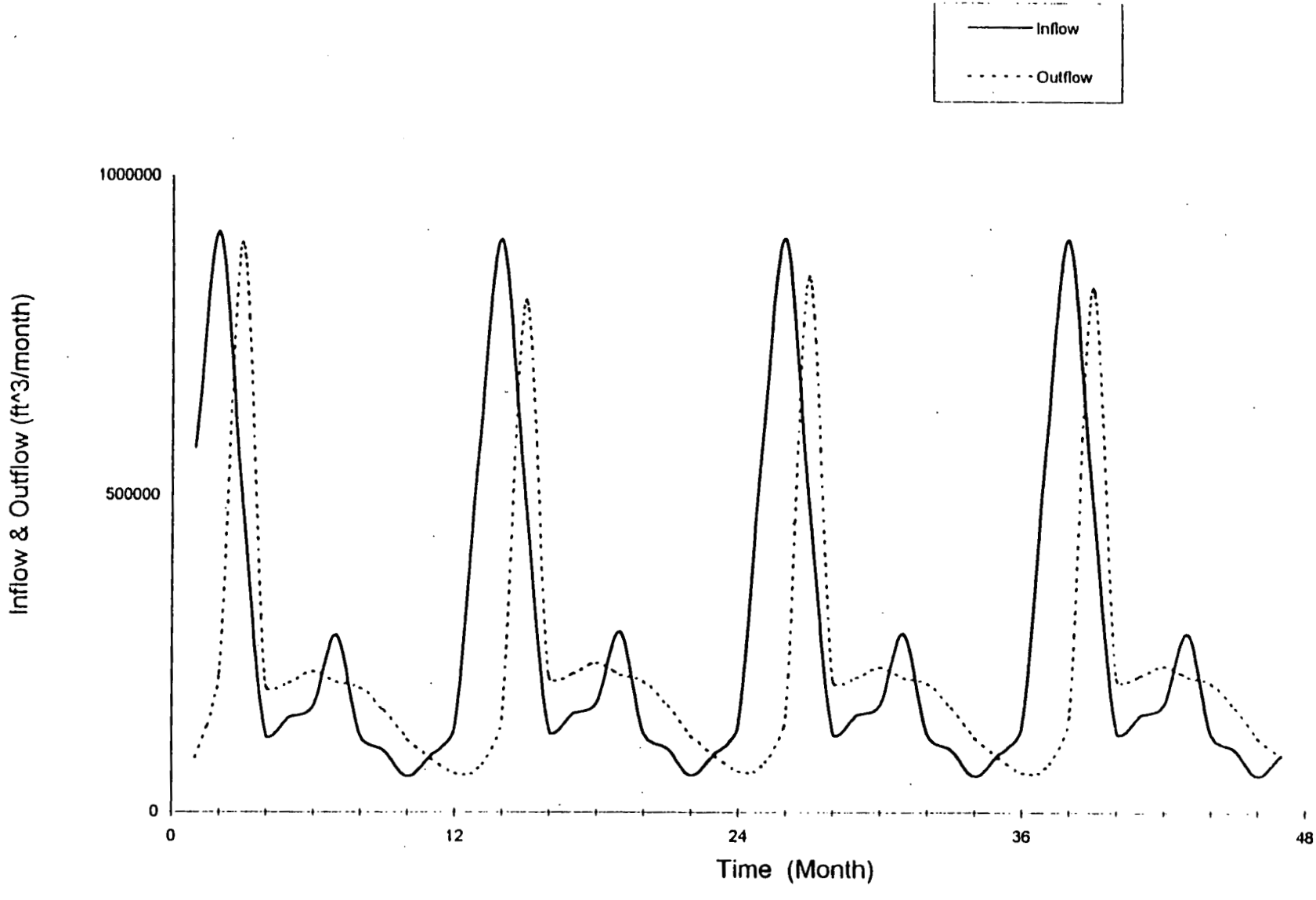

Figure 4-17 Monthly Inflow And Outflow Rates of Pond 3

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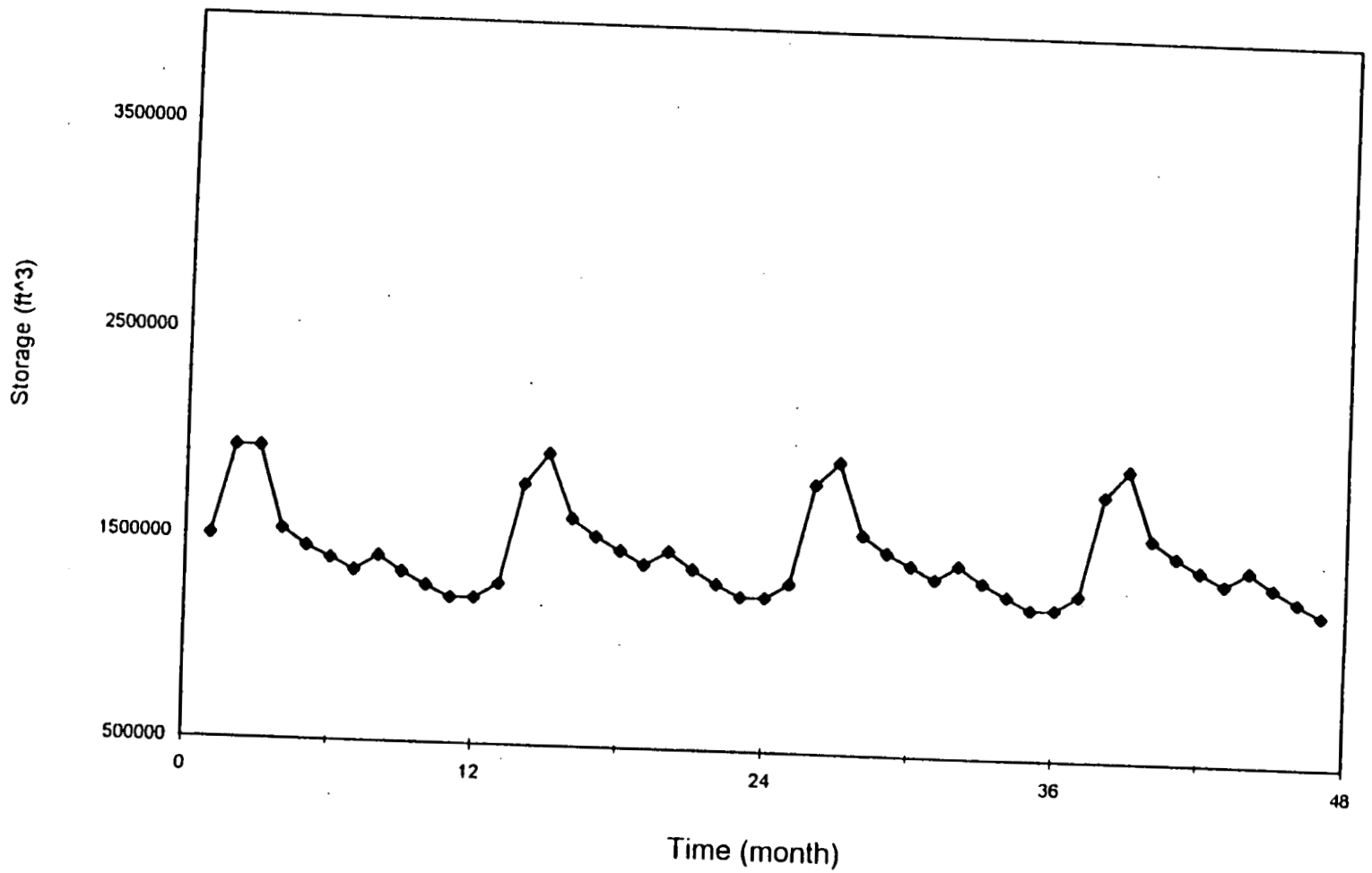

Figure 4-18 Monthly Storage Variations of Pond 3

000169

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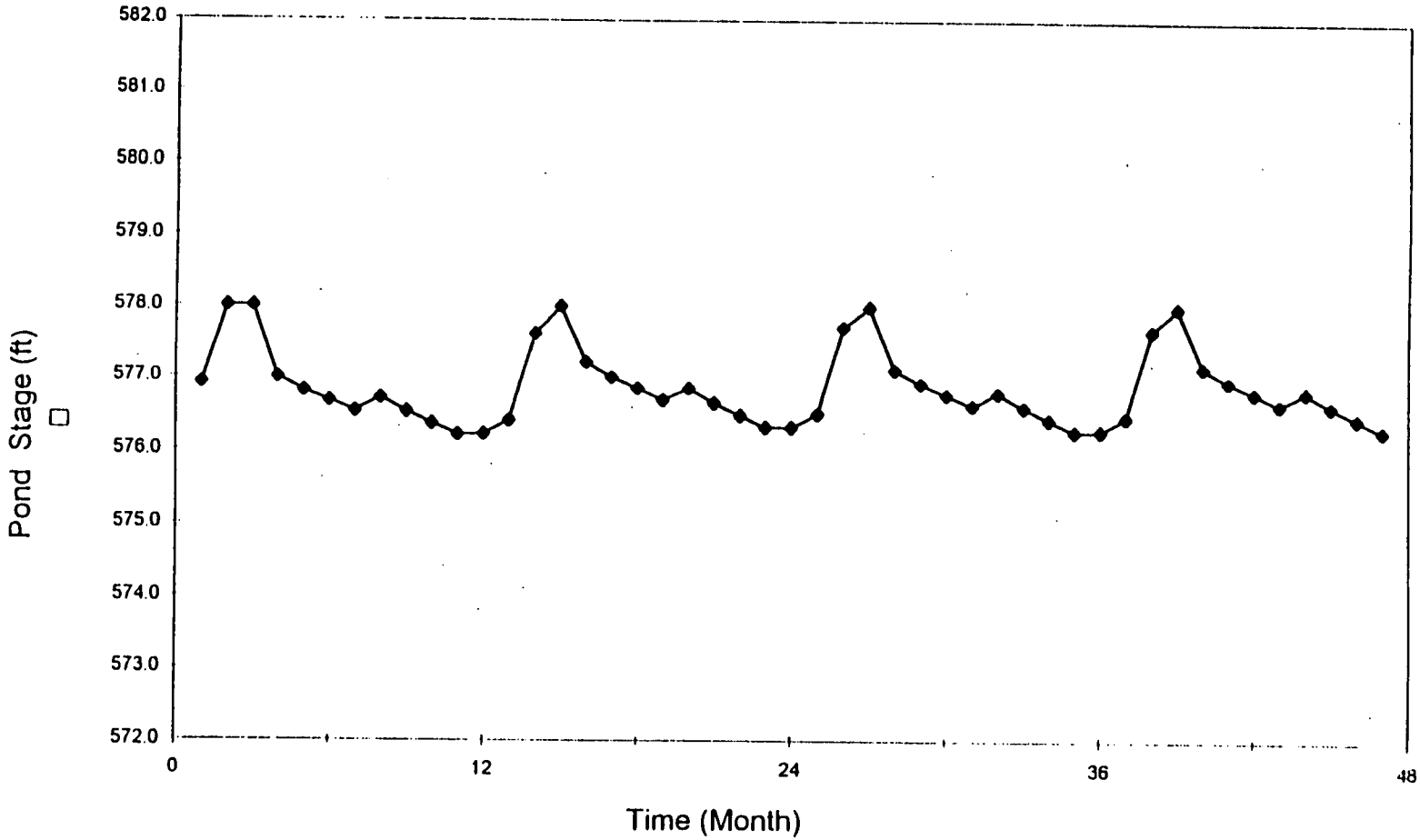

Figure 4-19 Monthly Stage Variations of Pond 3

000120

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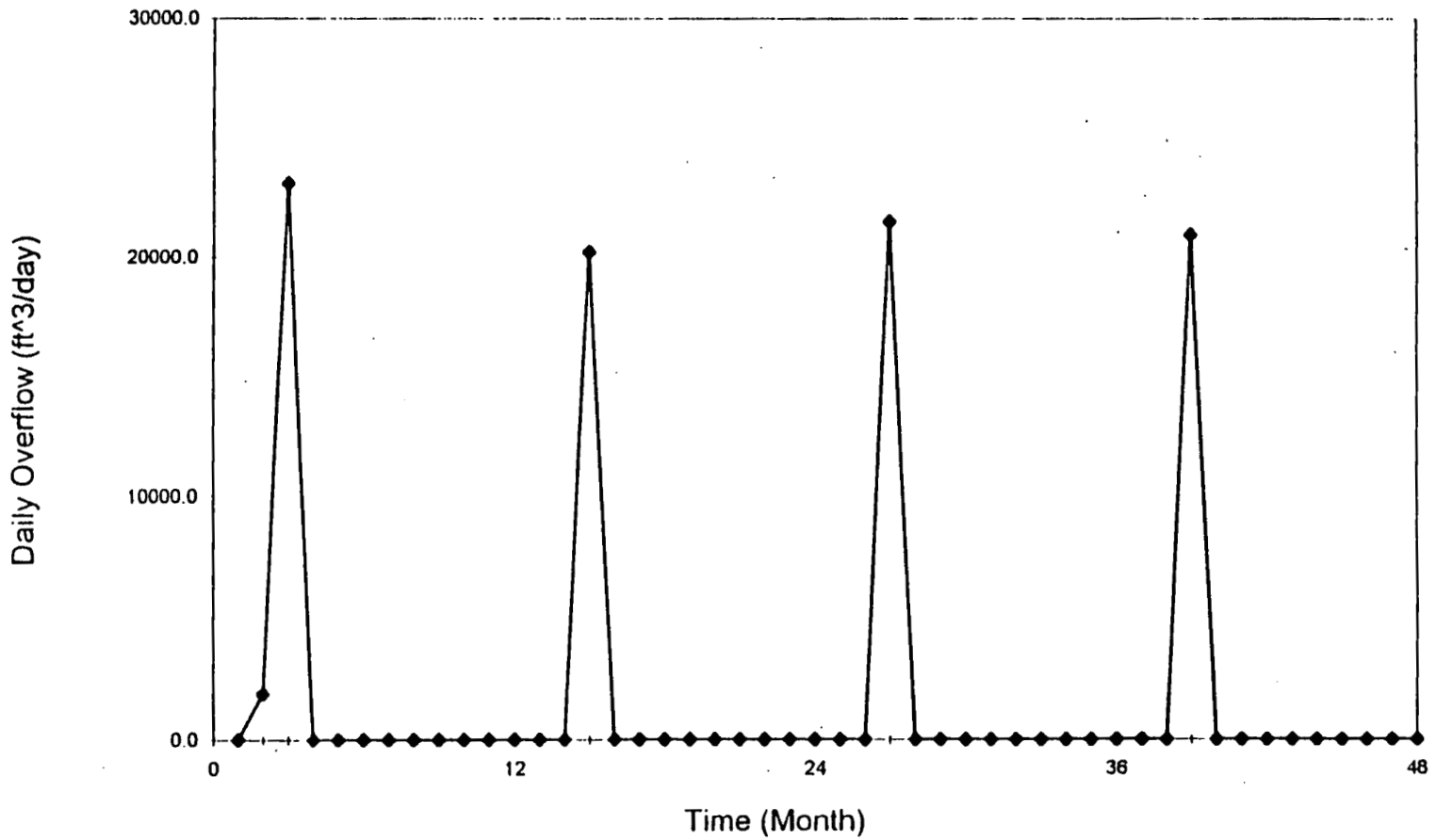

Figure 4-20 Daily Overflow Rates of Pond 3

0001721

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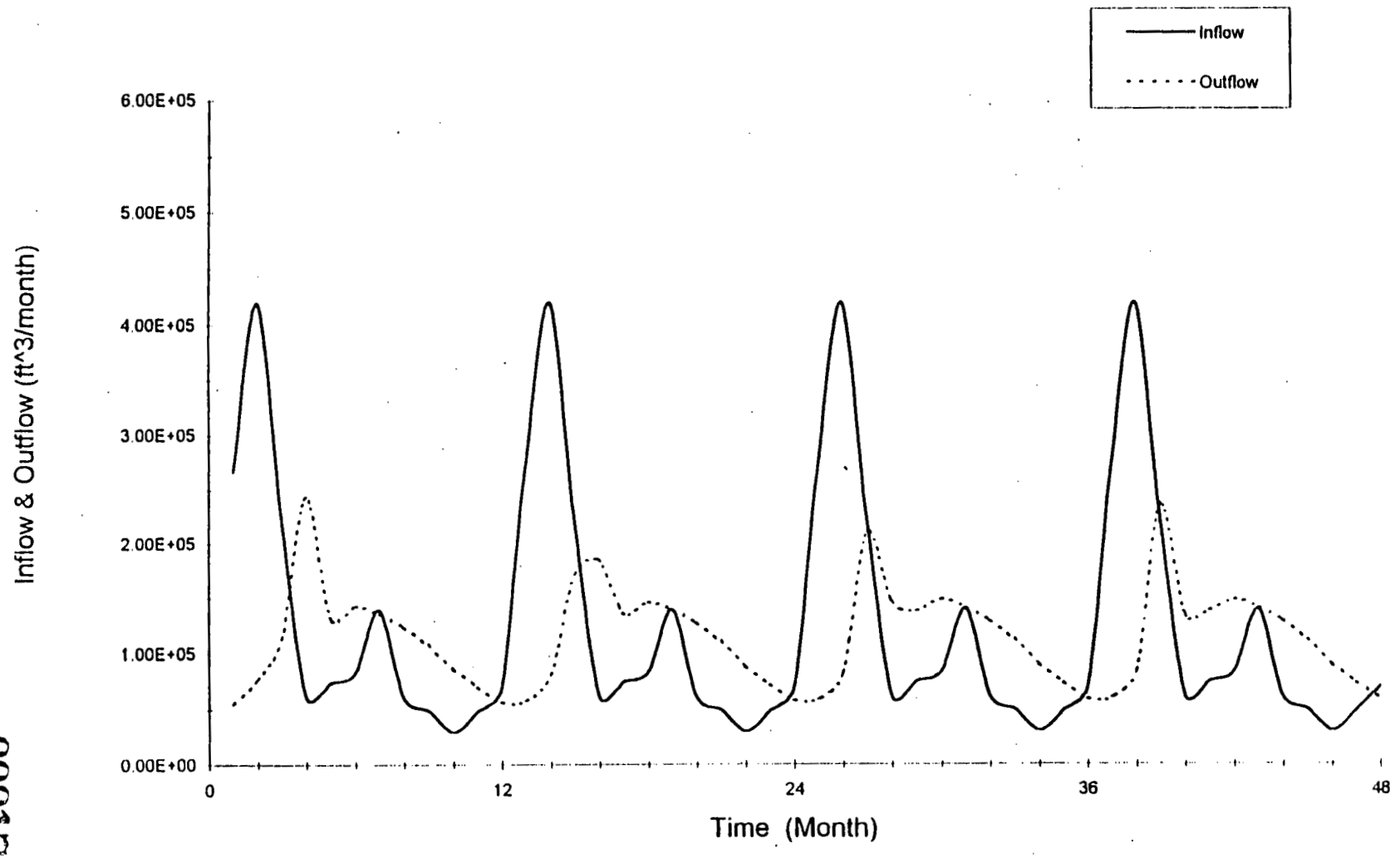

Figure 4-21 Monthly Inflow And Outflow Rates of Pond 4

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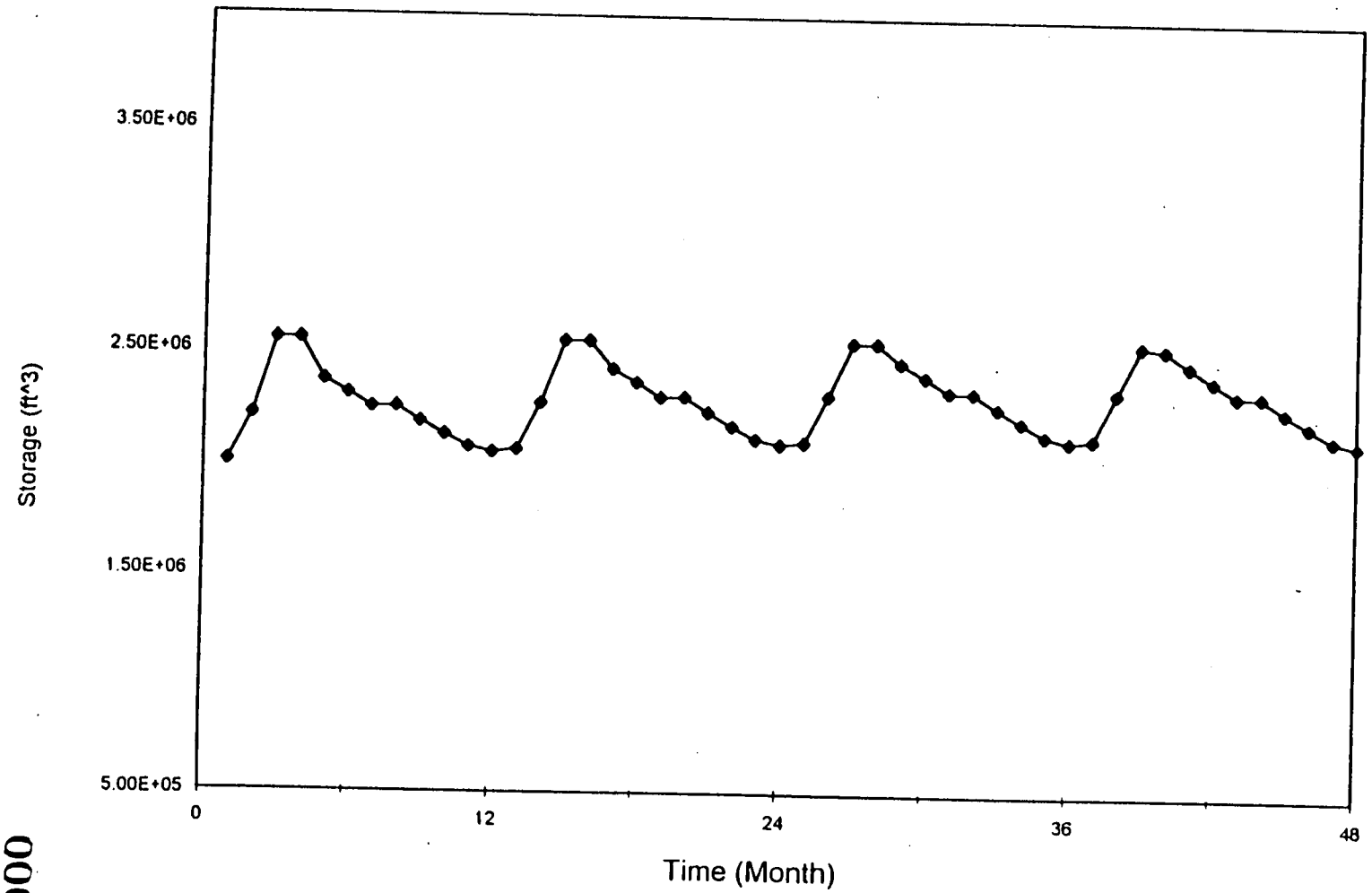

Figure 4-22 Monthly Storage Variations of Pond 4

000173

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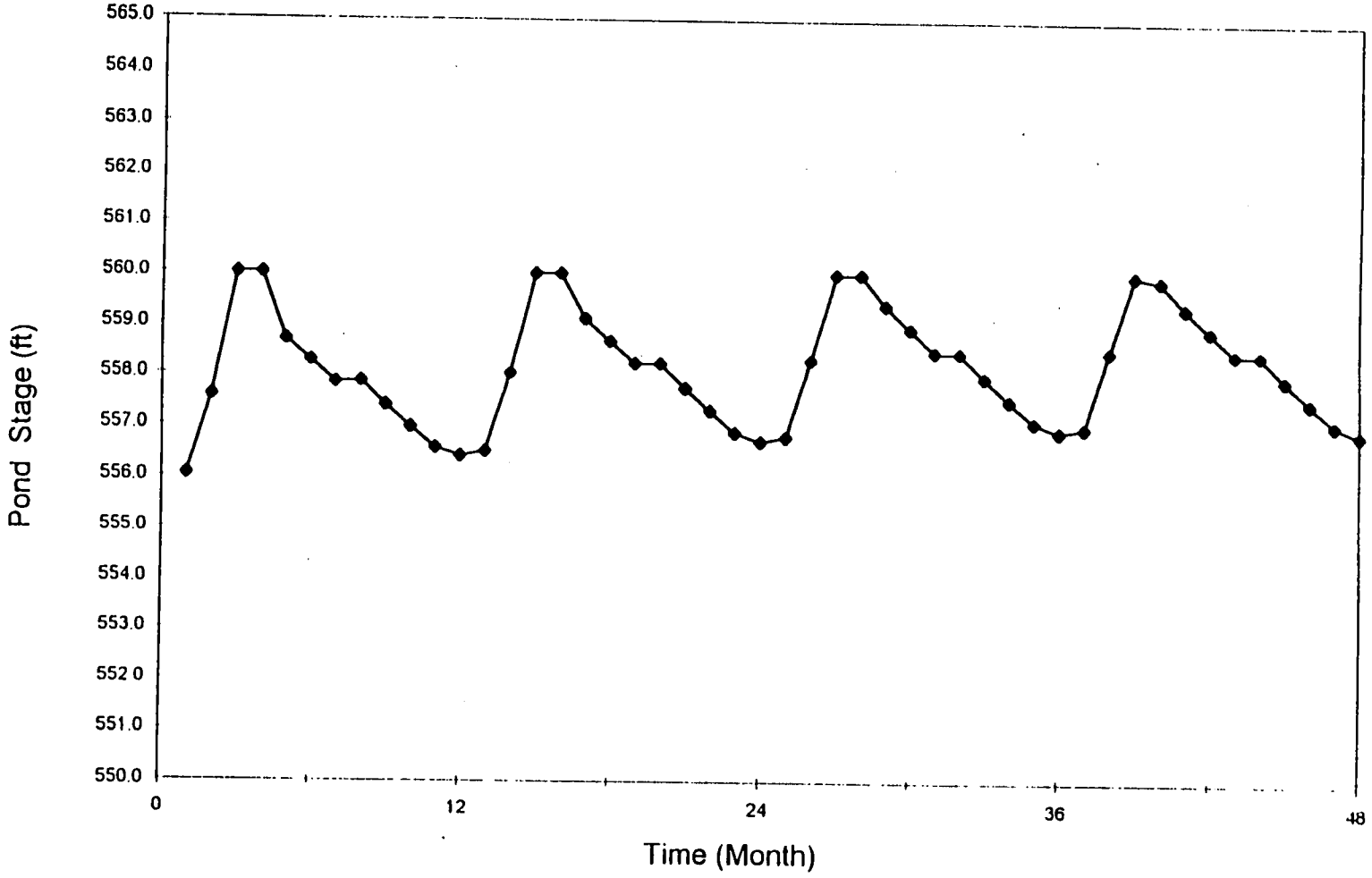

Figure 4-23 Monthly Stage Variations of Pond 4

000174

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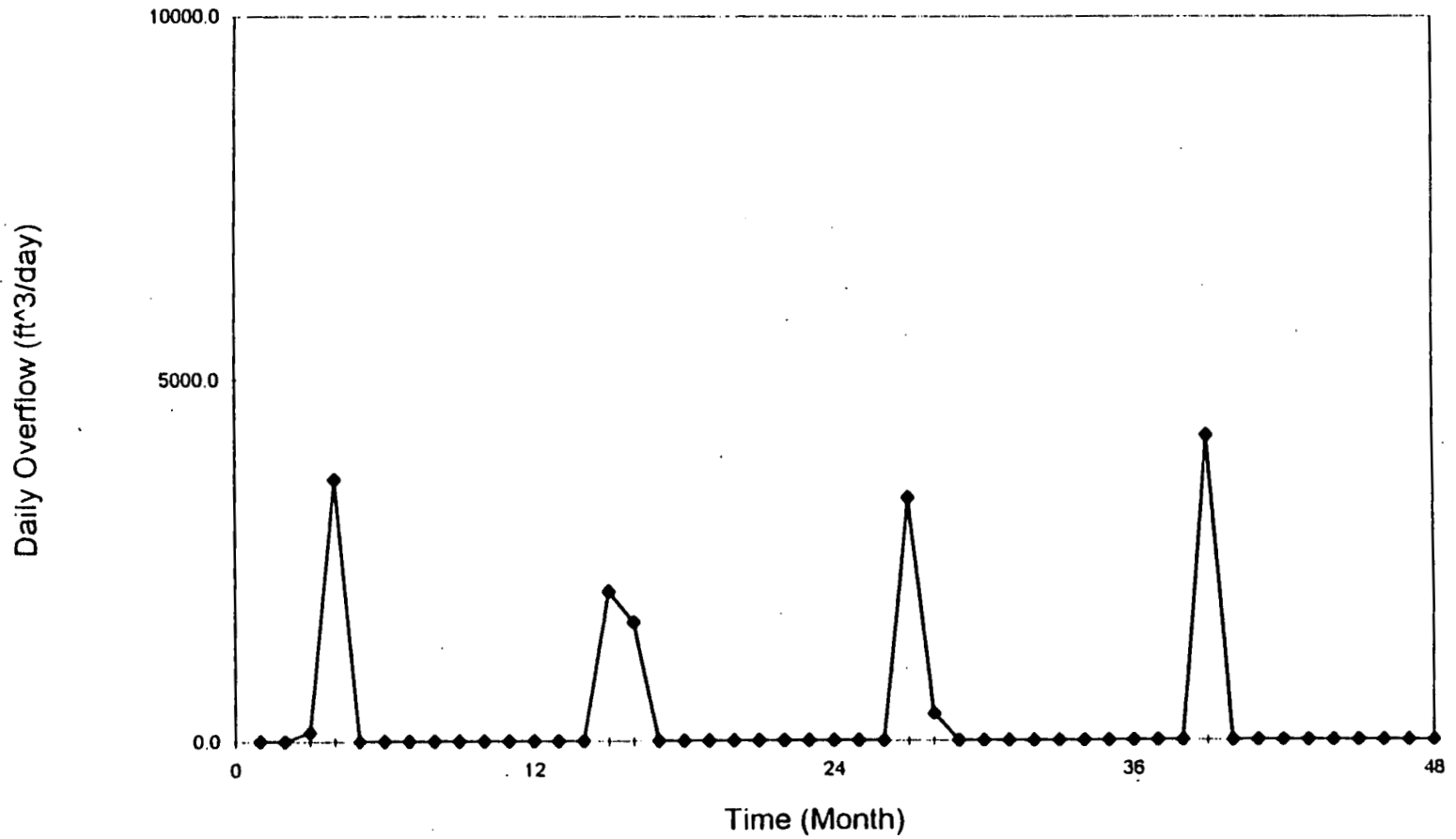

Figure 4-24 Daily Overflow Rates of Pond 4

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5.0 POND MODELING RESULTS UNDER EXTREME CONDITIONS

This section presents the storage routing modeling results under extreme conditions. The extreme conditions can be simulated by a storm event. The peak inflow rates generated by a storm event were modeled by using the TR55 method that is suitable for small watersheds. The characteristic storm typically considered in the TR55 method is a storm with a 25-year return period and a 24-hour duration. The input parameters and a brief description of inflow runoff routing using the TR55 method will be given first, then followed by the summary of modeling results generated by this characteristic storm.

5.1 INPUT PARAMETERS

The input data to the routing model used for the extreme conditions are briefly summarized in this subsection.

Drainage Area. The drainage areas are the total of their corresponding multiple subbasins. The drainage areas used in the TR55 method are the same as the normal conditions. Table 2-1 presents the areas of the subbasins that contribute runoff to each individual pond. Appendix B also presents the drainage areas and subbasin areas.

The following four parameters used for extreme conditions are the same as that for normal conditions.

- Pond Bottom Elevations.
- Pond Overflow Elevations.
- Groundwater Elevation.
- Pond Liner Hydraulic Conductivity.

The outflow components such as evaporation and infiltration through the pond liner were not considered in the routing process. The reason for this simplification is justified by the insignificant amount of loss of these two components within a relatively short period of the routing process (about three to five days).

Curve Number. A CN value of 74 was selected, based on site watershed hydrological soil groups.

25-year, 24 hour Rainfall Depth. A total of 4.7 inches of precipitation was selected from the Rainfall Frequency Atlas of the United Stated, TP No. 40.

Two-year, 24-hour Rainfall Depth. A total of 2.9 inches of precipitation was selected from the Rainfall Frequency Atlas of the United Stated, TP No. 40.

Other input parameters used in the TR55 method for characterizing the subbasins are Manning's roughness coefficient, land slope, flow length and flow width, and natural channel slope.. This data is also presented in Appendix B for each individual pond.

5.2 ROUTING HYDROGRAPH USING TR55 METHOD

Technical Release No. 55 (TR55), "Urban Hydrology for Small Watersheds," was originally developed by the United States Soil Conservation Service (SCS) in the 1970's, and was revised in 1986. TR55 was used to provide a hydrologic method for small watersheds. The Tabular Hydrograph Method is utilized for modeling multiple subareas that contribute runoff to one common design outfall point in a watershed. As a general guideline, the Tabular Hydrograph Method is applicable to a watershed with subbasin time of concentration between 0.1 and 2.0 hours, and subbasin travel time from 0.0 to 3.0 hours. For complicated watersheds, watersheds can be broken up into multiple subbasins such as the one shown in Figure 1-1. The effects of ground cover, time of concentration, reach routing times, drainage area, and precipitation for each subbasin can be taken into account independently first. Subsequently, it generates each subarea's runoff hydrograph and individually routes it to the watershed's outfall all in one step. All of the subarea's routed hydrographs are then summed directly at the watershed's outfall to obtain a composite hydrograph. Table 2-1 and Figure 1-1 presents the multiple subbasins that are related to their drainage areas.

5.3 POND INITIAL STAGES AND STORAGE

In order for the model to be conservative, the maximum storage volume predicted under normal conditions was used as the initial storage of the ponds, in addition to the peak discharge generated by a 25-year and 24-hour storm event. Table 5-1 presents the initial stage and corresponding storage of the four open water areas.

TABLE 5-1

POND INITIAL STAGES AND STORAGE

UNDER EXTREME CONDITIONS

	Stages (feet)	Storage (ft^3)
POND 1 (Northeast of FEMP)	573	4.45×10^6
POND 2 (Northwest of FEMP)	566.33	5.96×10^6
POND 3 (Southeast of FEMP)	578	1.93×10^6
POND 4 Retention Pond	560	2.55×10^6

As indicated in the above table, the initial stage of the four ponds are also the maximum stages designed for the normal conditions, since the weirs will facilitate outflow control. With the exception of Pond 2, the weir bottom elevations have set the maximum pool levels within the ponds.

Tables D-1 through D-4 in Appendix D present the storage routing calculations for a 25-year frequency and 24-hour duration storm.

5.4 POND INFLOW AND OUTFLOW HYDROGRAPH

TR55 method will generate a composite hydrograph for each pond given the physical and hydrologic parameters for the subbasins. The time step used in storage routing computation is six minutes. The input parameters used in TR55 method such as CN value and Mannings value for grassy condition are consistent with the OSDF surface water management study prepared by Parsons. A CN value of 74 was also selected, based on site watershed hydrological soil groups. The soil groups were classified as type B and C, for Dana Eden, Fincastle, Miamian-Russel, Ragsdale, and Xenia soils. A Mannings number of 0.3 was used for a dense bermude grass.

The results indicated that Pond 1 has the highest peak inflow rates of 129 cubic feet per second (cfs), while Pond 4 (retention pond) has a lowest inflow rates given the same characteristic storm event. This

difference in peak inflow rates is directly affected by the size of their drainage areas. Table 5-2 presents the peak inflow rates and the time it takes to reach the peak inflow rates.

TABLE 5-2
PEAK INFLOW RATES AND TIME TO PEAK DISCHARGE UNDER EXTREME CONDITIONS

	Peak Inflow Rates (cfs)	Time to Peak Inflow Rates (hours)
POND 1 (Northeast of FEMP)	129	13
POND 2 (Northwest of FEMP)	117	13
POND 3 (Southeast of FEMP)	95	12.8
POND 4 (Retention Pond)	43	13.2

Figures 5-9, 5-13, 5-17, and 5-21 present inflow and outflow hydrographs for the four ponds respectively. As indicated in the hydrographs, outflow generated by this characteristic storm will generally takes 130 hours or about five days to be dissipated through the weirs. The weirs width were designed as five feet for Pond 1, 2, and 3. The weir bottom width for retention pond is 20 feet, based on the exiting configurations.

5.5 POND STORAGE VARIATION WITH TIME

Figures 5-10, 5-14, 5-18, and 5-22 present pond storage variations with respect to time for the four ponds respectively. Time to reach the peak inflow rates ranged from 12.8 to 13.2 hours (also see Table 5-2). As indicated in the hydrograph, storage variations experienced within each pond are in the same order of magnitude. This is the result of regulation through the weirs. Table 5-3 presents the storage changes for each pond.

TABLE 5-3

MAXIMUM AND MINIMUM POND STORAGE UNDER EXTREME CONDITIONS

	Maximum Storage (ft^3)	Minimum Storage (ft^3)
POND 1 (Northeast of FEMP)	4.99×10^6	4.45×10^6
POND 2 (Northwest of FEMP)	6.77×10^6	5.96×10^6
POND 3 (Southeast of FEMP)	2.36×10^6	1.93×10^6
POND 4 (Retention Pond)	2.67×10^6	2.55×10^6

5.6 POND STAGE VARIATIONS WITH TIME

Figures 5-11, 5-15, 5-19, and 5-23 present stage variations with respect to time for the four ponds respectively. The time required to reach the peak stage are the same as that for the storage cases (Table 5-2). Figures 5-1, through 5-8 present the pond water surface outline for the four ponds. As indicated in the figures, stage variations experienced in Pond 1 is wider when compared to the other three ponds. This is due to the relatively smaller water storage, but with larger drainage area. Table 5-4 presents the stage changes for each pond. Pond 2 has a higher storage capacity, since it has a smaller drainage area, but will be excavated more extensively during the soil remediation. The purpose of Pond 3 is for a temporary runoff storage. Stormwater can be freely overflowed through a weir to SSOD. Of the four ponds, Pond 4 is the smallest one. Pond 4 can also be functioned as an intermediate retention basin prior to being overflowed to the SSOD. As indicated in Table 5-4, a hydraulic connection between Pond 1 and Pond 2 would physically combine Pond 1 and Pond 2 into one pond with higher storage capacity .

TABLE 5-4

MAXIMUM AND MINIMUM POND STAGE UNDER EXTREME CONDITIONS

FEMP - POST EXCAVATION CONDITION

	Pond Stage		Pond Top Edge Elevation (feet)
	Maximum (feet)	Minimum (feet)	
POND 1 (Northeast of FEMP)	574.05	573.0	575
POND 2 (Northwest of FEMP)	567.67	566.3	575
POND 3 (Southeast of FEMP)	579.06	578.0	580
POND 4 Retention Pond	560.51	560.0	575

5.7 MAXIMUM AND AVERAGE DEPTH AND ACERAGE OF THE PONDS

The maximum and average depths of the ponds were estimated for each time step during the entire length of routing process. As described in Section 4.0, the maximum depth was computed as the difference between the water surface elevation and the pond bottom elevation. The average depth was determined by the ratio of the average storage and the average surface water area. Figures 5-12, 5-16, 5-20, and 5-24 present the maximum and average water depths under extreme conditions. As indicated in the figures, maximum and average water depths reach the highest when the peak inflow rates occur (about 13.0 hours). The time it takes to reach the peak inflow rates is presented in Table 5-2. The maximum water depths estimated for the four ponds, when the peak inflow rates appear are approximately 19.05, 17.67, 14.06, and 25.51 feet respectively. At the same time, the average water depths estimated for the four ponds are 8.41, 10.65, 4.24, and 14.85 feet respectively. The corresponding maximum water surface acreage computed for the four ponds are 13.34, 14.0, 12.9, and 4.12 acres respectively. Also, the average water surface acreage computed for the four ponds are 13.03, 13.85, 12.0, and 4.02 13.03, 13.85, 12.0, and 4.02 acres respectively.

5.8 CONNECTION CHANNEL DIMENSION

Trapezoidal channels with grass were proposed for the conveyance of overflowed stormwater. The channels bottom width are three feet, with side slope of 1V:1H. The Manning's roughness used was 0.3 for a natural channel with grass and stones. The slope of channel was estimated as 0.1 percent. The corresponding discharge rates and water depth in the channel were 18 cfs and 2.1 feet respectively. The calculated velocity was1.3 feet/sec, which is considered as subcritical flow.

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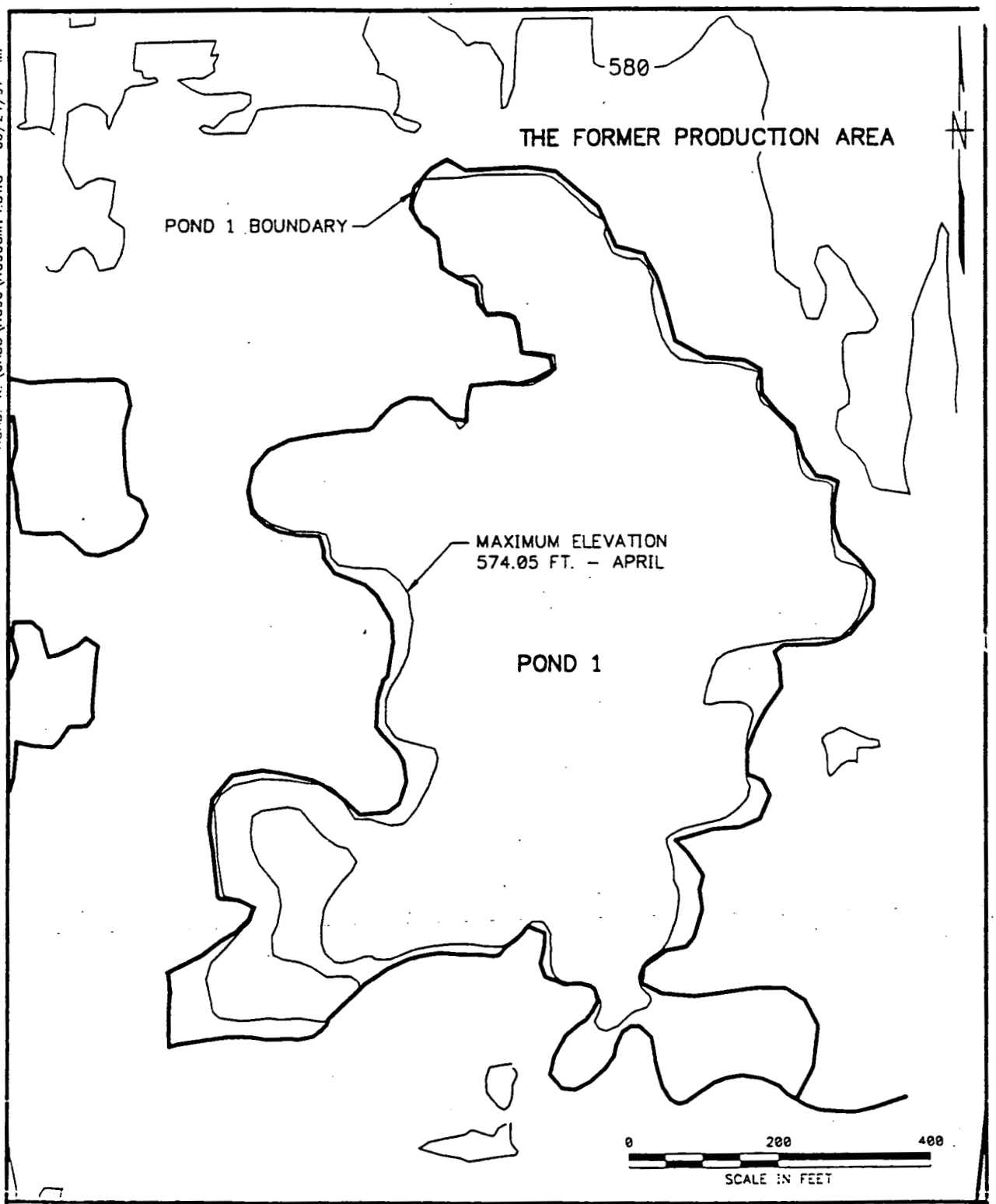

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COST/SCHED-AREA		APPROVED BY	DATE
SCALE AS NOTED		DRAWING NO. FIGURE 5-1	REV. 0

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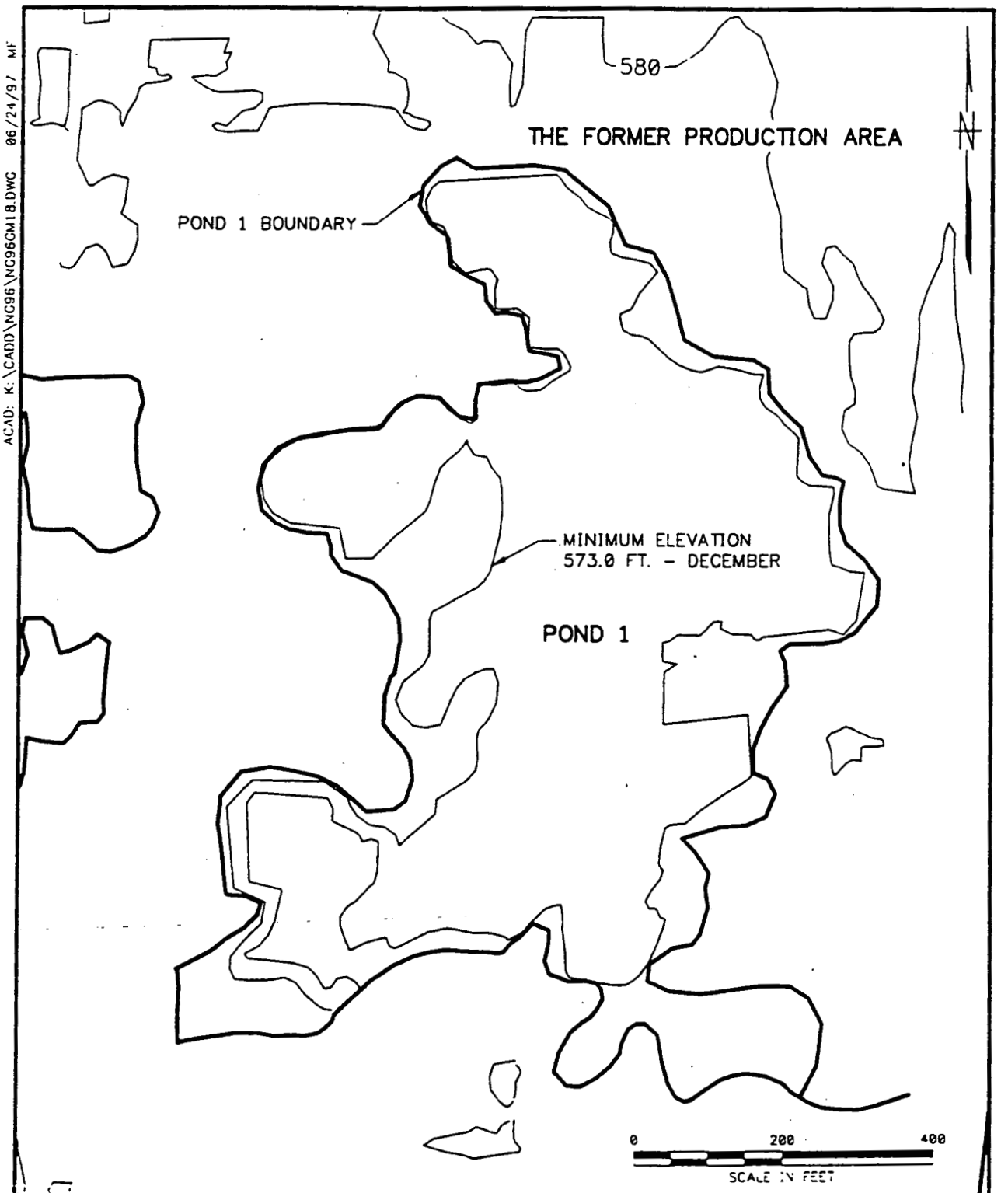

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CHECKED BY DATE	POND 1 WATER SURFACE OUTLINE UNDER EXTREME CONDITIONS MINIMUM ELEVATION FEMP	APPROVED BY	DATE
COST/SCHED-AREA		APPROVED BY	DATE
SCALE AS NOTED		DRAWING NO. FIGURE 5-2	REV. 0

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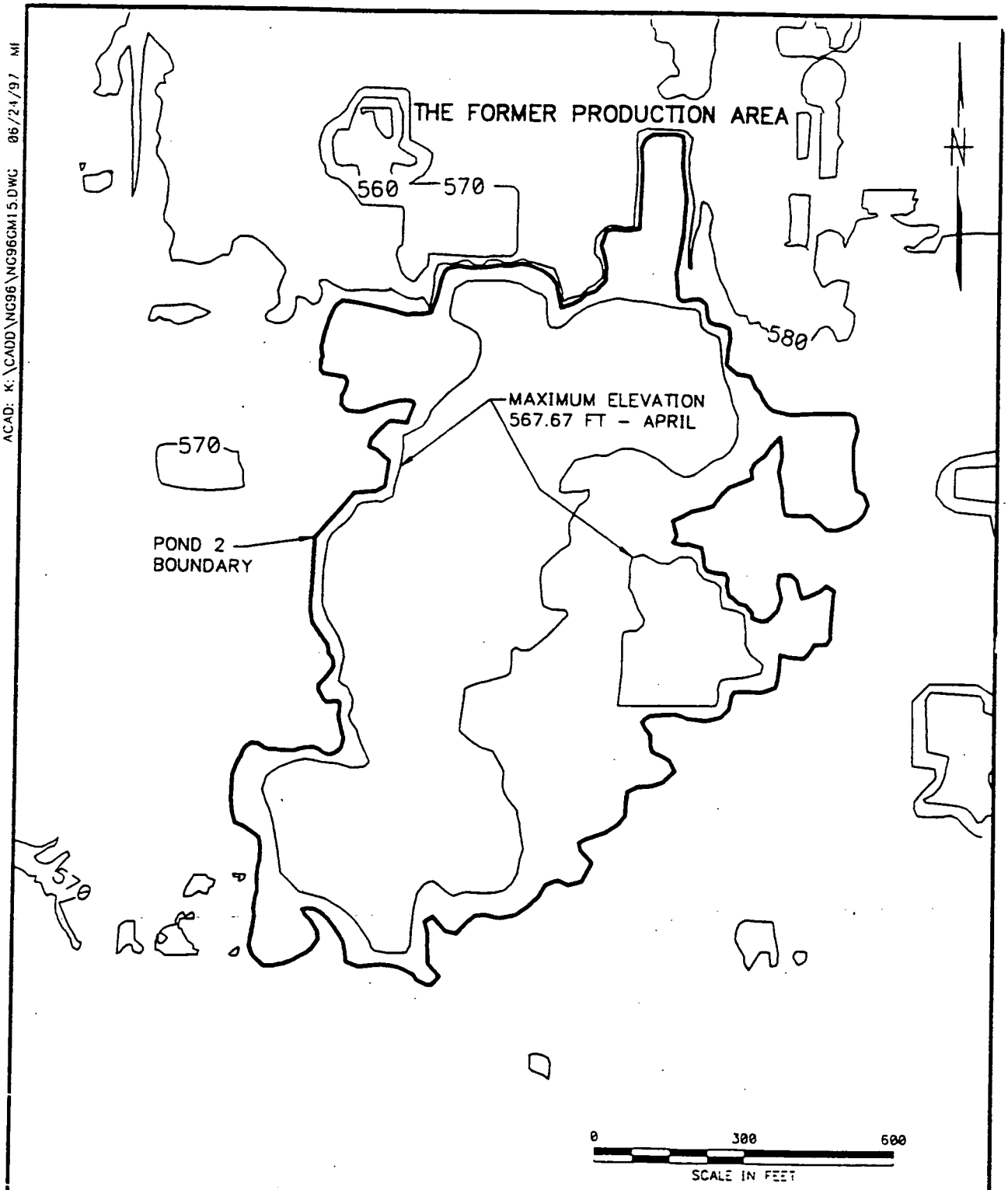

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COST/SCHED-AREA		APPROVED BY	DATE
SCALE AS NOTED		DRAWING NO. FIGURE 5-3	REV. 0

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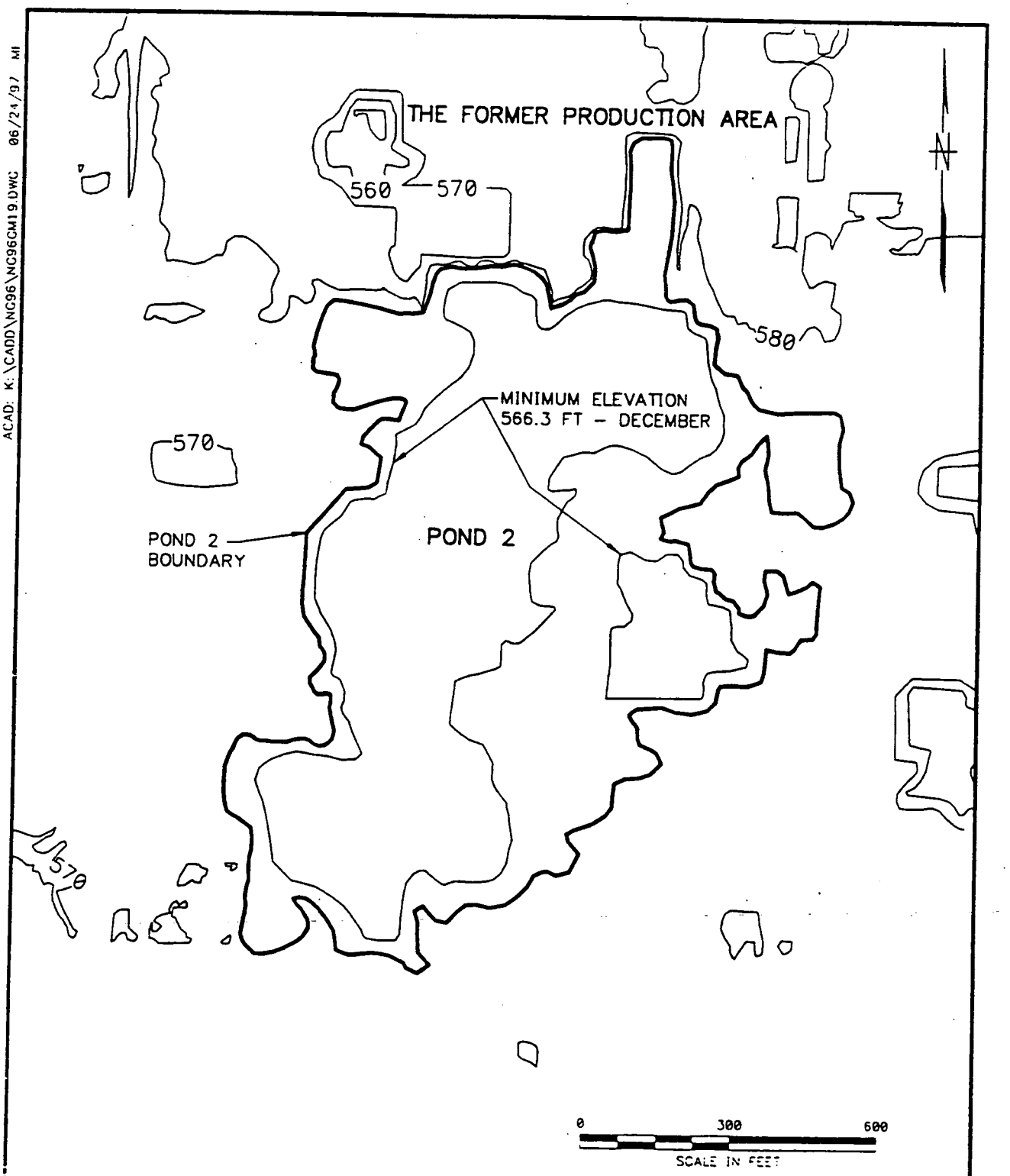

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COST/SCHED-AREA		APPROVED BY	DATE
SCALE AS NOTED		DRAWING NO. FIGURE 5-4	REV. 0

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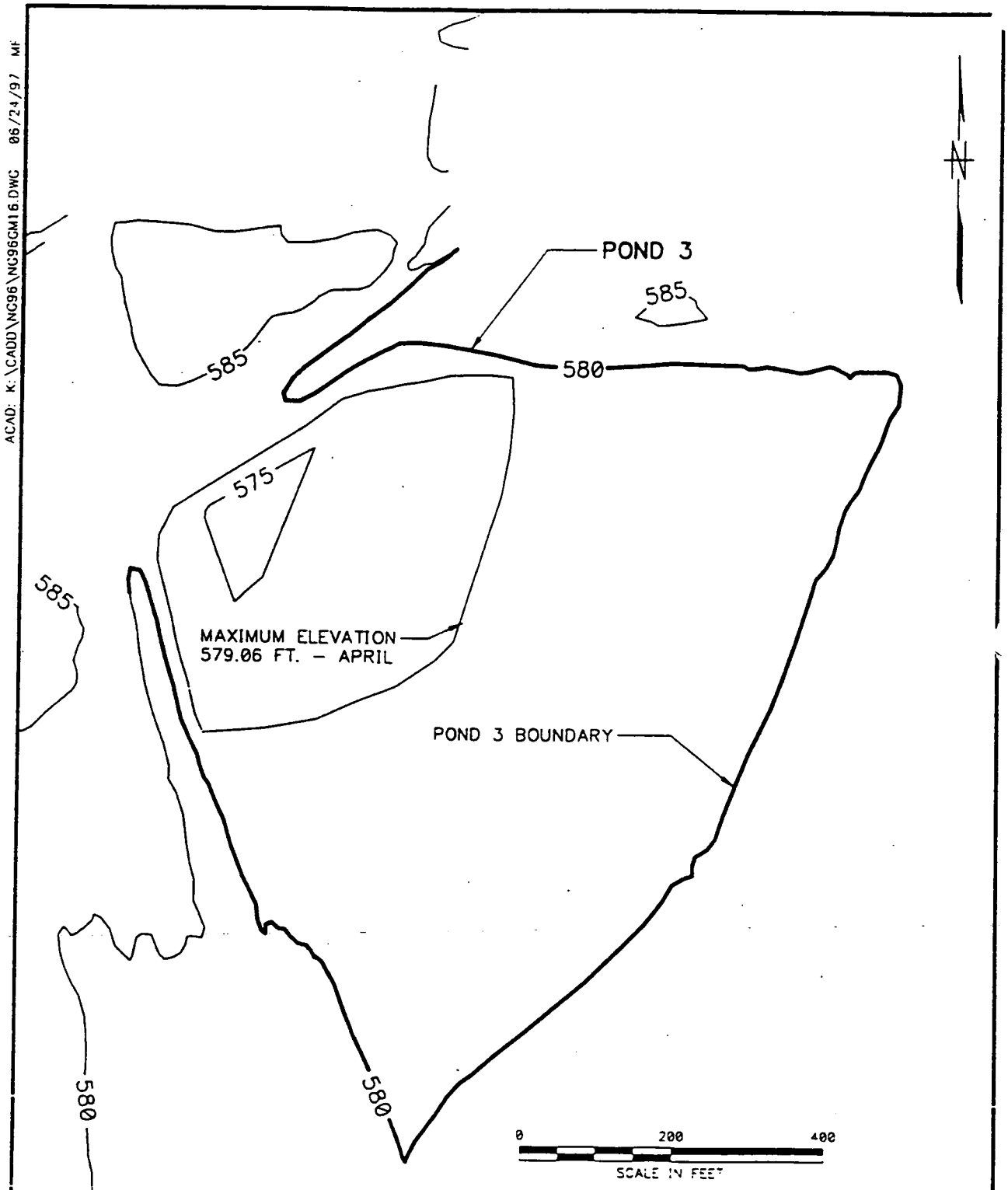

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COST/SCHED-AREA		APPROVED BY	DATE
SCALE AS NOTED		DRAWING NO. FIGURE 5-5	REV. 0

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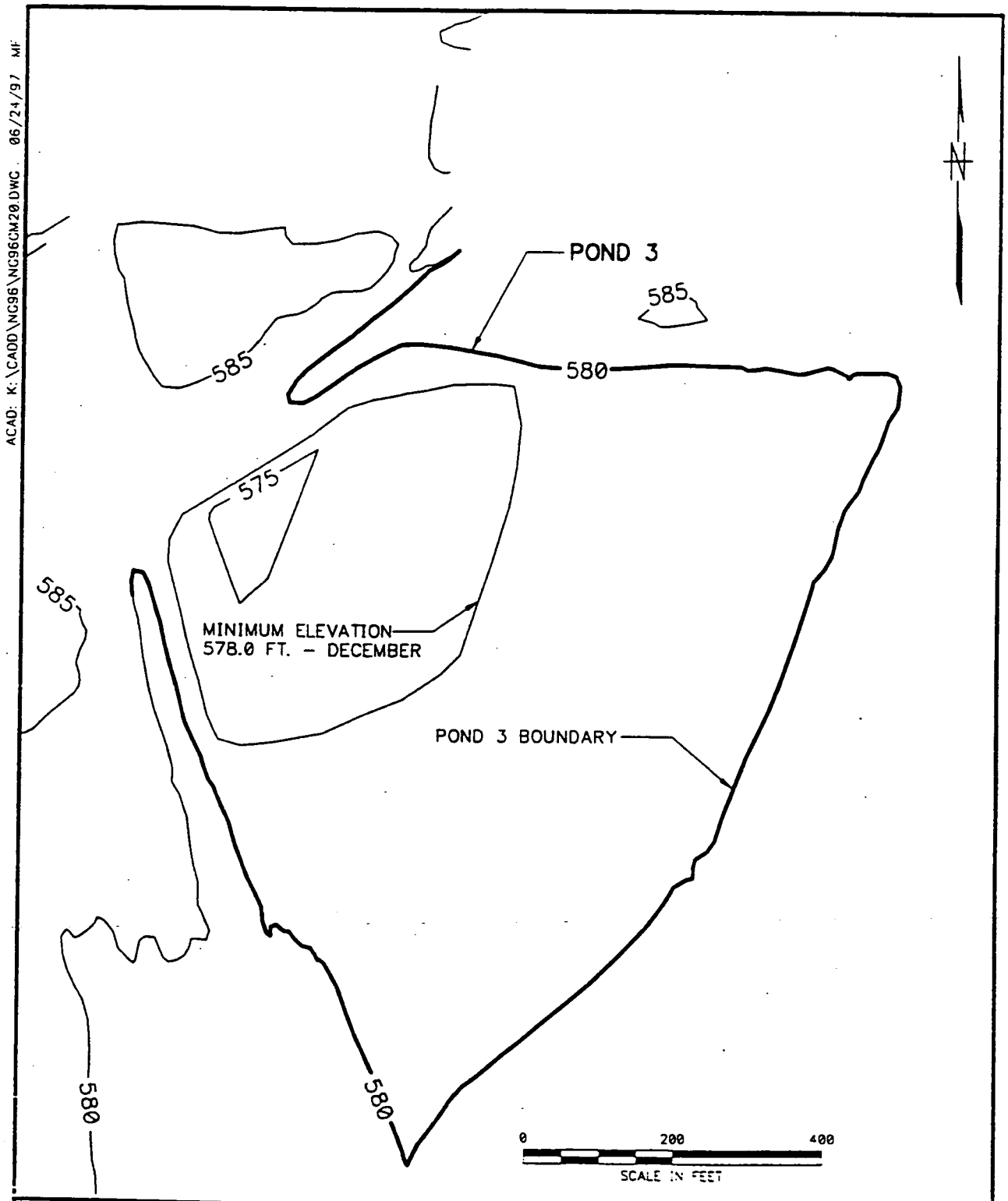

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COST/SCHED-AREA		APPROVED BY	DATE
SCALE AS NOTED		DRAWING NO. FIGURE 5-6	REV. 0

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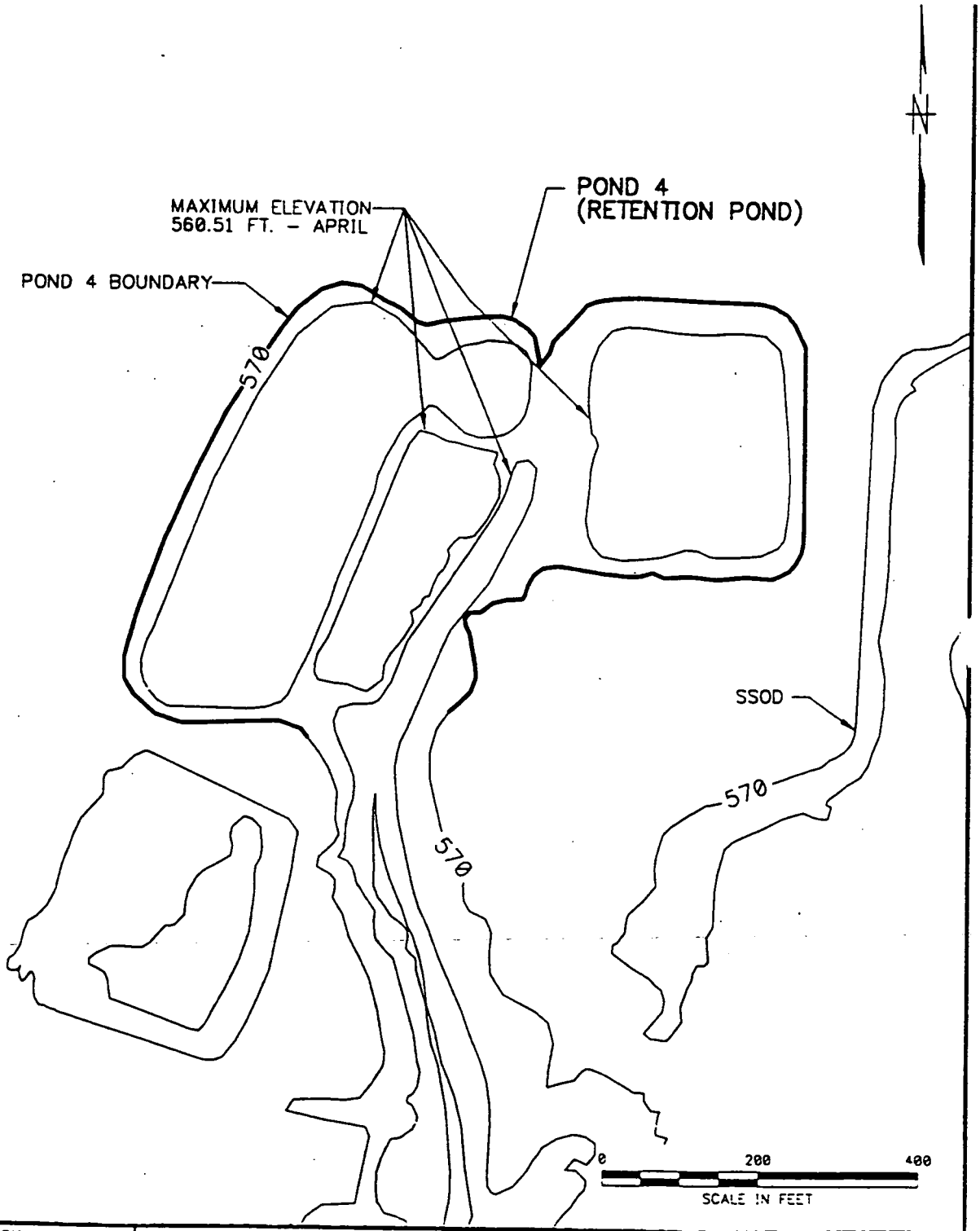

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COST/SCHED-AREA		APPROVED BY	DATE
SCALE AS NOTED		DRAWING NO. FIGURE 5-7	REV. 0

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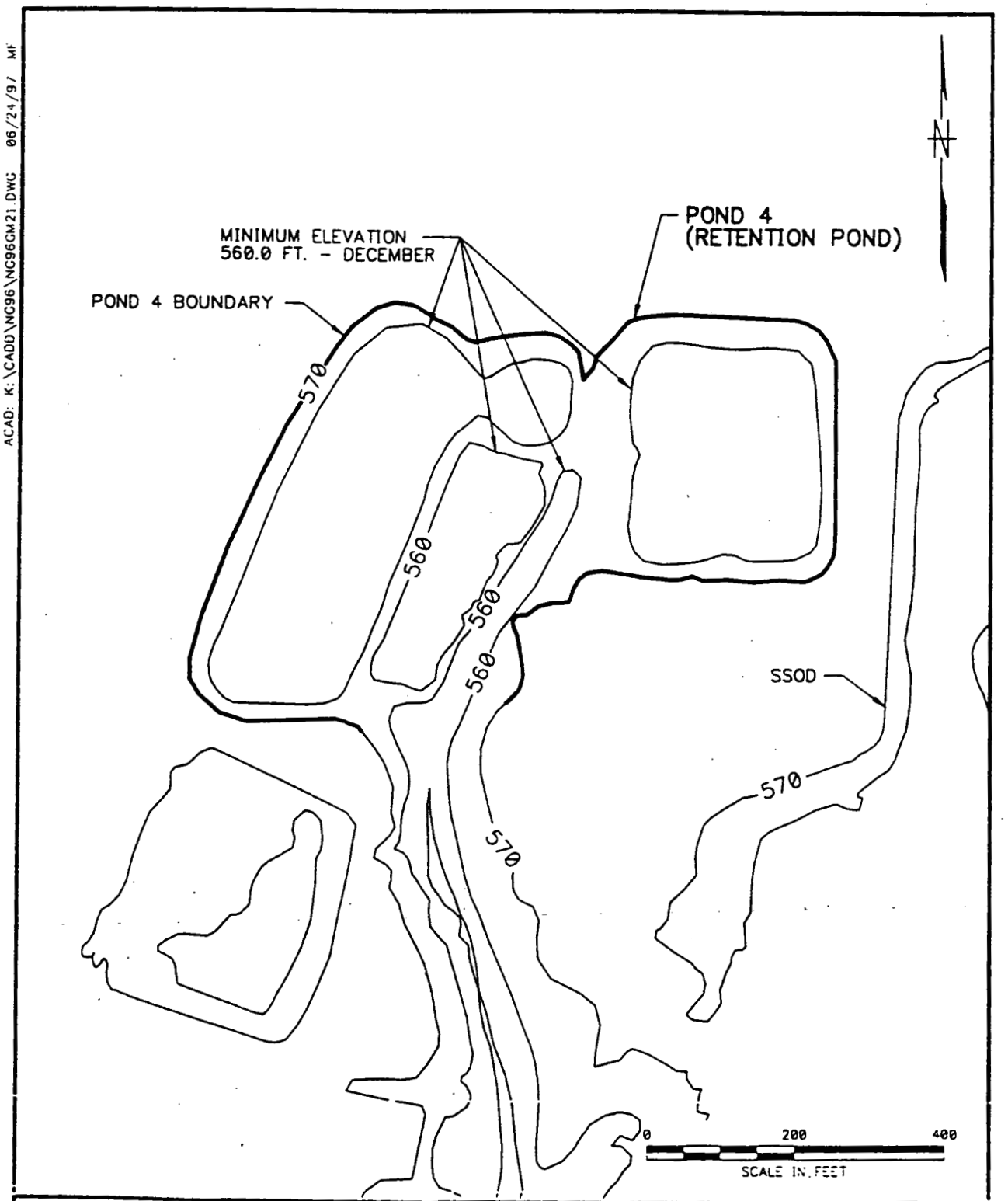

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CHECKED BY DATE	POND 4 WATER SURFACE OUTLINE UNDER EXTREME CONDITIONS MIMIMUM ELEVATION FEMP	APPROVED BY	DATE
COST/SCHED-AREA		APPROVED BY	DATE
SCALE AS NOTED		DRAWING NO. FIGURE 5-8	REV. 0

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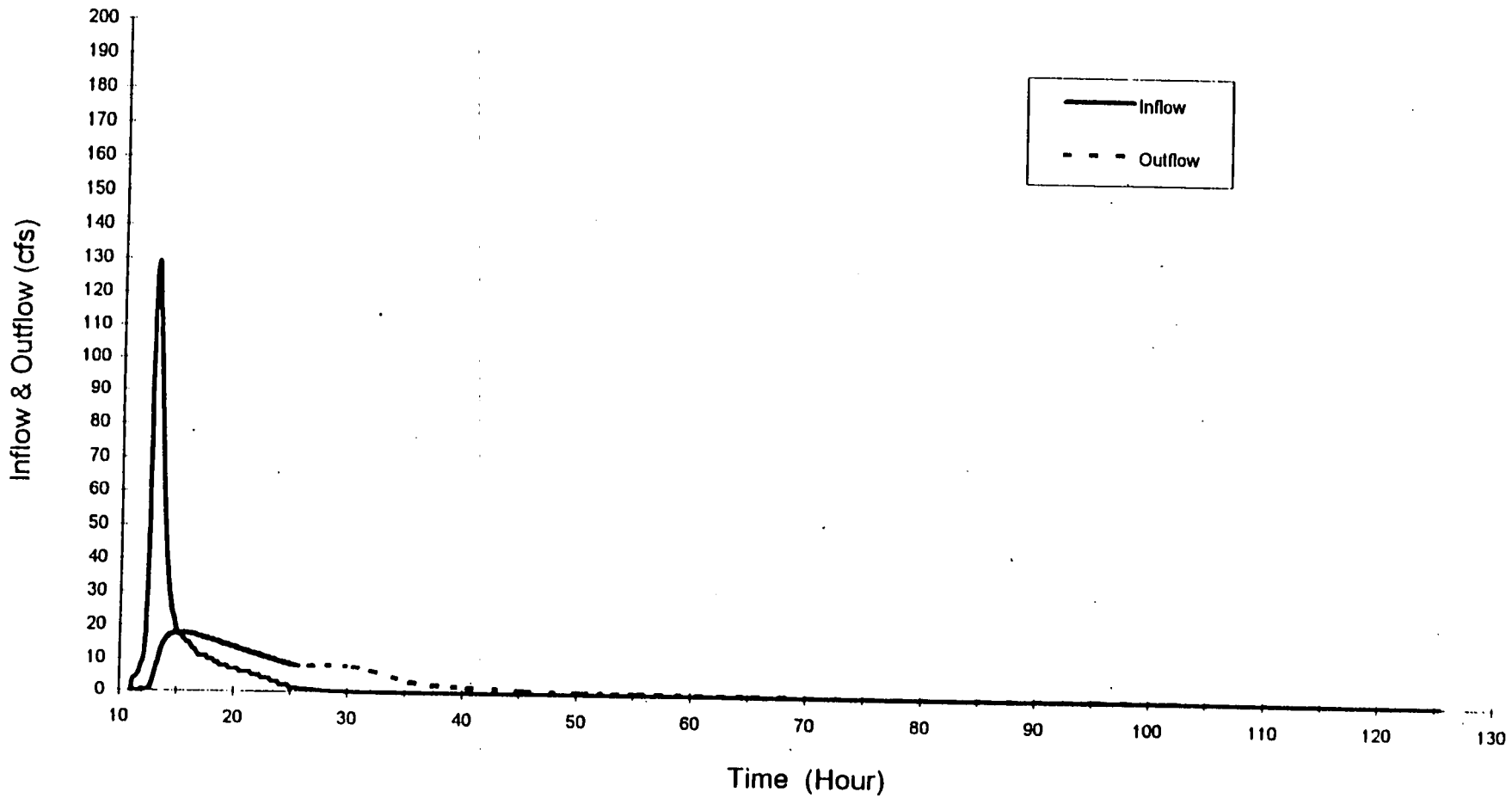

Figure 5-9 Inflow And Outflow Rates of Pond 1 Under Extreme Conditions

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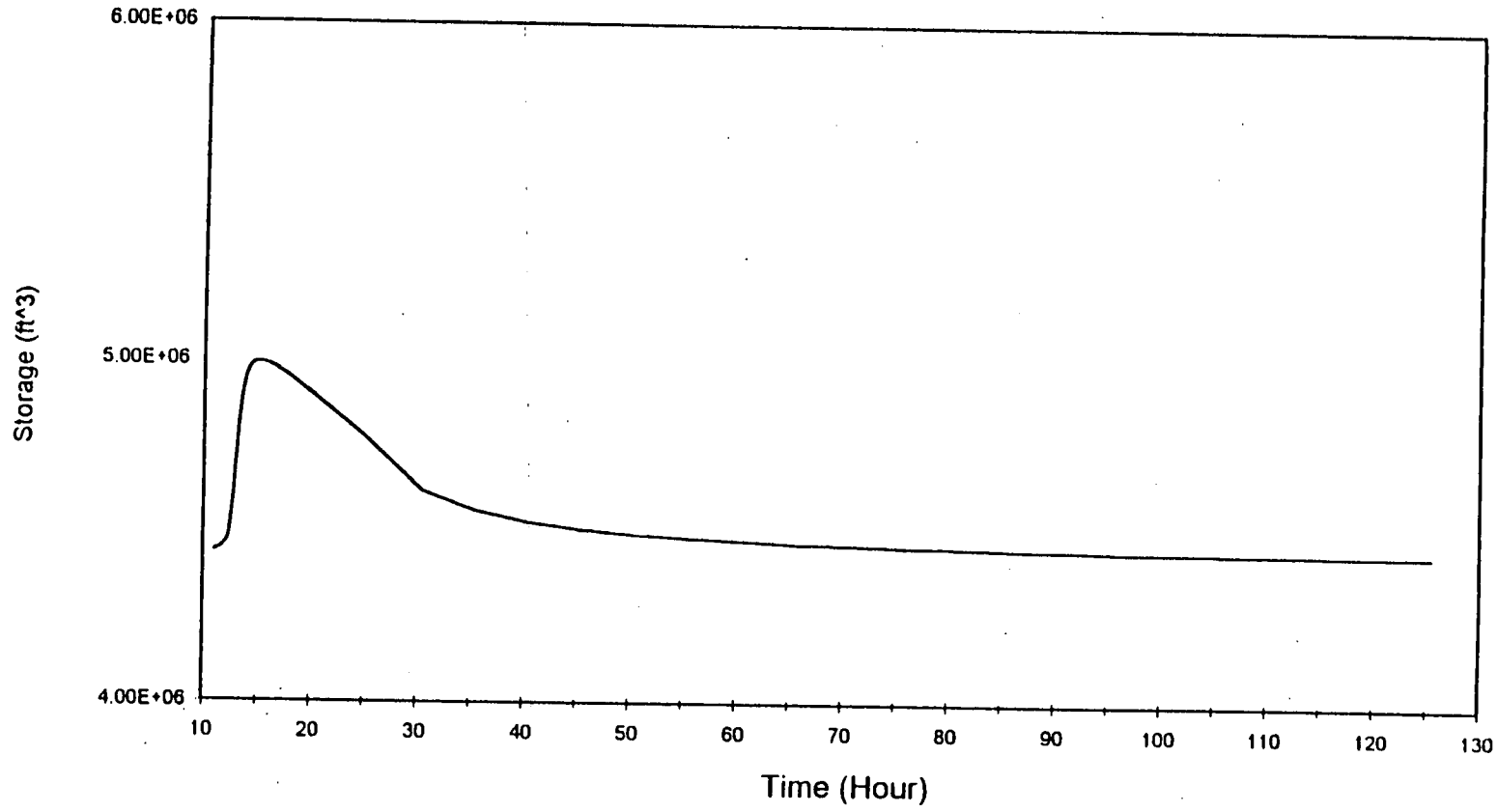

Figure 5-10 Storage Variations of Pond 1 Under Extreme Conditions

000192

8091

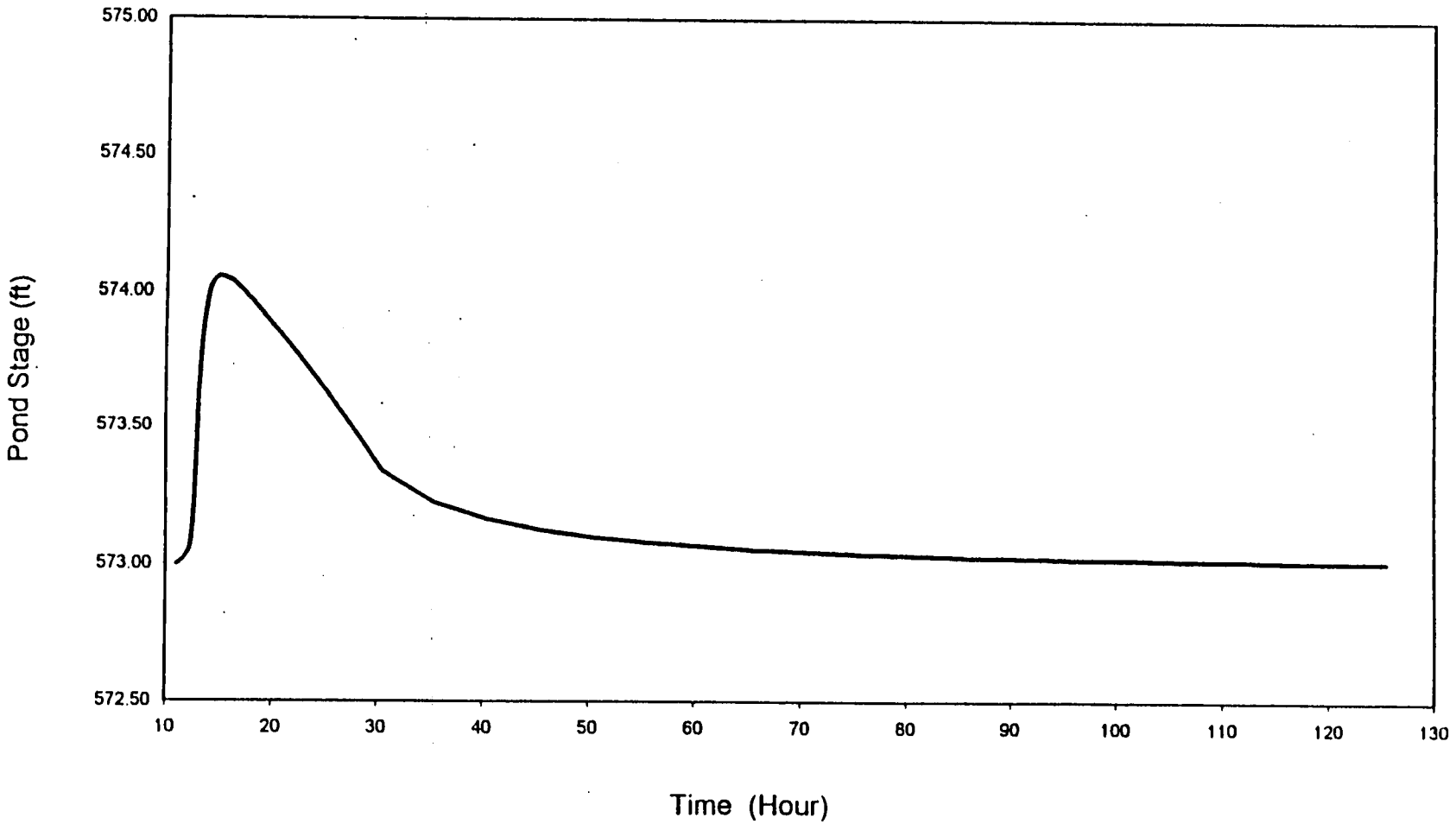

Figure 5-11 Stage Variations of Pond 1 Under Extreme Conditions

000193

8091

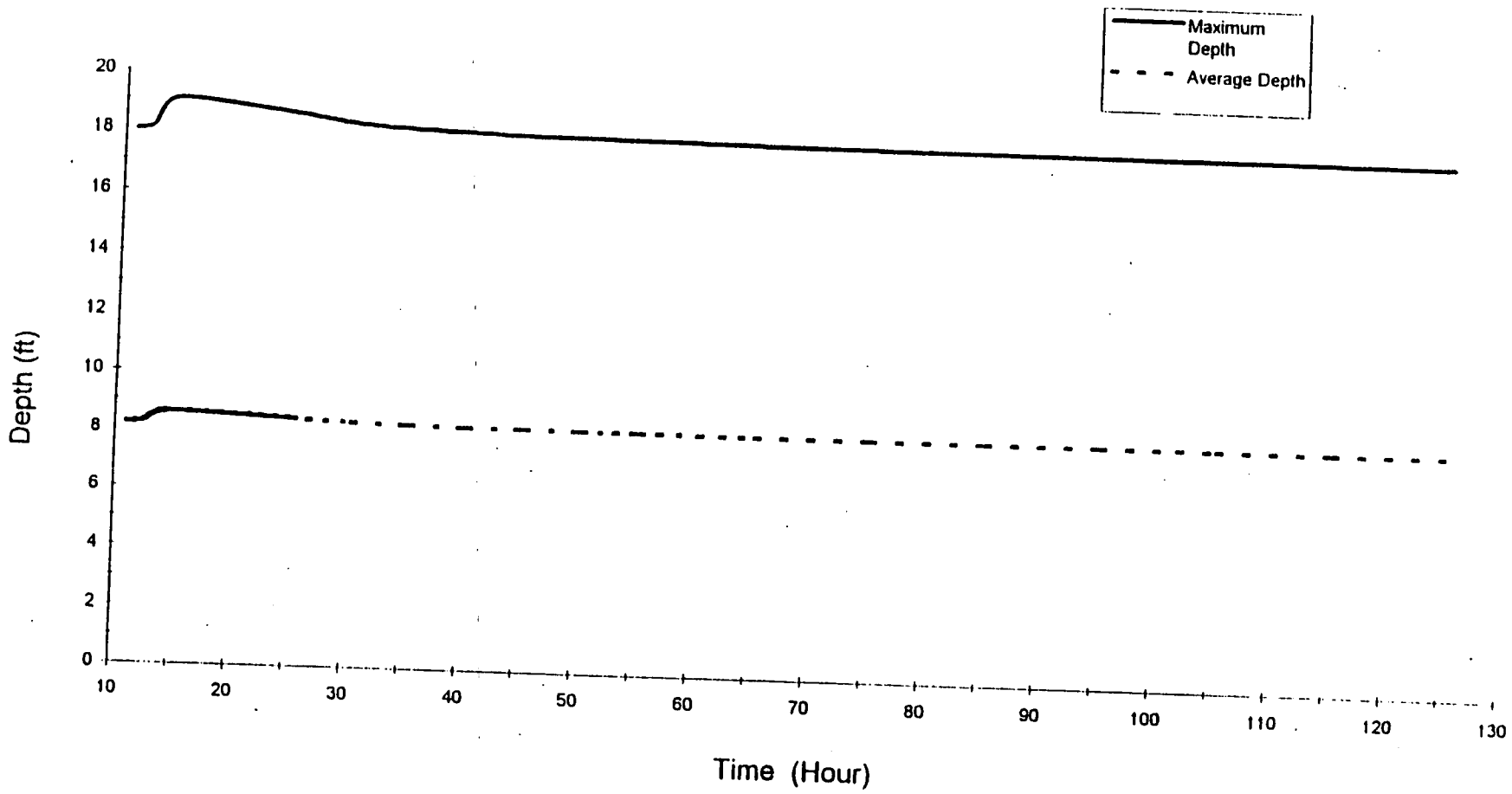

Figure 5-12 Maximum and Average Depth of Pond 1 Under Extreme Conditions

0001194

8091

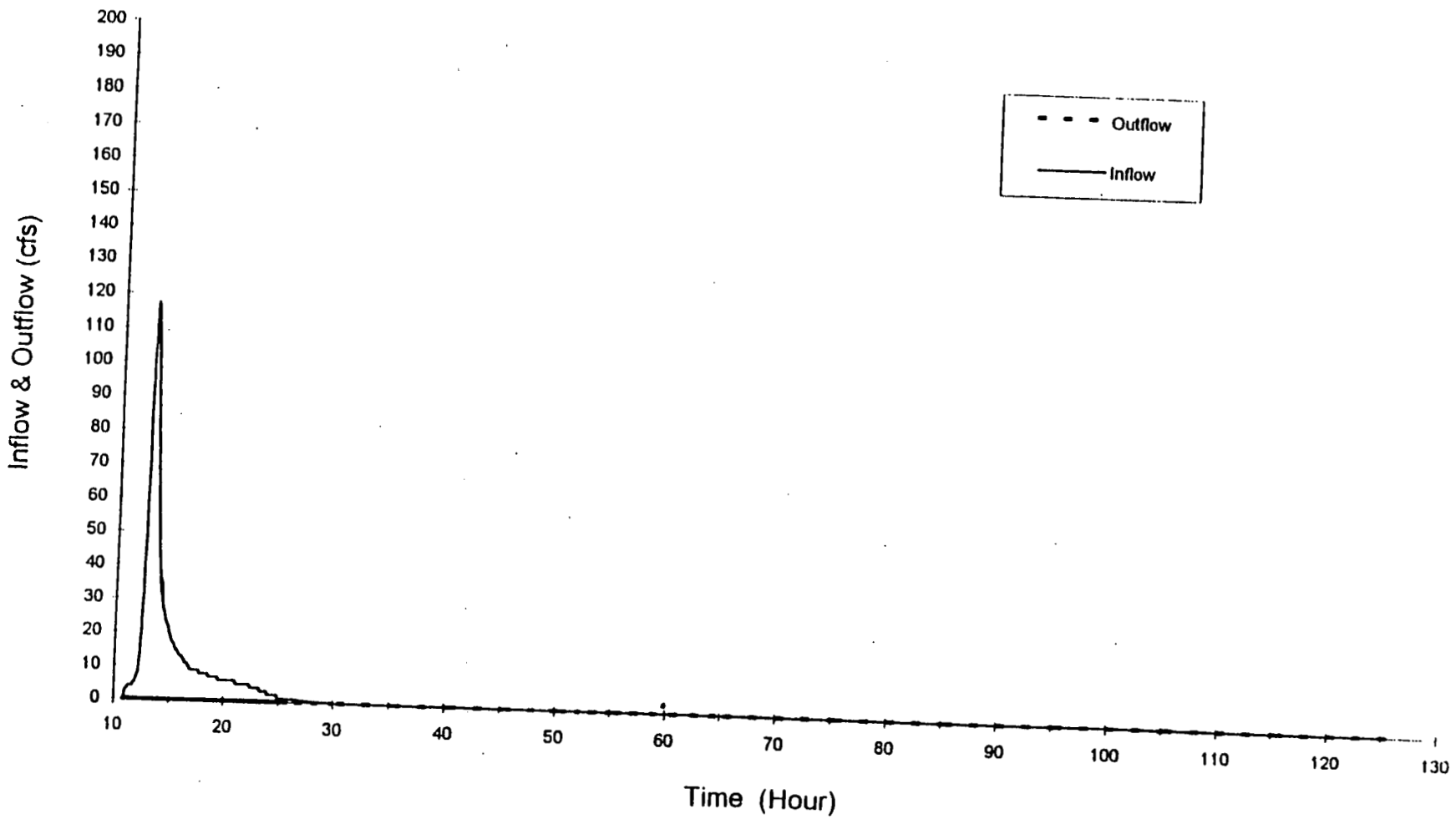

Figure 5-13 Inflow And Outflow Rates of Pond 2 Under Extreme Conditions

000195

8091

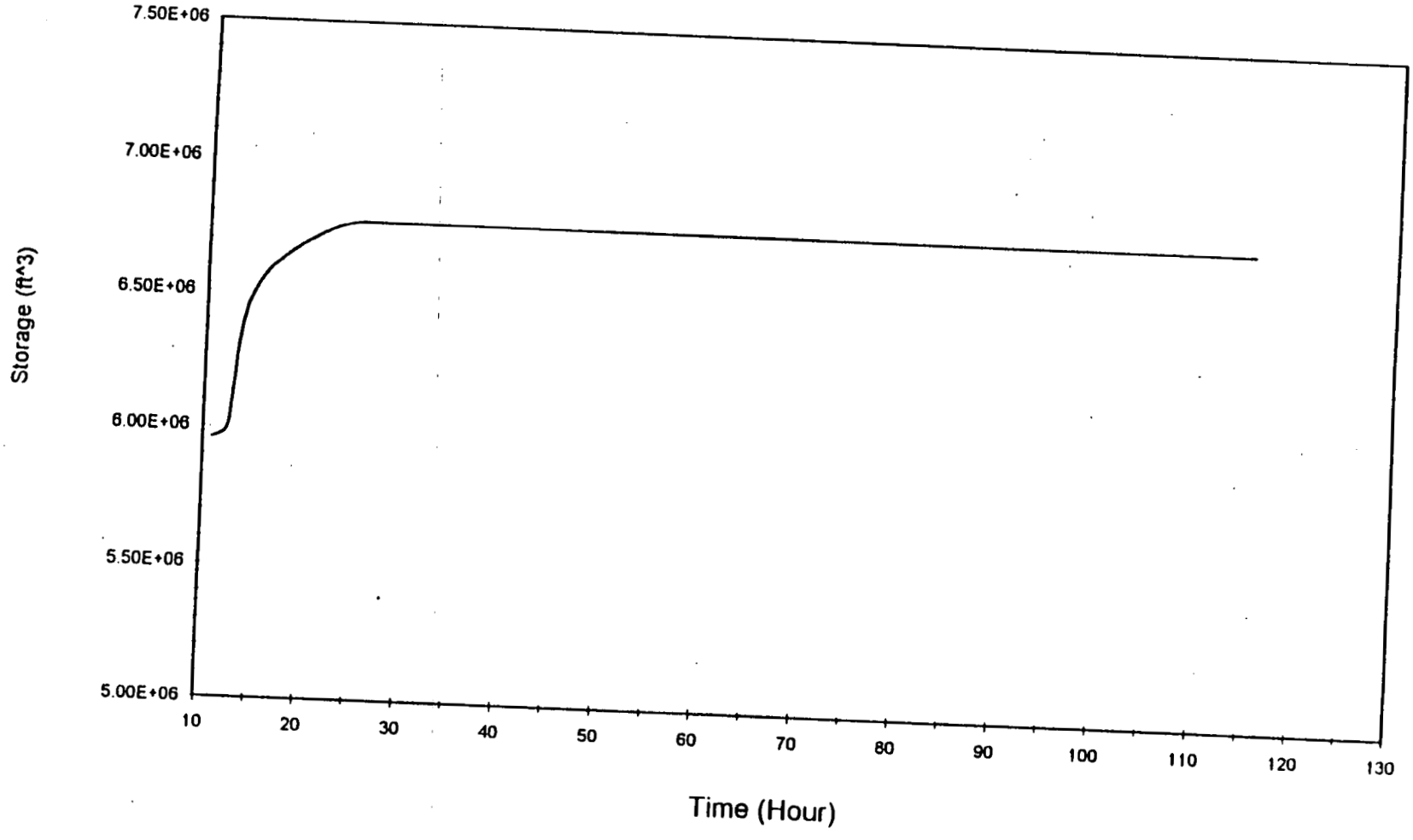

Figure 5-14 Storage Variations of Pond 2 Under Extreme Conditions

000196

8091

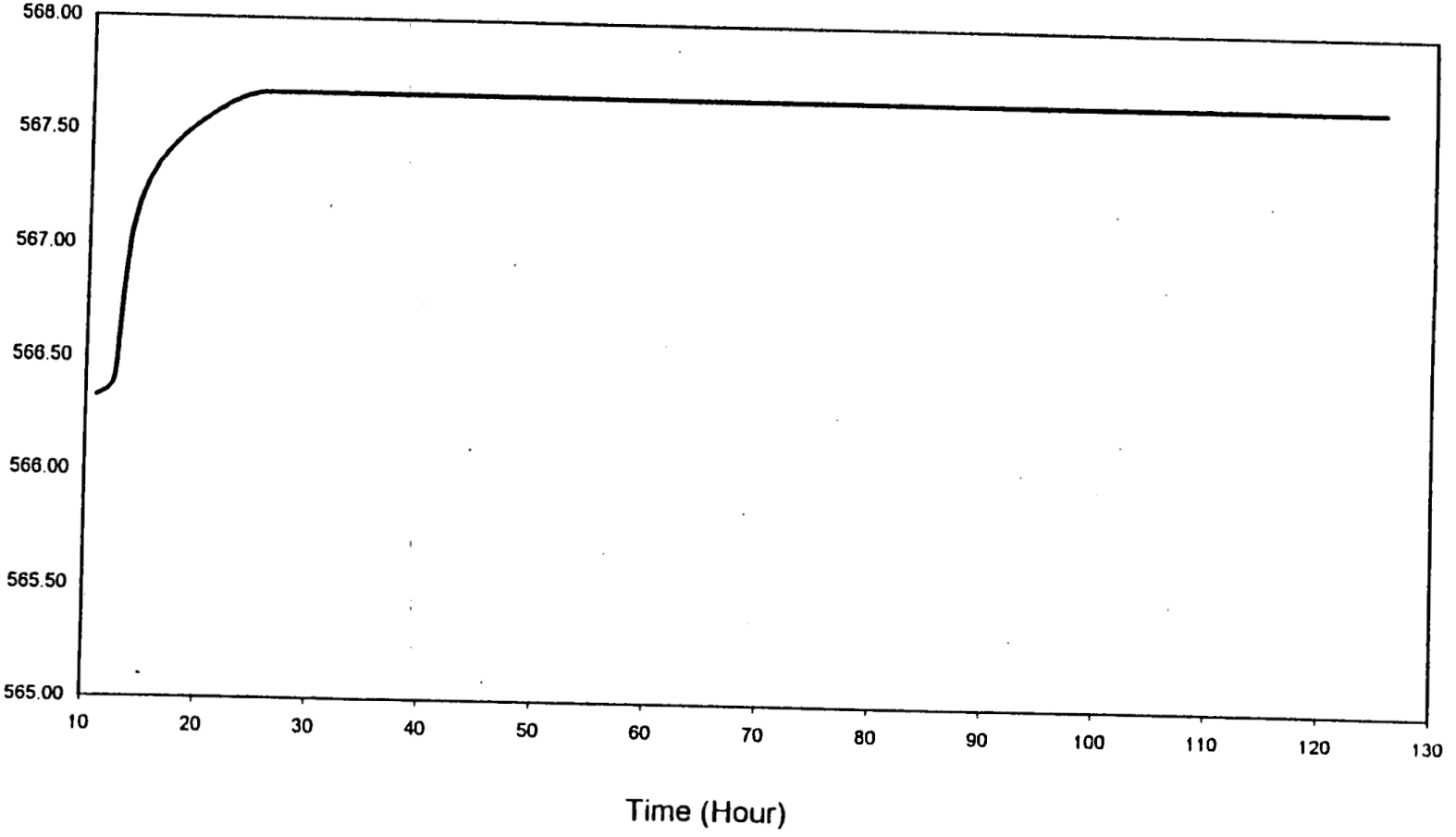

Figure 5-15 Stage Variations of Pond 2 Under Extreme Conditions

000197

1608

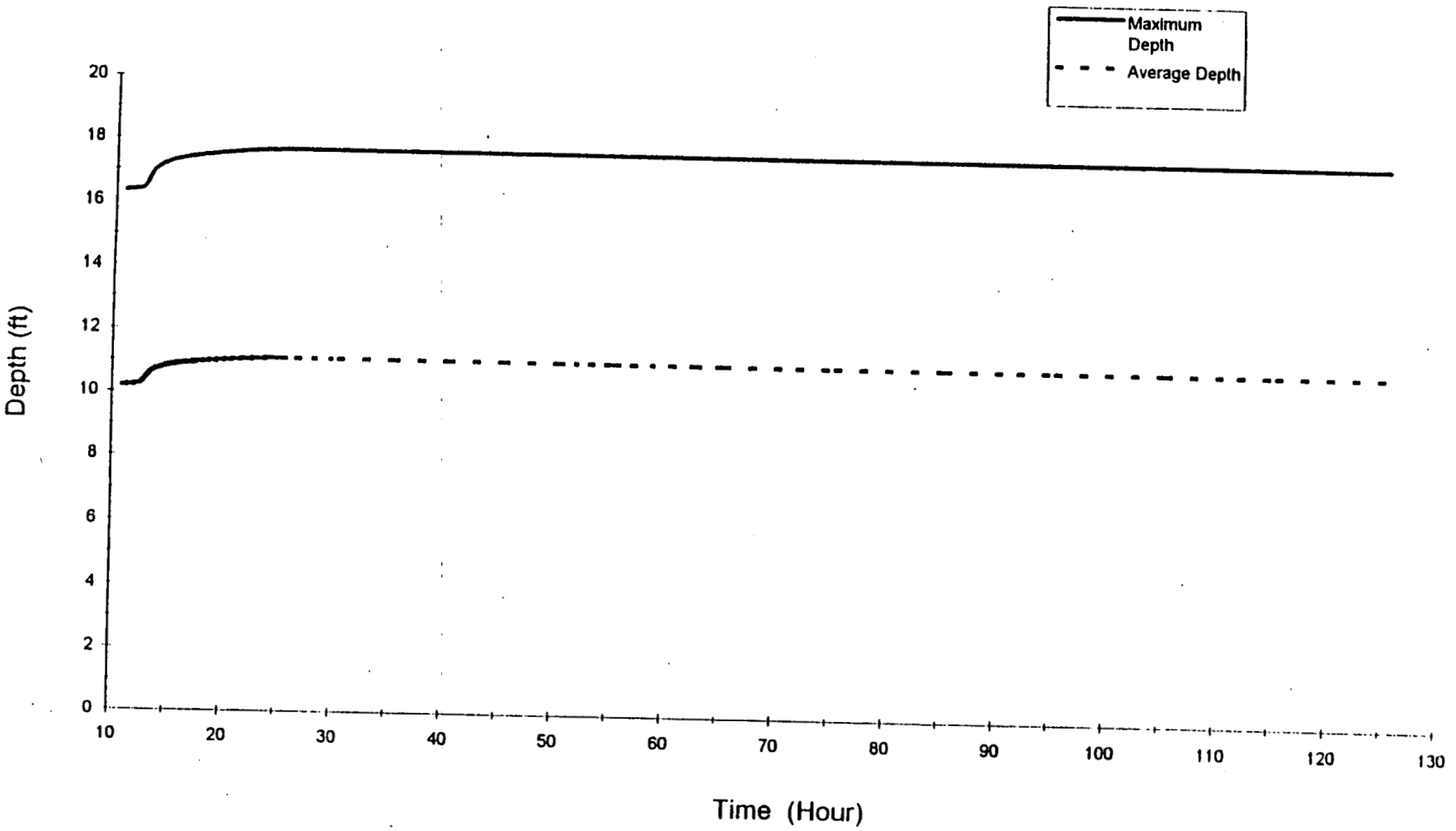

Figure 5-16 Maximum and Average Depth of Pond 2 Under Extreme Conditions

000198

8091

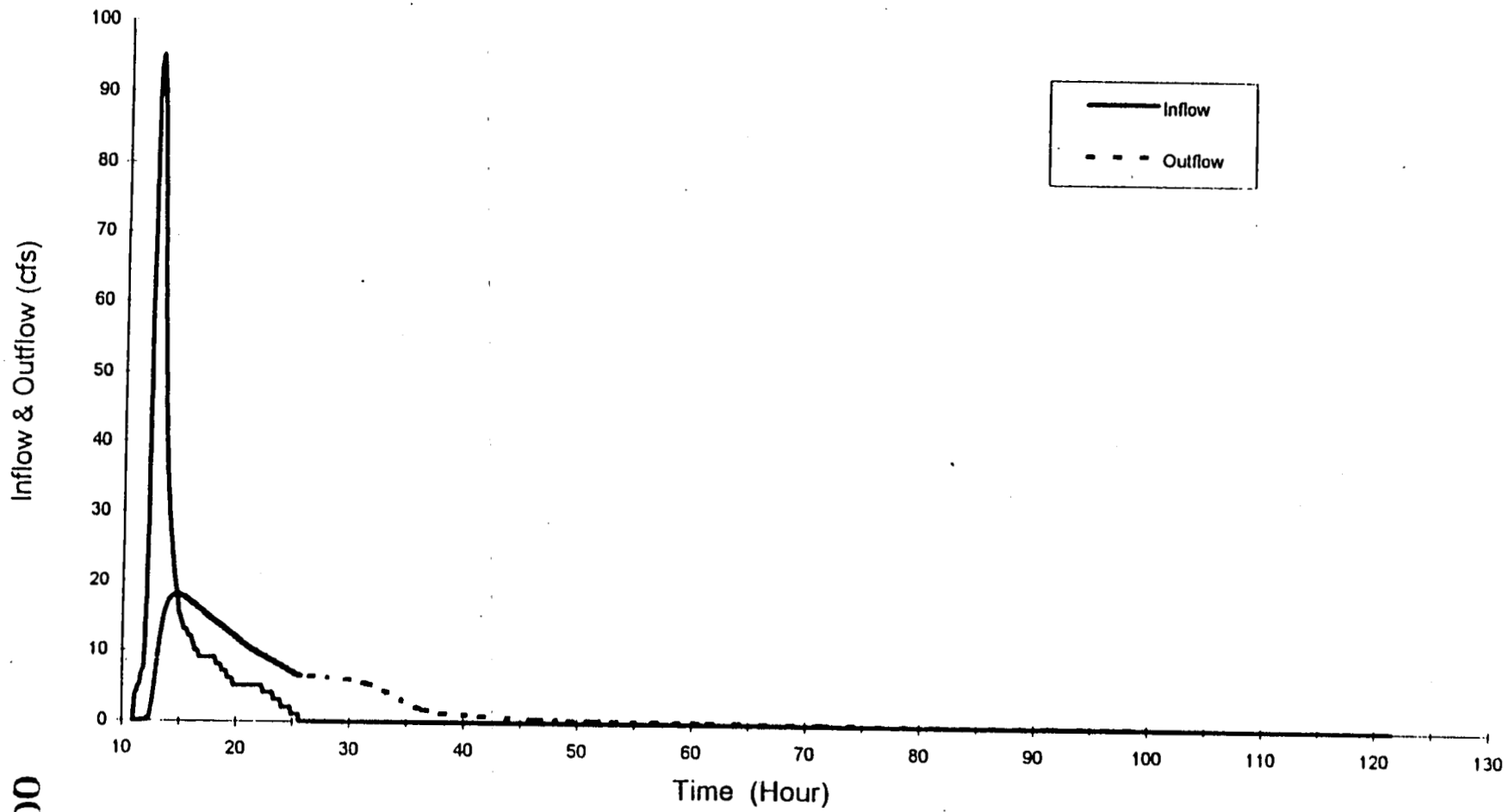

Figure 5-17 Inflow And Outflow Rates of Pond 3 Under Extreme Conditions

000159
1608

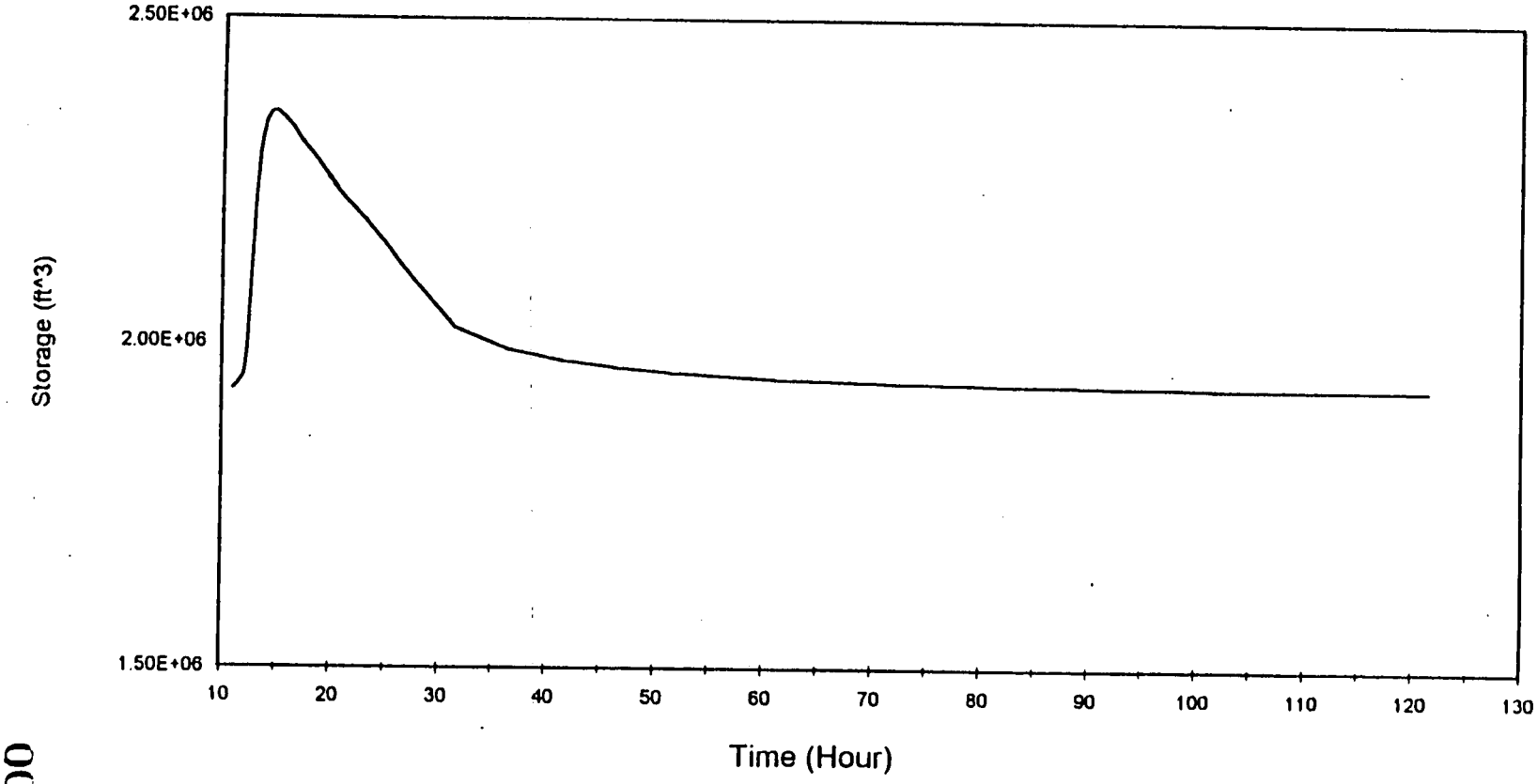

Figure 5-18 Storage Variations of Pond 3 Under Extreme Conditions

000400

1608

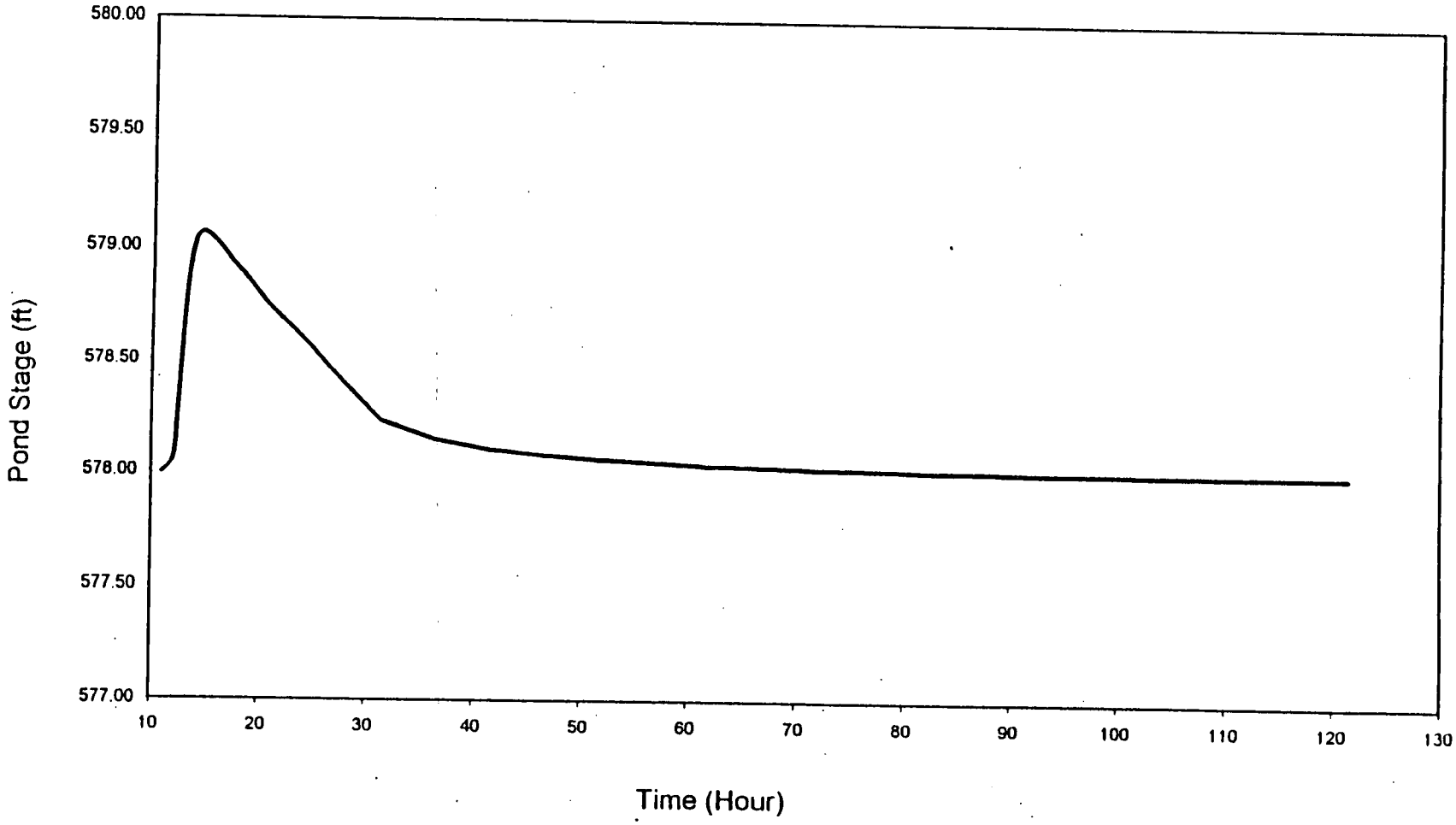

Figure 5-19 Stage Variations of Pond 3 Under Extreme Conditions

000201

1608

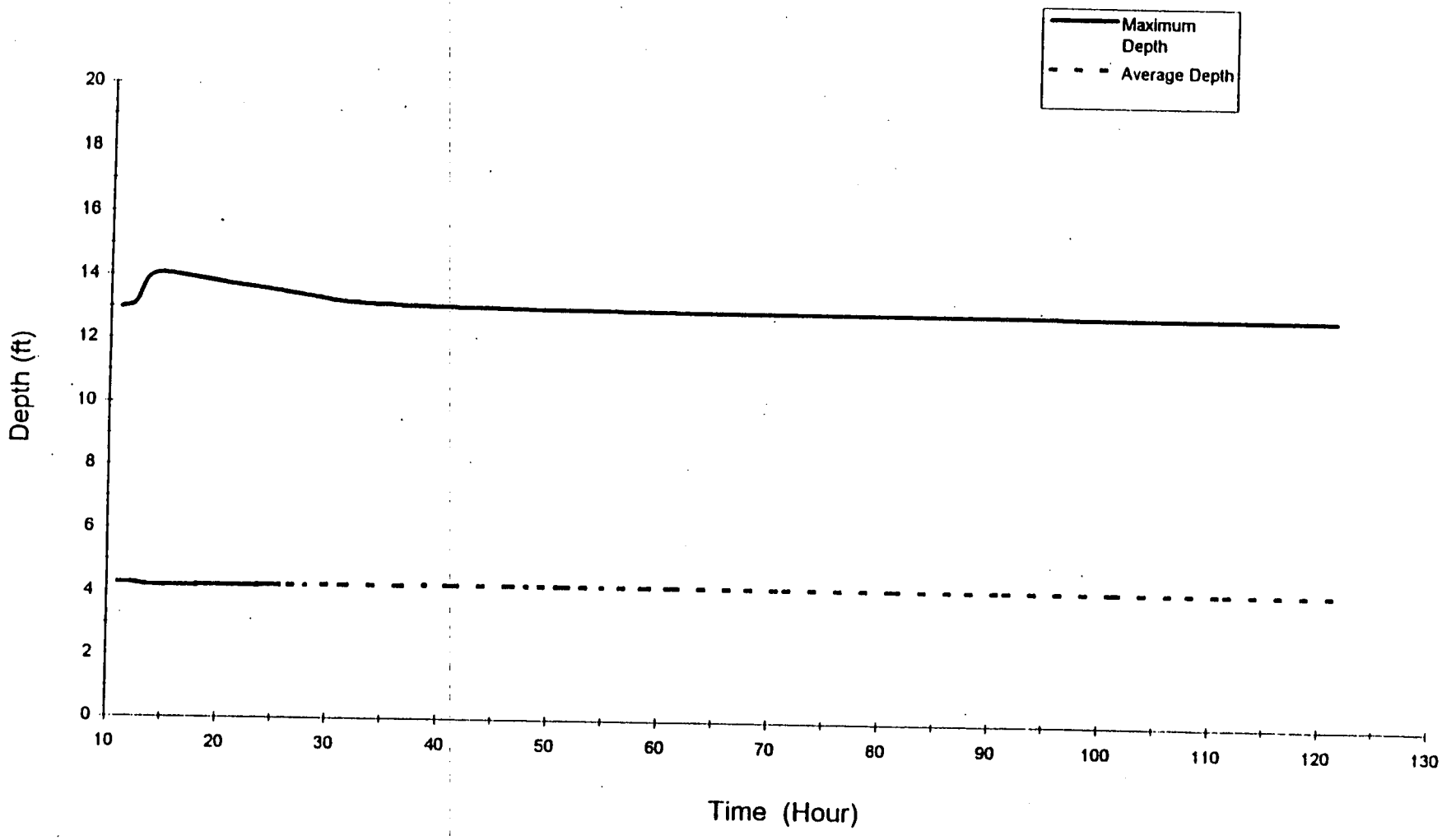

Figure 5-20 Maximum and Average Depth of Pond 3 Under Extreme Conditions

000202

8091

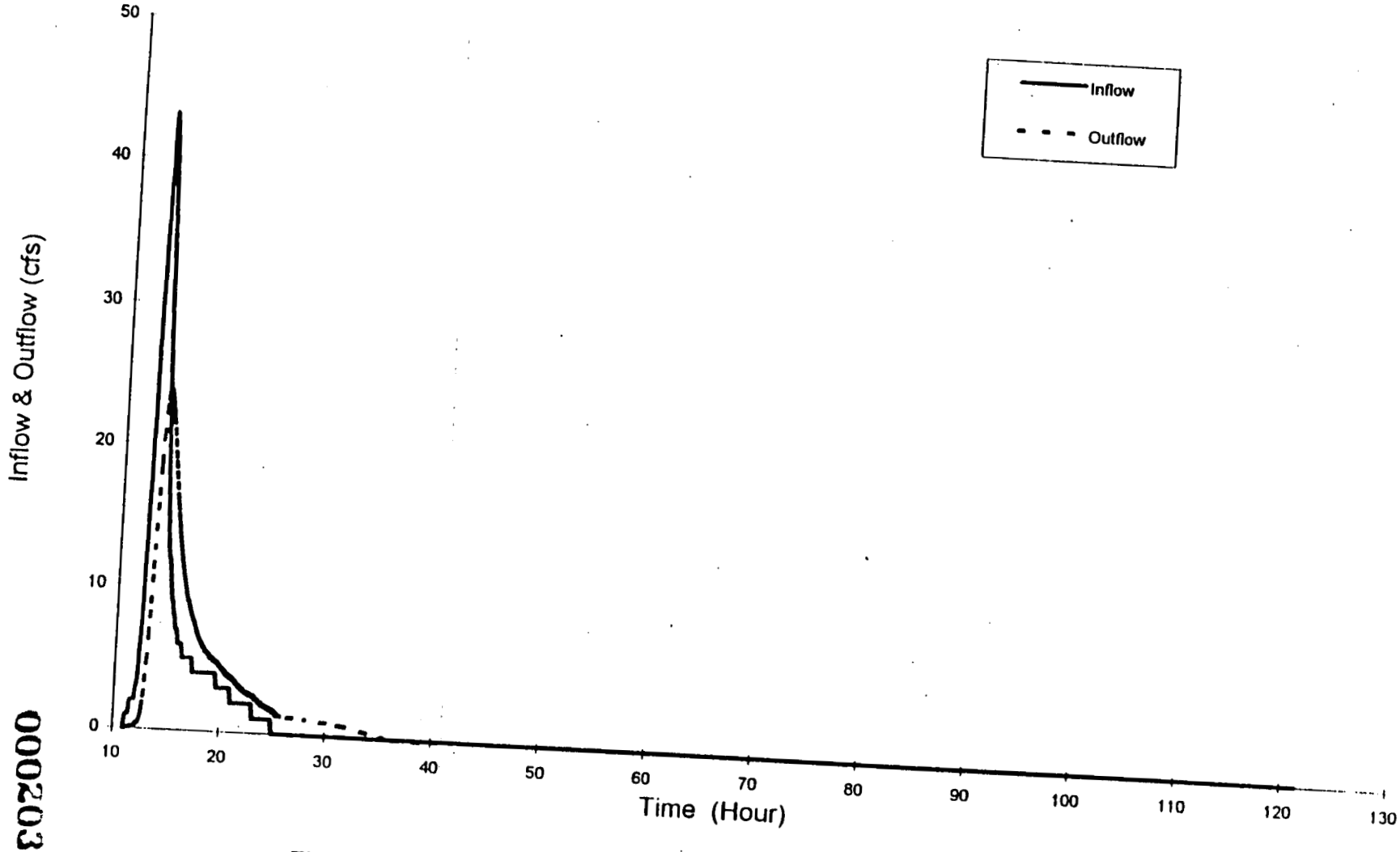

Figure 5-21 Inflow And Outflow Rates of Pond 4 Under Extreme Conditions

000203

8091

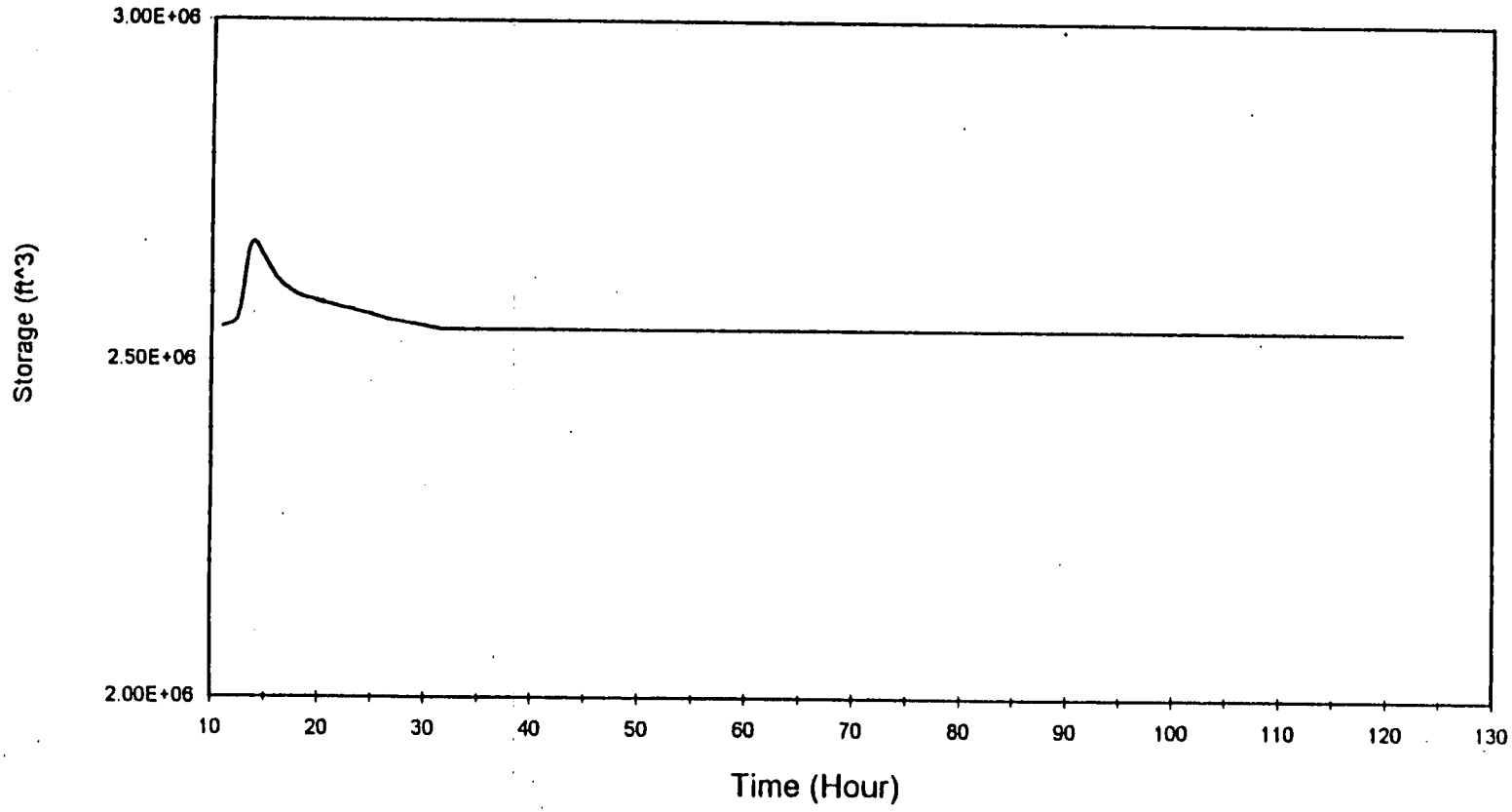

Figure 5-22 Storage Variations of Pond 4 Under Extreme Conditions

000204

8091

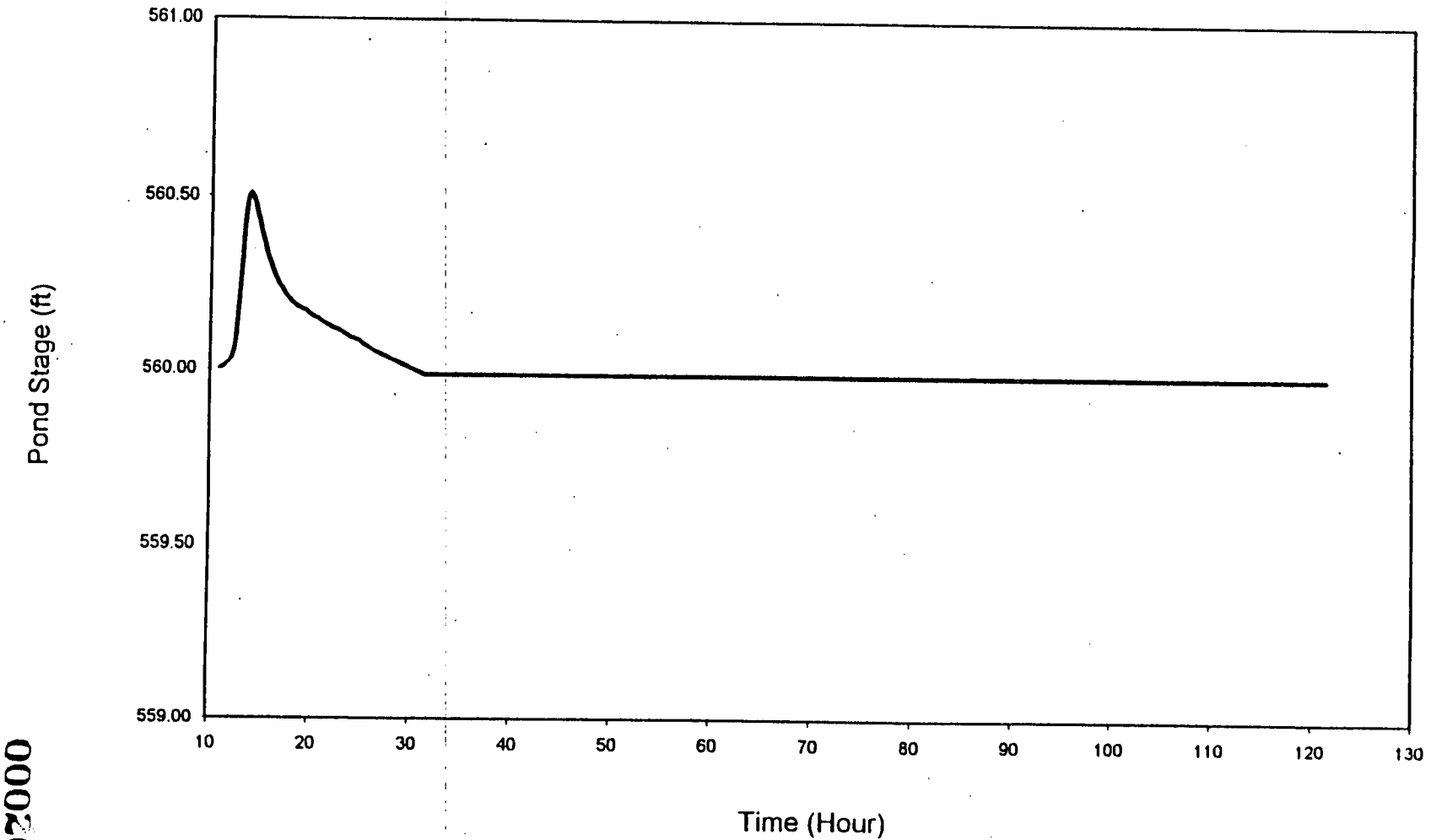

Figure 5-23 Storage Variations of Pond 4 Under Extreme Conditions

000203

8091

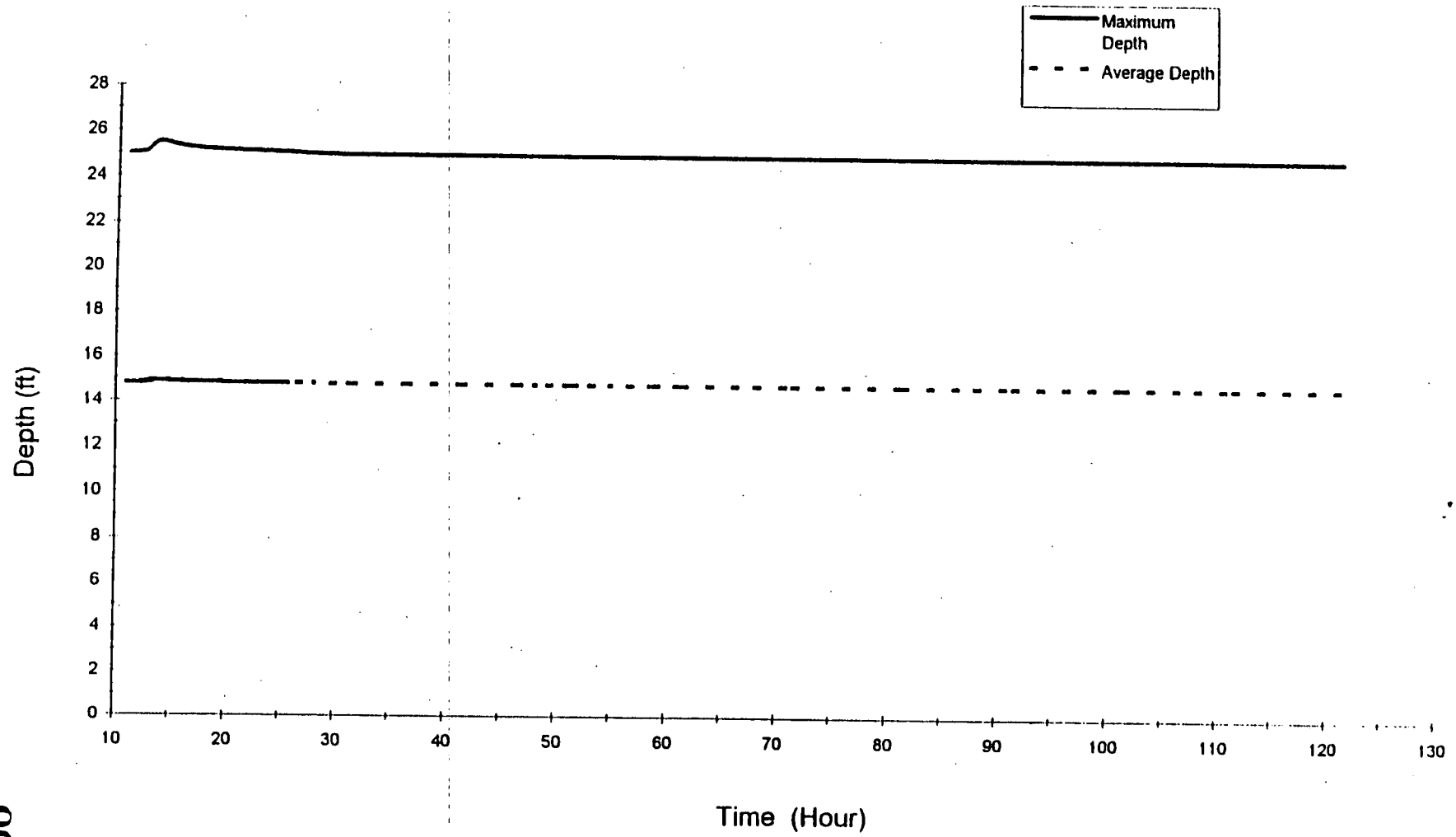

Figure 5-24 Maximum and Average Depth of Pond 4 Under Extreme Conditions

000206

8091

6.0 SUMMARY AND DISCUSSIONS

The routing modeling results indicated that the maximum pond elevations are constantly below the top edge of the ponds for both normal and extreme conditions evaluated. These results are based on allowing overflow from weirs when the pool levels exceed the outlet bottom elevations. The findings based on the storage routing modeling are briefly summarized for both modeled conditions.

Normal Conditions:

Modeling approaches for normal conditions have incorporated the monthly meteorological data, based on data available from NOAA. Any excessive storage that exceeds the designed outlet bottom elevations are overflowed to the final discharging point.

- Maximum inflow rates and maximum depth normally occur in April.
- Pond 1 has the highest stage (573 feet), if considering Pond 3 as a temporary retention pond.
- Pond 1 has the highest inflow rates (1.1×10^6 ft^3/month) among the four ponds.
- Pond 4 has the lowest inflow rates (4.2×10^5 ft^3/month) among the four ponds.
- Pond 2 has the highest storage (6.19×10^6 ft^3), and Pond 3 has the lowest storage (1.21×10^6 ft^3).
- Pond 3 has the highest daily overflow rates (2.31×10^4 ft^3/day).
- Maximum water depths estimated for the four ponds are 18, 16.7, 13, and 25 feet respectively.

Extreme Conditions:

The storm event was modeled by using the TR55 method. The Tabular Hydrograph Method is utilized for modeling multiple subareas that contribute runoff to one common design outfall point in the watershed.

- Time to peak inflow rates are approximately 13 hours.
- Pond 1 has the highest stage (574.1 feet), and Pond 4 has the lowest elevation (560 feet), if considering Pond 3 as a temporary retention pond.
- Pond 1 has the highest inflow rates (129 cfs) among the four ponds.
- Pond 4 has the lowest inflow rates (43 cfs) among the four ponds.
- Pond 2 has the highest storage (6.77×10^6 ft^3), and Pond 3 has the lowest storage (1.93×10^6 ft^3).
- Maximum and average water depths reach the highest when the peak inflow rates occur (about 13.0 hours from the beginning of storm inflow).
- Maximum water depths estimated for the four ponds, when the peak inflow appears are approximately 19, 18, 14, and 26 feet respectively

Excess runoff from Pond 1 is allowed to be discharged to the Storm Sewer Outfall Ditch (SSOD). Excess water is also allowed to be drained from Pond 2 to Pond 4 through an open channel. The final outfall point for stormwater runoff routing through Pond 1, Pond 3, and Pond 4 is the SSOD, then to Paddys Run, and eventually to the Great Miami River.

Since soil excavation in the Pond 1 area will reach the unsaturated Great Miami Aquifer, which is generally sandy material with a permeability range 10^{-2} to 10^{-3} cm/sec, the liner material for Pond 1 requires replacement with either a lower permeability clay soil or a synthetic liner. Replacing the sandy soil will facilitate minimum leakage of water through the liner materials.

Based on the modeling results, it is suggested that an underground pipe be connected between Pond 1 and Pond 2. This connection will greatly improve the regulation of water storage between Pond 1 and Pond 2, since Pond 2 has a much larger capacity with approximately seven feet of freeboard under all conditions considered.

REFERENCES

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David R. Maidment, 1993, Handbook of Hydrology, McGraw, Inc.

Haestad, 1989, "Quick TR55 Hydrology for Small Watersheds," Haestad Method Inc., Waterbury, CT.

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Parsons, 1997, On-sit Disposal Facility Surface Water Management, Pre-development vs. Post-development Site Discharge Rates, April 24.

U.S. Department of Commerce, 1986, National Oceanic and Atmospheric Administration, "Climate Data Summaries from Hourly Precipitation Data and State Climatic Divisions," August

U.S. Department of Commerce, 1987, National Oceanic and Atmospheric Administration, "Local Climatological Data Annual Summaries for 1987," part I eastern region

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APPENDIX A

MONTHLY RUNOFF CALCULATIONS (HELP MODEL)

```
******************************************************************************
******************************************************************************
 *
 *
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
**               HELP MODEL VERSION 3.03  (31 DECEMBER 1994)
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY
**                    USAE WATERWAYS EXPERIMENT STATION
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY
**
**
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:      C:\HELP3\POND2.D4
TEMPERATURE DATA FILE:        C:\HELP3\POND2.D7
SOLAR RADIATION DATA FILE:    C:\HELP3\POND2.D13
EVAPOTRANSPIRATION DATA:      C:\HELP3\POND2.D11
SOIL AND DESIGN DATA FILE:    C:\HELP3\POND2.D10
OUTPUT DATA FILE:             C:\HELP3\pond2.OUT


TIME:  10:48     DATE:   6/ 3/1997


******************************************************************************

     TITLE:  RUNOFF TO PONDS OF FEMP PER UNIT ACRE (infiltration zone IV)

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
            COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
                                  --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  22
          THICKNESS                    =    120.00   INCHES
          POROSITY                     =      0.4190 VOL/VOL
          FIELD CAPACITY               =      0.3070 VOL/VOL
          WILTING POINT                =      0.1800 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.3559 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.189999992000E-04 CM/SEC
        NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  1.80
                 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
```

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	120.00	INCHES
POROSITY	=	0.2000	VOL/VOL
FIELD CAPACITY	=	0.1500	VOL/VOL
WILTING POINT	=	0.1100	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1875	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.699999987000E-06	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

SCS RUNOFF CURVE NUMBER	=	74.00	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	9.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	2.860	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	3.771	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.620	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	65.212	INCHES
TOTAL INITIAL WATER	=	65.212	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
CINCINNATI OHIO

MAXIMUM LEAF AREA INDEX	=	1.00	
START OF GROWING SEASON (JULIAN DATE)	=	104	
END OF GROWING SEASON (JULIAN DATE)	=	295	
AVERAGE ANNUAL WIND SPEED	=	9.10	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	70.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	67.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	73.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	72.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CLEVELAND OHIO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC

3.66	2.98	3.67	3.55	3.78	3.59
4.09	2.80	2.59	2.11	3.01	2.86

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR CINCINNATI OHIO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
28.90	32.10	41.80	53.50	63.00	71.40
75.40	74.10	67.50	55.30	43.40	33.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR CINCINNATI OHIO

STATION LATITUDE = 39.10 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.57	3.10	3.75	3.30	3.52	3.55
	4.31	3.07	2.69	2.17	3.00	2.69
STD. DEVIATIONS	1.17	1.02	1.28	1.25	1.55	1.46
	2.17	1.42	1.26	1.02	1.21	1.09
RUNOFF						
TOTALS	1.242	2.125	0.954	0.053	0.121	0.191
	0.473	0.125	0.078	0.016	0.057	0.187
STD. DEVIATIONS	1.132	1.455	1.056	0.183	0.265	0.341
	0.746	0.315	0.206	0.066	0.214	0.582
EVAPOTRANSPIRATION						
TOTALS	0.913	1.116	2.543	3.052	3.048	3.073
	3.359	2.472	2.196	1.784	1.352	1.003
STD. DEVIATIONS	0.201	0.311	0.324	0.856	1.079	1.165
	1.199	0.996	0.856	0.642	0.297	0.174

PERCOLATION/LEAKAGE THROUGH LAYER 2

TOTALS	0.5452	0.4871	0.6067	0.6277	0.6384	0.5958
	0.6359	0.6489	0.6041	0.6430	0.5881	0.5954
STD. DEVIATIONS	0.2126	0.2022	0.1876	0.1621	0.1647	0.1997
	0.1754	0.1556	0.1739	0.1486	0.1718	0.1703

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES		CU. FEET	PERCENT
IPITATION	38.74	(4.539)	140625.5	100.00
FF	5.621	(2.2746)	20403.37	14.509
OTRANSPIRATION	25.911	(2.7428)	94058.02	66.885
OLATION/LEAKAGE THROUGH YER 2	7.21624	(1.50650)	26194.961	18.62746
GE IN WATER STORAGE	-0.008	(2.9189)	-30.81	-0.022

****

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	4.24	15391.199
RUNOFF	3.420	12414.7588
PERCOLATION/LEAKAGE THROUGH LAYER 2	0.023811	86.43263
SNOW WATER	5.69	20667.5918

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4190
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1297

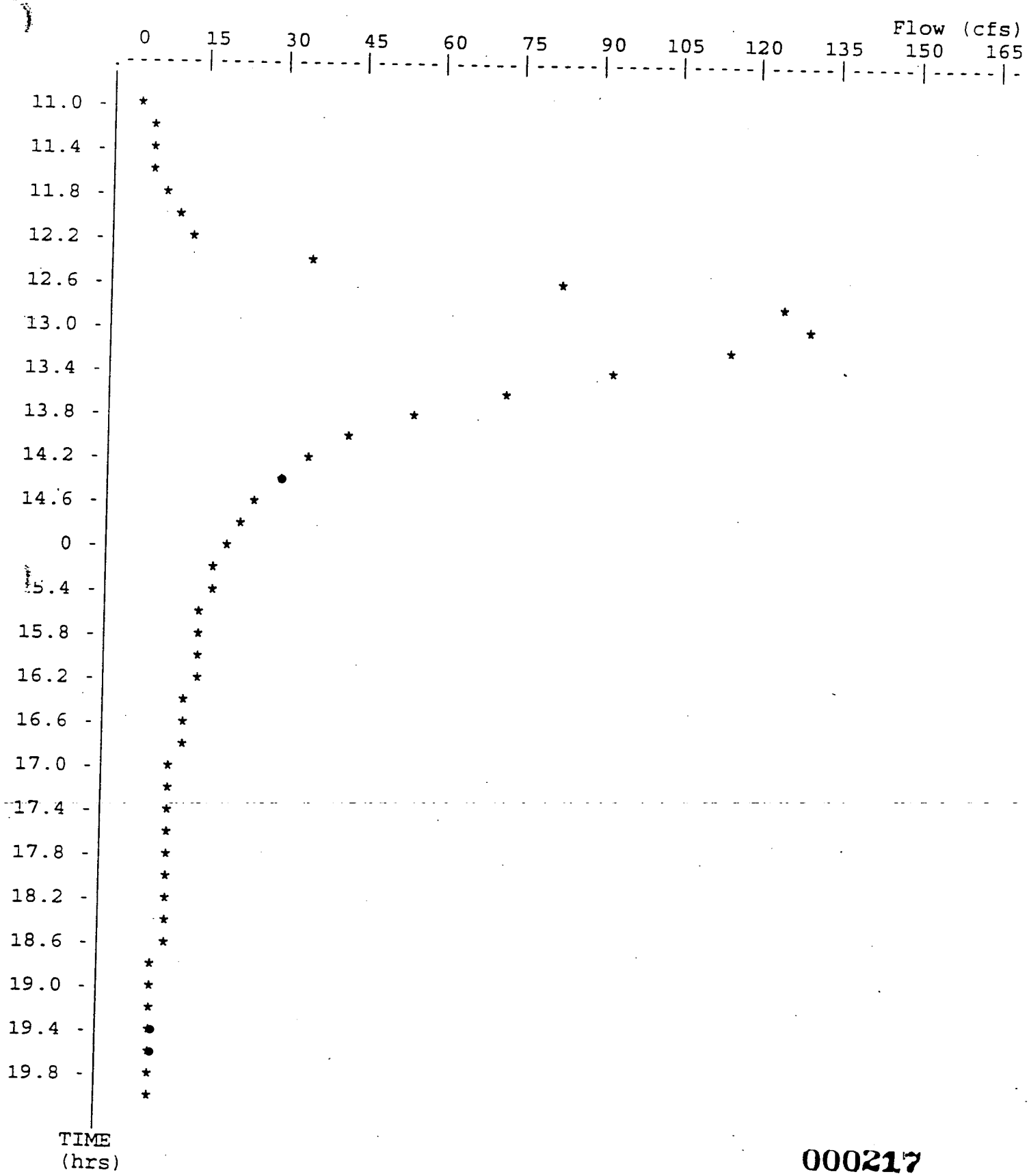
****

APPENDIX B

PEAK DISCHARGE AND HYDROGRAPH (TR55 METHOD)

Quick TR-55 Version: 5.46 S/N:
Plotted: 06-05-1997 14:50:23

8091



000217

File: c:\qtr55\POND1-25.HYD Qmax = 129.0 cfs

Quick TR-55 Version: 5.46 S/N:

Return Frequency: 25 year

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-05-1997 14:40:50
Watershed file: --> C:\QTR55\POND1 .MOP
Hydrograph file: --> C:\QTR55\POND1-25.HYD

TABULAR HYDROGRAPH - POND 1 NORTHEAST OF FEMP
TR-55 METHOD
TYPE II DISTRIBUTION; 25 YEAR RETURN PERIOD AND 24 HR. DURA. STORM
FEMP

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
SUBAREA A	26.40	74.0	0.40	0.50	4.70	2.13	I.15	.15
SUBAREA B	7.10	74.0	0.40	0.40	4.70	2.13	I.15	.15
SUBAREA O	51.30	74.0	0.50	0.50	4.70	2.13	I.15	.15
SUBAREA L	42.50	74.0	0.75	0.75	4.70	2.13	I.15	.15

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 127.30 acres or 0.1989 sq.mi
Peak discharge = 129 cfs

WARNING: Drainage areas of two or more subareas differ by a factor of 5 or greater.

>>>> Computer Modifications of Input Parameters <<<<

Subarea Description	Input Values Tc (hr)	* Tt (hr)	Rounded Values Tc (hr)	* Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
SUBAREA A	0.43	0.43	0.40	0.50	Yes	--
SUBAREA B	0.39	0.39	0.40	0.40	Yes	--
SUBAREA O	0.55	0.55	0.50	0.50	Yes	--
SUBAREA L	0.74	0.74	0.75	0.75	Yes	--

Travel time from subarea outfall to composite watershed outfall point.

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-05-1997 14:40:50
Watershed file: --> C:\QTR55\POND1 .MOP
Hydrograph file: --> C:\QTR55\POND1-25.HYD

TABULAR HYDROGRAPH - POND 1 NORTHEAST OF FEMP
TR-55 METHOD
TYPE II DISTRIBUTION; 25 YEAR RETURN PERIOD AND 24 HR. DURA. STORM
FEMP

>>>> Summary of Subarea Times to Peak <<<<

Subarea	Peak Discharge at Composite Outfall (cfs)	Time to Peak at Composite Outfall (hrs)
SUBAREA A	36	12.8
SUBAREA B	10	12.7
SUBAREA O	64	12.8
SUBAREA L	44	13.4
Composite Watershed	129	13.0

Quick TR-55 Version: 5.46 S/N:

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-05-1997 14:40:50
Watershed file: --> C:\QTR55\POND1 .MOP
Hydrograph file: --> C:\QTR55\POND1-25.HYD

TABULAR HYDROGRAPH - POND 1 NORTHEAST OF FEMP
TR-55 METHOD
TYPE II DISTRIBUTION; 25 YEAR RETURN PERIOD AND 24 HR. DURA. STORM
FEMP

Composite Hydrograph Summary (cfs)

Subarea Description	11.0 hr	11.3 hr	11.6 hr	11.9 hr	12.0 hr	12.1 hr	12.2 hr	12.3 hr	12.4 hr
SUBAREA A	1	1	1	2	2	3	4	7	12
SUBAREA B	0	0	0	1	1	1	1	2	4
SUBAREA O	1	2	3	4	4	5	6	9	15
SUBAREA L	1	1	1	2	2	2	2	3	3
Total (cfs)	3	4	5	9	9	11	13	21	34

Subarea Description	12.5 hr	12.6 hr	12.7 hr	12.8 hr	13.0 hr	13.2 hr	13.4 hr	13.6 hr	13.8 hr
UBAREA A	20	28	35	36	30	20	13	9	7
UBAREA B	7	9	10	10	7	5	3	2	2
UBAREA O	26	40	54	64	63	48	32	22	16
UBAREA L	4	6	10	15	29	41	44	39	30
otal (cfs)	57	83	109	125	129	114	92	72	55

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-05-1997 14:40:50
Watershed file: --> C:\QTR55\POND1 .MOP
Hydrograph file: --> C:\QTR55\POND1-25.HYD

TABULAR HYDROGRAPH - POND 1 NORTHEAST OF FEMP
TR-55 METHOD
TYPE II DISTRIBUTION; 25 YEAR RETURN PERIOD AND 24 HR. DURA. STORM
FEMP

Composite Hydrograph Summary (cfs)

Subarea Description	14.0 hr	14.3 hr	14.6 hr	15.0 hr	15.5 hr	16.0 hr	16.5 hr	17.0 hr	17.5 hr
SUBAREA A	6	5	4	3	3	3	2	2	2
SUBAREA B	1	1	1	1	1	1	1	1	1
SUBAREA O	13	10	8	7	6	6	5	4	4
SUBAREA L	23	15	11	8	6	5	5	4	4
ıl (cfs)	43	31	24	19	16	15	13	11	11

Subarea Description	18.0 hr	19.0 hr	20.0 hr	22.0 hr	26.0 hr
SUBAREA A	2	2	1	1	0
SUBAREA B	1	0	0	0	0
SUBAREA O	4	3	3	2	0
SUBAREA L	3	3	3	2	0
Total (cfs)	10	8	7	5	0

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-05-1997 14:40:50
Watershed file: --> C:\QTR55\POND1 .MOP
Hydrograph file: --> C:\QTR55\POND1-25.HYD

TABULAR HYDROGRAPH - POND 1 NORTHEAST OF FEMP
TR-55 METHOD
TYPE II DISTRIBUTION; 25 YEAR RETURN PERIOD AND 24 HR. DURA. STORM
FEMP

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
11.0	3	14.8	22
11.1	3	14.9	20
11.2	4	15.0	19
11.3	4	15.1	18
11.4	4	15.2	18
11.5	5	15.3	17
11.6	5	15.4	17
11.7	6	15.5	16
11.8	8	15.6	16
11.9	9	15.7	16
12.0	9	15.8	15
12.1	11	15.9	15
12.2	13	16.0	15
12.3	21	16.1	15
12.4	34	16.2	14
12.5	57	16.3	14
12.6	83	16.4	13
12.7	109	16.5	13
12.8	125	16.6	13
12.9	127	16.7	12
13.0	129	16.8	12
13.1	122	16.9	11
13.2	114	17.0	11
13.3	103	17.1	11
13.4	92	17.2	11
13.5	82	17.3	11
13.6	72	17.4	11
13.7	63	17.5	11
13.8	55	17.6	11
13.9	49	17.7	11
14.0	43	17.8	10
14.1	39	17.9	10
14.2	35	18.0	10
14.3	31	18.1	10
14.4	29	18.2	10
14.5	26	18.3	9

14.6	24	18.4	9
14.7	23	18.5	9

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-05-1997 14:40:50
Watershed file: --> C:\QTR55\POND1 .MOP
Hydrograph file: --> C:\QTR55\POND1-25.HYD

TABULAR HYDROGRAPH - POND 1 NORTHEAST OF FEMP
TR-55 METHOD
TYPE II DISTRIBUTION; 25 YEAR RETURN PERIOD AND 24 HR. DURA. STORM
FEMP

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
18.6	9	22.4	4
18.7	9	22.5	4
18.8	8	22.6	4
18.9	8	22.7	4
19.0	8	22.8	4
19.1	8	22.9	4
19.2	8	23.0	4
19.3	8	23.1	4
19.4	8	23.2	4
19.5	8	23.3	3
19.6	7	23.4	3
19.7	7	23.5	3
19.8	7	23.6	3
19.9	7	23.7	3
20.0	7	23.8	3
20.1	7	23.9	3
20.2	7	24.0	2
20.3	7	24.1	2
20.4	7	24.2	2
20.5	6	24.3	2
20.6	6	24.4	2
20.7	6	24.5	2
20.8	6	24.6	2
20.9	6	24.7	2
21.0	6	24.8	2
21.1	6	24.9	1
21.2	6	25.0	1
21.3	6	25.1	1
21.4	6	25.2	1
21.5	6	25.3	1
21.6	5	25.4	1
21.7	5	25.5	1
21.8	5	25.6	0
21.9	5	25.7	0
22.0	5	25.8	0
22.1	5	25.9	0
22.2	5		
22.3	5		

Quick TR-55 Ver.5.46 S/N:
Executed: 11:29:57 06-05-1997 c:\qtr55\POND1.TCT

SUMMARY SHEET FOR Tc or Tt COMPUTATIONS
(Solved for Time using TR-55 Methods)

POND 1
FEMP

Subarea descr.	Tc or Tt	Time (hrs)
SUBAREA A	Tc	0.43
SUBBASIN B	Tc	0.39
SUBBASIN O	Tc	0.55
SUBAREA L	Tc	0.74

8091

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Quick TR-55 Ver.5.46   S/N:
Executed: 11:29:57   06-05-1997    c:\qtr55\POND1.TCT

                                 POND 1
                                  FEMP


                    Tc COMPUTATIONS FOR: SUBAREA A

SHEET FLOW (Applicable to Tc only)
    Segment ID                                      A1
    Surface description                        GRASS
    Manning's roughness coeff., n                   0.3000
    Flow length, L (total < or = 300)     ft       200.0
    Two-yr 24-hr rainfall, P2              in        2.900
    Land slope, s                        ft/ft      0.1480
                         0.8
         .007 * (n*L)
    T =  --------------                  hrs        0.23                =  0.23
           0.5    0.4
         P2   •   s

SHALLOW CONCENTRATED FLOW
    Segment ID
    Surface (paved or unpaved)?                     Unpaved
    Flow length, L                         ft       380.0
    Watercourse slope, s                 ft/ft      0.1480

                           0.5
    Avg.V =  Csf •   (s)                 ft/s       6.2071
    where:   Unpaved Csf = 16.1345
             Paved   Csf = 20.3282

    T = L / (3600*V)                     hrs        0.02                =  0.02


CHANNEL FLOW
    Segment ID                                      A3
    Cross Sectional Flow Area, a         sq.ft     16.00
    Wetted perimeter, Pw                   ft      11.30
    Hydraulic radius, r = a/Pw             ft      1.416
    Channel slope, s                     ft/ft     0.0050
    Manning's roughness coeff., n                  0.0340

                      2/3    1/2
         1.49  •  r    *   s
    V =  --------------------            ft/s      3.9074
                    n

    Flow length, L                         ft       2460

    T = L / (3600*V)                     hrs        0.17                =  0.17

  :::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
                                              TOTAL TIME (hrs)          0.43
```

000226

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Quick TR-55 Ver.5.46   S/N:                                      8091
Executed: 11:29:57   06-05-1997    c:\qtr55\POND1.TCT

                                POND 1
                                 FEMP


                    Tc COMPUTATIONS FOR: SUBBASIN B

 SHEET FLOW (Applicable to Tc only)
     Segment ID
     Surface description                    GRASS
     Manning's roughness coeff., n                0.3000
     Flow length, L (total < or = 300)     ft     300.0
     Two-yr 24-hr rainfall, P2             in     2.900
     Land slope, s                       ft/ft    0.1480
                          0.8
          .007 * (n*L)
     T =  -------------                    hrs      0.32                 =  0.32
             0.5    0.4
           P2   *  s

 SHALLOW CONCENTRATED FLOW
     Segment ID
     Surface (paved or unpaved)?                 Unpaved
     Flow length, L                         ft     150.0
     Watercourse slope, s                ft/ft    0.1480

                            0.5
     Avg.V =  Csf *  (s)                  ft/s    6.2071
     where:   Unpaved Csf = 16.1345
              Paved   Csf = 20.3282

     T = L / (3600*V)                      hrs      0.01                 =  0.01


 CHANNEL FLOW
     Segment ID
     Cross Sectional Flow Area, a       sq.ft     16.00
     Wetted perimeter, Pw                   ft     11.30
     Hydraulic radius, r = a/Pw             ft     1.416
     Channel slope, s                    ft/ft    0.0050
     Manning's roughness coeff., n               0.0340

                        2/3    1/2
          1.49  *  r   *  s
     V =  --------------------            ft/s    3.9074
                       n

     Flow length, L                         ft       810

     T = L / (3600*V)                      hrs      0.06                 =  0.06
                                                                   000226
 ::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
                                               TOTAL TIME (hrs)        0.39
```
000226

Quick TR-55 Ver.5.46 S/N:
Executed: 11:29:57 06-05-1997 c:\qtr55\POND1.TCT

POND 1
FEMP

Tc COMPUTATIONS FOR: SUBBASIN O

SHEET FLOW (Applicable to Tc only)

Segment ID			
Surface description		GRASS	
Manning's roughness coeff., n		0.3000	
Flow length, L (total < or = 300)	ft	300.0	
Two-yr 24-hr rainfall, P2	in	2.900	
Land slope, s	ft/ft	0.2300	
$T = \frac{.007 * (n*L)^{0.8}}{P2^{0.5} * s^{0.4}}$	hrs	0.27	= 0.27

SHALLOW CONCENTRATED FLOW

Segment ID			
Surface (paved or unpaved)?		Unpaved	
Flow length, L	ft	1650.0	
Watercourse slope, s	ft/ft	0.0100	
$Avg.V = Csf * (s)^{0.5}$	ft/s	1.6135	
where: Unpaved Csf = 16.1345			
Paved Csf = 20.3282			
T = L / (3600*V)	hrs	0.28	= 0.28

CHANNEL FLOW

Segment ID			
Cross Sectional Flow Area, a	sq.ft	0.00	
Wetted perimeter, Pw	ft	0.00	
Hydraulic radius, r = a/Pw	ft	0.000	
Channel slope, s	ft/ft	0.0000	
Manning's roughness coeff., n		0.0000	
$V = \frac{1.49 * r^{2/3} * s^{1/2}}{n}$	ft/s	0.0000	
Flow length, L	ft	0	
T = L / (3600*V)	hrs	0.00	= 0.00

::

TOTAL TIME (hrs) 0.55

Quick TR-55 Ver.5.46 S/N:
Executed: 11:29:57 06-05-1997 c:\qtr55\POND1.TCT

POND 1
FEMP

Tc COMPUTATIONS FOR: SUBAREA L

SHEET FLOW (Applicable to Tc only)

Segment ID			
Surface description		GRASS	
Manning's roughness coeff., n		0.3000	
Flow length, L (total < or = 300)	ft	150.0	
Two-yr 24-hr rainfall, P2	in	2.900	
Land slope, s	ft/ft	0.0100	
$T = \frac{.007 * (n*L)^{0.8}}{P2^{0.5} * s^{0.4}}$	hrs	0.55	= 0.55

SHALLOW CONCENTRATED FLOW

Segment ID			
Surface (paved or unpaved)?		Unpaved	
Flow length, L	ft	950.0	
Watercourse slope, s	ft/ft	0.0070	
$Avg.V = Csf \bullet (s)^{0.5}$	ft/s	1.3499	
where: Unpaved Csf = 16.1345			
Paved Csf = 20.3282			
T = L / (3600*V)	hrs	0.20	= 0.20

CHANNEL FLOW

Segment ID			
Cross Sectional Flow Area, a	sq.ft	0.00	
Wetted perimeter, Pw	ft	0.00	
Hydraulic radius, r = a/Pw	ft	0.000	
Channel slope, s	ft/ft	0.0000	
Manning's roughness coeff., n		0.0000	
$V = \frac{1.49 \bullet r^{2/3} \bullet s^{1/2}}{n}$	ft/s	0.0000	
Flow length, L	ft	0	
T = L / (3600*V)	hrs	0.00	= 0.00

::

TOTAL TIME (hrs) 0.74

Quick TR-55 Ver.5.46 S/N:
Executed: 14:18:47 06-05-1997

SUMMARY SHEET FOR Tc or Tt COMPUTATIONS
(Solved for Time using Length/Velocity)

TRAVEL TIME COMPUTATION
POND1 - NORTHEAST OF FEMP
FEMP

Subarea descr.	Tc or Tt	Time (hrs)
SUBAREA A	Tt	0.00
SUBAREA B	Tt	0.00
SUBAREA O	Tt	0.19
SUBAREA L	Tt	0.00

Quick TR-55 Version: 5.46 S/N:

>>>>> GRAPHICAL PEAK DISCHARGE METHOD <<<<<

GRAPHICAL PEAK DISCHARGE
POND 1 -AT NORTHEAST OF FEMP

CALCULATED .GPD
DISK FILE: c:\qtr55\POND1 .GPD

Drainage Area	(acres)	127.3 --->	0.1989 sq.mi.	
Runoff Curve Number	(CN)	74		
Time of Concentration,Tc	(hrs)	.75		
Rainfall Distribution	(Type)	II		
Pond and Swamp Areas	(%)	1 --->	1.3 acres	

	Storm #1	Storm #2	Storm #3
Frequency (years)	5	25	100
Rainfall, P, 24-hr (in)	3.7	4.7	5.6
Initial Abstraction, Ia (in)	0.703	0.703	0.703
Ia/p Ratio	0.190	0.150	0.125
Unit Discharge, * qu (csm/in)	390	405	414
Runoff, Q (in)	1.38	2.13	2.85
Pond & Swamp Adjustment Factor	0.87	0.87	0.87
PEAK DISCHARGE, qp (cfs)	93	149	204

Summary of Computations for qu

Ia/p	#1	0.100	0.100	0.100
C0	#1	2.553	2.553	2.553
C1	#1	-0.615	-0.615	-0.615
C2	#1	-0.164	-0.164	-0.164
qu (csm)	#1	424.152	424.152	424.152
Ia/p	#2	0.300	0.300	0.300
C0	#2	2.465	2.465	2.465
C1	#2	-0.623	-0.623	-0.623
C2	#2	-0.117	-0.117	-0.117
qu (csm)	#2	347.763	347.763	347.763
* qu (csm)		390	405	414

* Interpolated for computed Ia/p ratio (between Ia/p #1 & Ia/p #2)
If computed Ia/p exceeds Ia/p limits, bounding limit for Ia/p is used.

$$\log(qu) = C0 + (C1 * \log(Tc)) + (C2 * (\log(Tc))^2)$$

qp (cfs) = qu(csm) * Area(sq.mi.) * Q(in.) * (Pond & Swamp Adj.)

Quick TR-55 Version: 5.46 S/N:

>>>>> DETENTION STORAGE ESTIMATE <<<<<

DETENTION STORAGE ESTIMATE
POND1 - NORTHEAST FEMP
FEMP

CALCULATED
DISK FILE: c:\qtr55\POND1 .DET

Drainage Area	(acres)	127.3	0.1989 sq.mi.
Rainfall Distribution	(Type)	II	

	Storm #1	Storm #2	Storm #3
Frequency (years)	5	25	100
Peak Inflow, qi (cfs)	93	149	204
Inflow Runoff, Q (in)	1.38	2.13	2.85
Peak Outflow, qo (cfs)	0	0	0
qo/qi Ratio	0.000	0.000	0.000
* Vs/Vr Ratio	0.682	0.682	0.682
Inflow Volume, Vr (ac-ft)	14.6	22.6	30.2
STORAGE VOLUME, Vs (ac-ft)	10.0	15.4	20.6

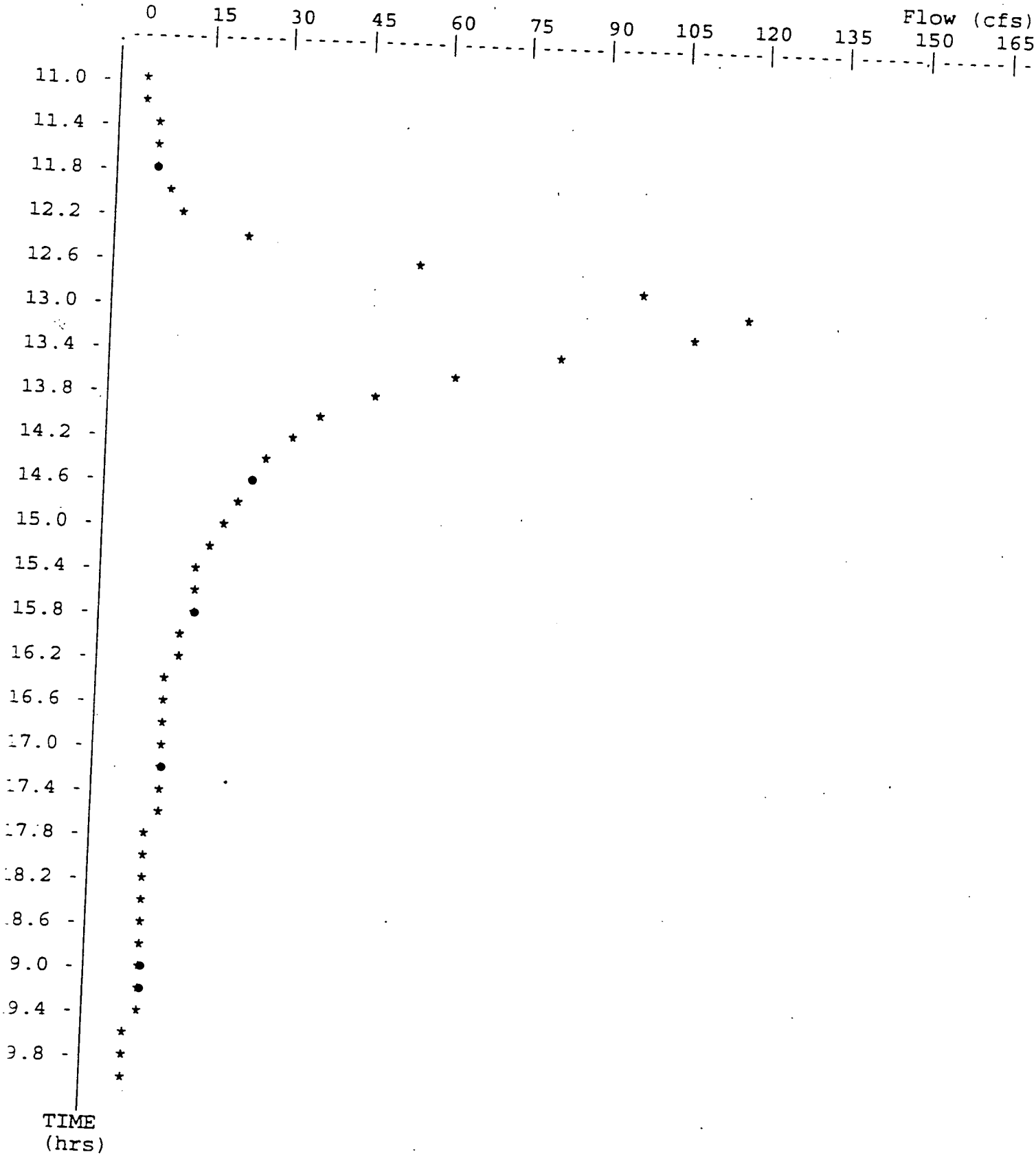
Summary of Volume Computations

C0	0.682	0.682	0.682
C1	-1.430	-1.430	-1.430
C2	1.640	1.640	1.640
C3	-0.804	-0.804	-0.804
* Vs/Vr	0.682	0.682	0.682

$$* \quad Vs/Vr = C0 + (C1*(qo/qi)) + (C2*(qo/qi)^2) + (C3*(qo/qi)^3)$$

Quick TR-55 Version: 5.46 S/N:
Plotted: 06-05-1997 15:47:36

8091



* File: c:\qtr55\POND2-25.HYD Qmax = 117.0 cfs

000232

Quick TR-55 Version: 5.46 S/N:

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-05-1997 15:45:04
Watershed file: --> C:\QTR55\POND2 .MOP
Hydrograph file: --> C:\QTR55\POND2-25.HYD

TABULAR HYDROGRAPH
POND 2 - NORTHWEST FEMP
FEMP

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
SUBBASIN N	51.80	74.0	0.20	0.75	4.70	2.13	I.15	.15
SUBBASIN M	57.40	74.0	1.50	0.00	4.70	2.13	I.15	.15

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 109.20 acres or 0.1706 sq.mi
Peak discharge = 117 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	* Tt (hr)	Rounded Values Tc (hr)	* Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
SUBBASIN N	0.29	0.65	0.20	0.75	Yes	--
SUBBASIN M	1.44	0.00	1.50	0.00	Yes	--

* Travel time from subarea outfall to composite watershed outfall point.

Return Frequency: 25 yea-

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-05-1997 15:45:04
Watershed file: --> C:\QTR55\POND2 .MOP
Hydrograph file: --> C:\QTR55\POND2-25.HYD

TABULAR HYDROGRAPH
POND 2 - NORTHWEST FEMP
FEMP

>>>> Summary of Subarea Times to Peak <<<<

Subarea	Peak Discharge at Composite Outfall (cfs)	Time to Peak at Composite Outfall (hrs)
SUBBASIN N	71	13.0
SUBBASIN M	50	13.2
Composite Watershed	117	13.0

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-05-1997 15:45:04
Watershed file: --> C:\QTR55\POND2 .MOP
Hydrograph file: --> C:\QTR55\POND2-25.HYD

TABULAR HYDROGRAPH
POND 2 - NORTHWEST FEMP
FEMP

Composite Hydrograph Summary (cfs)

Subarea Description	11.0 hr	11.3 hr	11.6 hr	11.9 hr	12.0 hr	12.1 hr	12.2 hr	12.3 hr	12.4 hr
SUBBASIN N	1	2	2	3	3	4	4	6	9
SUBBASIN M	1	2	2	3	4	4	6	9	13
Total (cfs)	2	4	4	6	7	8	10	15	22

Subarea Description	12.5 hr	12.6 hr	12.7 hr	12.8 hr	13.0 hr	13.2 hr	13.4 hr	13.6 hr	13.8 hr
SUBBASIN N	17	29	45	60	71	57	38	25	17
SUBBASIN M	19	25	32	38	46	50	44	37	30
Total (cfs)	36	54	77	98	117	107	82	62	47

Subarea Description	14.0 hr	14.3 hr	14.6 hr	15.0 hr	15.5 hr	16.0 hr	16.5 hr	17.0 hr	17.5 hr
SUBBASIN N	13	10	9	7	6	6	5	4	4
SUBBASIN M	25	19	15	12	9	7	6	5	5
Total (cfs)	38	29	24	19	15	13	11	9	9

ıbarea ɔcription	18.0 hr	19.0 hr	20.0 hr	22.0 hr	26.0 hr
SUBBASIN N	4	3	3	2	0
SUBBASIN M	4	4	3	3	0

Total (cfs)	8	7	6	5	0	8091

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Quick TR-55 Ver.5.46   S/N:
 xecuted: 16:17:01   06-05-1997   c:\qtr55\POND3.TCT

                        TIME OF CONCENTRATION
                      POND 3 - SOUTHEAST FEMP
                               FEMP

                  Tc COMPUTATIONS FOR: SUBBASIN F

 SHEET FLOW (Applicable to Tc only)
     Segment ID
     Surface description                      GRASS
     Manning's roughness coeff., n                  0.3000
     Flow length, L (total < or = 300)      ft     300.0
     Two-yr 24-hr rainfall, P2               in     2.900
     Land slope, s                        ft/ft    0.0150
                          0.8
          .007 * (n*L)
     T =  -------------                    hrs      0.81             =  0.81
             0.5    0.4
           P2    *  s

 SHALLOW CONCENTRATED FLOW
     Segment ID
     Surface (paved or unpaved)?                   Unpaved
     Flow length, L                          ft     510.0
     Watercourse slope, s                 ft/ft    0.0200

                            0.5
     Avg.V =  Csf *  (s)                  ft/s    2.2818
     where:   Unpaved Csf = 16.1345
              Paved   Csf = 20.3282

     T = L / (3600*V)                      hrs      0.06             =  0.06

 CHANNEL FLOW
     Segment ID
     Cross Sectional Flow Area, a        sq.ft     32.00
     Wetted perimeter, Pw                    ft     17.90
     Hydraulic radius, r = a/Pw              ft     1.788
     Channel slope, s                     ft/ft    0.0050
     Manning's roughness coeff., n                  0.0340

                      2/3     1/2
          1.49  •  r    *   s
     V =  --------------------            ft/s    4.5645
                     n

     Flow length, L                          ft      2070

     T = L / (3600*V)                      hrs      0.13             =  0.13

    ::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
                                               TOTAL TIME (hrs)      1.00
```

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Quick TR-55 Ver.5.46   S/N:
Executed: 16:17:01   06-05-1997    c:\qtr55\POND3.TCT

                         TIME OF CONCENTRATION
                       POND 3 - SOUTHEAST FEMP
                                 FEMP

                  Tc COMPUTATIONS FOR: SUBBASIN H

SHEET FLOW (Applicable to Tc only)
    Segment ID
    Surface description                      GRASS
    Manning's roughness coeff., n                  0.3000
    Flow length, L (total < or = 300)       ft     300.0
    Two-yr 24-hr rainfall, P2               in     2.900
    Land slope, s                        ft/ft     0.0100
                         0.8
         .007 * (n*L)
    T =  -------------                      hrs      0.95              =  0.95
            0.5    0.4
          P2   *  s

SHALLOW CONCENTRATED FLOW
    Segment ID
    Surface (paved or unpaved)?                   Unpaved
    Flow length, L                          ft     1400.0
    Watercourse slope, s                 ft/ft     0.0100

                           0.5
    Avg.V =  Csf *  (s)                   ft/s     1.6135
    where:   Unpaved Csf = 16.1345
             Paved   Csf = 20.3282

    T = L / (3600*V)                        hrs      0.24              =  0.24


CHANNEL FLOW
    Segment ID
    Cross Sectional Flow Area, a       sq.ft       0.00
    Wetted perimeter, Pw                  ft       0.00
    Hydraulic radius, r = a/Pw            ft      0.000
    Channel slope, s                   ft/ft     0.0000
    Manning's roughness coeff., n                0.0000

                       2/3   1/2
         1.49  *  r   *   s
    V =  --------------------             ft/s     0.0000
                    n

    Flow length, L                          ft          0

    T = L / (3600*V)                        hrs      0.00              =  0.00

  ::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
                                                  TOTAL TIME (hrs)      1.19
```

Quick TR-55 Version: 5.46 S/N:

>>>>> GRAPHICAL PEAK DISCHARGE METHOD <<<<<

POND 2 - NORTHWEST FEMP
FEMP
25 YEAR RETURN PERIOD, 24 HOUR DURATION STORM

CALCULATED
DISK FILE: c:\qtr55\POND2 .GPD

Drainage Area	(acres)	109.2	--->	0.1706 sq.mi.
Runoff Curve Number	(CN)	74		
Time of Concentration,Tc	(hrs)	.95		
Rainfall Distribution	(Type)	II		
Pond and Swamp Areas	(%)	1	--->	1.1 acres

	Storm #1	Storm #2	Storm #3
Frequency (years)	25		
Rainfall, P, 24-hr (in)	4.7		
Initial Abstraction, Ia (in)	0.703	0.703	0.703
Ia/p Ratio	0.150	0.000	0.000
Unit Discharge, * qu (csm/in)	352	0	0
Runoff, Q (in)	2.13	0.00	0.00
Pond & Swamp Adjustment Factor	0.87	0.87	0.87
PEAK DISCHARGE, qp (cfs)	111	0	0

Summary of Computations for qu

Ia/p	#1	0.100	0.000	0.000
C0	#1	2.553	0.000	0.000
C1	#1	-0.615	0.000	0.000
C2	#1	-0.164	0.000	0.000
qu (csm)	#1	368.851	0.000	0.000
Ia/p	#2	0.300	0.000	0.000
C0	#2	2.465	0.000	0.000
C1	#2	-0.623	0.000	0.000
C2	#2	-0.117	0.000	0.000
qu (csm)	#2	301.391	0.000	0.000
• qu (csm)		352	0	0

• Interpolated for computed Ia/p ratio (between Ia/p #1 & Ia/p #2)
If computed Ia/p exceeds Ia/p limits, bounding limit for Ia/p is used.

$$\log(qu) = C0 + (C1 * \log(Tc)) + (C2 * (\log(Tc))^2)$$

qp (cfs) = qu(csm) * Area(sq.mi.) * Q(in.) * (Pond & Swamp Adj.)

Quick TR-55 Version: 5.46 S/N: 8091

>>>>> DETENTION STORAGE ESTIMATE <<<<<

DETENTION STORAGE ESTIMATE
POND 2 - NORTHWEST FEMP
FEMP

CALCULATED
DISK FILE: c:\qtr55\POND2 .DET

Drainage Area	(acres)	109.2	0.1706 sq.mi.
Rainfall Distribution	(Type)	II	

	Storm #1	Storm #2	Storm #3
Frequency (years)	25		
Peak Inflow, qi (cfs)	117		
Inflow Runoff, Q (in)	2.13		
Peak Outflow, qo (cfs)	0		
qo/qi Ratio	0.000	0.000	0.000
* Vs/Vr Ratio	0.682	0.000	0.000
Inflow Volume, Vr (ac-ft)	19.4	0.0	0.0
STORAGE VOLUME, Vs (ac-ft)	13.2	0.0	0.0

Summary of Volume Computations

C0	0.682	0.682	0.682
C1	-1.430	-1.430	-1.430
C2	1.640	1.640	1.640
C3	-0.804	-0.804	-0.804
* Vs/Vr	0.682	0.000	0.000

$$* \quad Vs/Vr = C0 + (C1*(qo/qi)) + (C2*(qo/qi)^2) + (C3*(qo/qi)^3)$$

Quick TR-55 Version: 5.46 S/N:

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-06-1997 10:03:14
Watershed file: --> C:\QTR55\POND3 .MOP
Hydrograph file: --> C:\QTR55\POND3-25.HYD

TABULAR HYDROGRAPH
POND 3 -SOUTHEAST FEMP
FEMP

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input	Ia/p used
SUBBASIN C	36.50	74.0	0.50	0.10	4.70	2.13	I.15	.15
SUBBASIN E	7.20	74.0	1.00	0.30	4.70	2.13	I.15	.15
SUBBASIN F	23.00	74.0	1.00	0.10	4.70	2.13	I.15	.15
SUBBASIN H	37.30	74.0	1.25	0.00	4.70	2.13	I.15	.15

* Travel time from subarea outfall to composite watershed outfall point.
- Subarea where user specified interpolation between Ia/p tables.

Total area = 104.00 acres or 0.1625 sq.mi
Peak discharge = 95 cfs

WARNING: Drainage areas of two or more subareas differ by a factor of 5 or greater.

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
SUBBASIN C	0.59	0.07	0.50	0.10	Yes	--
SUBBASIN E	1.02	0.24	1.00	0.30	Yes	--
SUBBASIN F	1.00	0.07	1.00	0.10	Yes	--
SUBBASIN H	1.19	0.00	1.25	0.00	Yes	--

* Travel time from subarea outfall to composite watershed outfall point.

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-06-1997 10:03:14
Watershed file: --> C:\QTR55\POND3 .MOP
Hydrograph file: --> C:\QTR55\POND3-25.HYD

TABULAR HYDROGRAPH
POND 3 -SOUTHEAST FEMP
FEMP

>>>> Summary of Subarea Times to Peak <<<<

Subarea	Peak Discharge at Composite Outfall (cfs)	Time to Peak at Composite Outfall (hrs)
SUBBASIN C	57	12.5
SUBBASIN E	7	13.0
SUBBASIN F	25	13.0
SUBBASIN H	37	13.0
Composite Watershed	95	12.8

Quick TR-55 Version: 5.46 S/N:

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-06-1997 10:03:14
Watershed file: --> C:\QTR55\POND3 .MOP
Hydrograph file: --> C:\QTR55\POND3-25.HYD

TABULAR HYDROGRAPH
POND 3 -SOUTHEAST FEMP
FEMP

Composite Hydrograph Summary (cfs)

Subarea Description	11.0 hr	11.3 hr	11.6 hr	11.9 hr	12.0 hr	12.1 hr	12.2 hr	12.3 hr	12.4 hr
JBBASIN C	1	2	3	5	7	13	24	40	52
JBBASIN E	0	0	0	0	0	1	1	1	1
JBBASIN F	1	1	1	1	2	2	2	4	6
JBBASIN H	1	1	2	2	3	4	5	8	13
(cfs)	3	4	6	8	12	20	32	53	72

Subarea Description	12.5 hr	12.6 hr	12.7 hr	12.8 hr	13.0 hr	13.2 hr	13.4 hr	13.6 hr	13.8 hr
JBBASIN C	57	52	43	34	21	14	11	9	7
JBBASIN E	2	3	4	6	7	7	6	5	4
JBBASIN F	10	14	18	22	25	22	17	13	10
JBBASIN H	18	24	29	33	37	32	26	20	16
tal (cfs)	87	93	94	95	90	75	60	47	37

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-06-1997 10:03:14
Watershed file: --> C:\QTR55\POND3 .MOP
Hydrograph file: --> C:\QTR55\POND3-25.HYD

TABULAR HYDROGRAPH
POND 3 -SOUTHEAST FEMP
FEMP

Composite Hydrograph Summary (cfs)

Subarea Description	14.0 hr	14.3 hr	14.6 hr	15.0 hr	15.5 hr	16.0 hr	16.5 hr	17.0 hr	17.5 hr
SUBBASIN C	7	6	5	4	4	4	3	3	3
SUBBASIN E	3	2	2	1	1	1	1	1	1
SUBBASIN F	8	6	5	4	3	3	2	2	2
SUBBASIN H	13	10	8	6	5	4	4	3	3
Total (cfs)	31	24	20	15	13	12	10	9	

Subarea Description	18.0 hr	19.0 hr	20.0 hr	22.0 hr	26.0 hr
SUBBASIN C	3	2	2	2	0
SUBBASIN E	1	0	0	0	0
SUBBASIN F	2	2	1	1	0
SUBBASIN H	3	3	2	2	0
Total (cfs)	9	7	5	5	0

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-06-1997 10:03:14
Watershed file: --> C:\QTR55\POND3 .MOP
Hydrograph file: --> C:\QTR55\POND3-25.HYD

TABULAR HYDROGRAPH
POND 3 -SOUTHEAST FEMP
FEMP

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
11.0	3	14.8	18
11.1	3	14.9	16
11.2	4	15.0	15
11.3	4	15.1	15
11.4	5	15.2	14
11.5	5	15.3	14
11.6	6	15.4	13
11.7	7	15.5	13
11.8	7	15.6	13
11.9	8	15.7	13
12.0	12	15.8	12
12.1	20	15.9	12
12.2	32	16.0	12
12.3	53	16.1	12
12.4	72	16.2	11
12.5	87	16.3	11
12.6	93	16.4	10
12.7	94	16.5	10
12.8	95	16.6	10
12.9	92	16.7	10
13.0	90	16.8	9
13.1	82	16.9	9
13.2	75	17.0	9
13.3	67	17.1	9
13.4	60	17.2	9
13.5	54	17.3	9
13.6	47	17.4	9
13.7	42	17.5	9
13.8	37	17.6	9
13.9	34	17.7	9
14.0	31	17.8	9
14.1	29	17.9	9
14.2	26	18.0	9
14.3	24	18.1	9
14.4	23	18.2	9
14.5	21	18.3	8

14.6	20	18.4	8
14.7	19	18.5	8

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-05-1997 15:45:04
Watershed file: --> C:\QTR55\POND2 .MOP
Hydrograph file: --> C:\QTR55\POND2-25.HYD

TABULAR HYDROGRAPH
POND 2 - NORTHWEST FEMP
FEMP

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
11.0	2	14.8	22
11.1	3	14.9	20
11.2	3	15.0	19
11.3	4	15.1	18
11.4	4	15.2	17
11.5	4	15.3	17
11.6	4	15.4	16
11.7	5	15.5	15
11.8	5	15.6	15
11.9	6	15.7	14
12.0	7	15.8	14
12.1	8	15.9	13
12.2	10	16.0	13
12.3	15	16.1	13
12.4	22	16.2	12
12.5	36	16.3	12
12.6	54	16.4	11
12.7	77	16.5	11
12.8	98	16.6	11
12.9	108	16.7	10
13.0	117	16.8	10
13.1	112	16.9	9
13.2	107	17.0	9
13.3	94	17.1	9
13.4	82	17.2	9
13.5	72	17.3	9
13.6	62	17.4	9
13.7	54	17.5	9
13.8	47	17.6	9
13.9	42	17.7	9
14.0	38	17.8	8
14.1	35	17.9	8
14.2	32	18.0	8
14.3	29	18.1	8
14.4	27	18.2	8
14.5	26	18.3	8

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-05-1997 15:45:04
Watershed file: --> C:\QTR55\POND2 .MOP
Hydrograph file: --> C:\QTR55\POND2-25.HYD

TABULAR HYDROGRAPH
POND 2 - NORTHWEST FEMP
FEMP

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
18.6	7	22.4	4
18.7	7	22.5	4
18.8	7	22.6	4
18.9	7	22.7	4
19.0	7	22.8	4
19.1	7	22.9	4
19.2	7	23.0	4
19.3	7	23.1	4
19.4	7	23.2	4
19.5	6	23.3	3
19.6	6	23.4	3
19.7	6	23.5	3
19.8	6	23.6	3
19.9	6	23.7	3
20.0	6	23.8	3
20.1	6	23.9	3
20.2	6	24.0	2
20.3	6	24.1	2
20.4	6	24.2	2
20.5	6	24.3	2
20.6	6	24.4	2
20.7	6	24.5	2
20.8	6	24.6	2
20.9	6	24.7	2
21.0	6	24.8	2
21.1	5	24.9	1
21.2	5	25.0	1
21.3	5	25.1	1
21.4	5	25.2	1
21.5	5	25.3	1
21.6	5	25.4	1
21.7	5	25.5	1
21.8	5	25.6	0
21.9	5	25.7	0
22.0	5	25.8	0
22.1	5	25.9	0
22.2	5		
22.3	5		

Quick TR-55 Ver.5.46 S/N:
Executed: 16:44:51 06-05-1997

SCS RUNOFF CN NUMBER
POND 3 - SOUTHEAST FEMP
FEMP

RUNOFF CURVE NUMBER SUMMARY

Subarea Description	Area (acres)	CN (weighted)
SUBBASIN C	36.50	74
SUBBASIN E	7.20	74
SUBBASIN F	23.00	74
SUBBASIN H	37.30	74

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Quick TR-55 Ver.5.46   S/N:
Executed: 16:17:01   06-05-1997    c:\qtr55\POND3.TCT

                              TIME OF CONCENTRATION
                            POND 3 - SOUTHEAST FEMP
                                      FEMP

                       Tc COMPUTATIONS FOR: SUBBASIN C

 SHEET FLOW (Applicable to Tc only)
     Segment ID
     Surface description                     GRASS
     Manning's roughness coeff., n                 0.3000
     Flow length, L (total < or = 300)     ft     300.0
     Two-yr 24-hr rainfall, P2             in     2.900
     Land slope, s                        ft/ft   0.1480
                         0.8
           .007 * (n*L)
     T =   --------------                 hrs      0.32              =  0.32
             0.5     0.4
           P2     *   s

 SHALLOW CONCENTRATED FLOW
     Segment ID
     Surface (paved or unpaved)?                 Unpaved
     Flow length, L                        ft     190.0
     Watercourse slope, s                 ft/ft   0.1480

                            0.5
     Avg.V =   Csf *   (s)                 ft/s   6.2071
     where:    Unpaved Csf = 16.1345
               Paved   Csf = 20.3282

     T = L / (3600*V)                      hrs      0.01              =  0.01

 CHANNEL FLOW
     Segment ID
     Cross Sectional Flow Area, a        sq.ft    40.50
     Wetted perimeter, Pw                   ft    27.70
     Hydraulic radius, r = a/Pw             ft    1.462
     Channel slope, s                     ft/ft   0.0050
     Manning's roughness coeff., n                0.0340

                      2/3     1/2
          1.49   *   r    *   s
     V =  --------------------             ft/s   3.9919
                     n

     Flow length, L                        ft      3720

     T = L / (3600*V)                      hrs      0.26              =  0.26
:::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
                                           TOTAL TIME (hrs)          0.59
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Quick TR-55 Ver.5.46   S/N:
Executed: 16:17:01   06-05-1997    c:\qtr55\POND3.TCT

                         TIME OF CONCENTRATION
                       POND 3 - SOUTHEAST FEMP
                                FEMP

                Tc COMPUTATIONS FOR: SUBBASIN E

SHEET FLOW (Applicable to Tc only)
    Segment ID
    Surface description                         GRASS
    Manning's roughness coeff., n                     0.3000
    Flow length, L (total < or = 300)          ft     300.0
    Two-yr 24-hr rainfall, P2                  in     2.900
    Land slope, s                           ft/ft     0.0100
                       0.8
         .007 * (n*L)
    T = --------------                        hrs      0.95          =  0.95
            0.5    0.4
          P2   *  s

SHALLOW CONCENTRATED FLOW
    Segment ID
    Surface (paved or unpaved)?                      Unpaved
    Flow length, L                             ft      60.0
    Watercourse slope, s                    ft/ft     0.0100

                           0.5
    Avg.V =  Csf *  (s)                      ft/s     1.6135
    where:   Unpaved Csf = 16.1345
             Paved   Csf = 20.3282

    T = L / (3600*V)                          hrs      0.01          =  0.01


CHANNEL FLOW
    Segment ID
    Cross Sectional Flow Area, a           sq.ft      32.00
    Wetted perimeter, Pw                       ft      17.90
    Hydraulic radius, r = a/Pw                 ft      1.788
    Channel slope, s                        ft/ft     0.0050
    Manning's roughness coeff., n                     0.0340

                    2/3    1/2
         1.49  *  r    *  s
    V = --------------------                 ft/s     4.5645
                  n

    Flow length, L                             ft        980

    T = L / (3600*V)                          hrs      0.06          =  0.06

    ::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
                                          TOTAL TIME (hrs)           1.02
```

14.6	24	18.4	8
14.7	23	18.5	8

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-06-1997 10:03:14
Watershed file: --> C:\QTR55\POND3 .MOP
Hydrograph file: --> C:\QTR55\POND3-25.HYD

TABULAR HYDROGRAPH
POND 3 -SOUTHEAST FEMP
FEMP

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
18.6	8	22.4	4
18.7	8	22.5	4
18.8	7	22.6	4
18.9	7	22.7	4
19.0	7	22.8	4
19.1	7	22.9	4
19.2	7	23.0	4
19.3	6	23.1	4
19.4	6	23.2	4
19.5	6	23.3	3
19.6	6	23.4	3
19.7	6	23.5	3
19.8	5	23.6	3
19.9	5	23.7	3
20.0	5	23.8	3
20.1	5	23.9	3
20.2	5	24.0	2
20.3	5	24.1	2
20.4	5	24.2	2
20.5	5	24.3	2
20.6	5	24.4	2
20.7	5	24.5	2
20.8	5	24.6	2
20.9	5	24.7	2
21.0	5	24.8	2
21.1	5	24.9	1
21.2	5	25.0	1
21.3	5	25.1	1
21.4	5	25.2	1
21.5	5	25.3	1
21.6	5	25.4	1
21.7	5	25.5	1
21.8	5	25.6	0
21.9	5	25.7	0
22.0	5	25.8	0
22.1	5	25.9	0
22.2	5		
22.3	5		

Quick TR-55 Ver.5.46 S/N:
Executed: 16:17:01 06-05-1997 c:\qtr55\POND3.TCT

SUMMARY SHEET FOR Tc or Tt COMPUTATIONS
(Solved for Time using TR-55 Methods)

TIME OF CONCENTRATION
POND 3 - SOUTHEAST FEMP
FEMP

Subarea descr.	Tc or Tt	Time (hrs)
SUBBASIN C	Tc	0.59
SUBBASIN E	Tc	1.02
SUBBASIN F	Tc	1.00
SUBBASIN H	Tc	1.19

Quick TR-55 Ver.5.46 S/N:
Executed: 16:40:59 06-05-1997

SUMMARY SHEET FOR Tc or Tt COMPUTATIONS
(Solved for Time using Length/Velocity)

TRAVEL TIME COMPUTATION
POND 3 - SOUTHEAST FEMP
FEMP

Subarea descr.	Tc or Tt	Time (hrs)
SUBBASIN C	Tt	0.07
SUBBASIN E	Tt	0.24
SUBBASIN F	Tt	0.07
SUBBASIN H	Tt	0.00

Quick TR-55 Ver.5.46 S/N:
Executed: 16:40:59 06-05-1997

TRAVEL TIME COMPUTATION
POND 3 - SOUTHEAST FEMP
FEMP

Tc or Tt DATA
::

Subarea: SUBBASIN C DESCRIPTION	LENGTH (feet)	VELOCITY (ft/sec)	TIME minutes		TIME hours
CHANNEL THROUGH A CULVERT TO	1200	4.54	4.4	=	0.07
			minutes		hours
		TOTAL Tt --->	4.4	=	0.07

::::::::::::::::::::::::::::::::::::

Subarea: SUBBASIN E DESCRIPTION	LENGTH (feet)	VELOCITY (ft/sec)	TIME minutes		TIME ho
CHANNEL THROUGH SUBAREA F	2700	4.50	10.0	=	0.[illegible]
CHANNEL THROUGH CULVERT PIPE	1200	4.50	4.4	=	0.07
			minutes		hours
		TOTAL Tt --->	14.4	=	0.24

::::::::::::::::::::::::::::::::::::

Subarea: SUBBASIN F DESCRIPTION	LENGTH (feet)	VELOCITY (ft/sec)	TIME minutes		TIME hours
CHANNEL THROUGH CULVERT PIPE	1200	4.50	4.4	=	0.07
			minutes		hours
		TOTAL Tt --->	4.4	=	0.07

::::::::::::::::::::::::::::::::::::

'uick TR-55 Ver.5.46 S/N:
:ecuted: 16:40:59 06-05-1997

Subarea: SUBBASIN H DESCRIPTION	LENGTH (feet)	VELOCITY (ft/sec)	TIME minutes	TIME hours

	minutes		hours
TOTAL Tt --->	0.0	=	0.00

::::::::::::::::::::::::::::::::::::

Quick TR-55 Version: 5.46 S/N: **8091**

>>>>> GRAPHICAL PEAK DISCHARGE METHOD <<<<<

GRAPHICAL PEAK DISCHARGE
POND 3 - SOUTHEAST FEMP
FEMP

CALCULATED
DISK FILE: c:\qtr55\POND3 .GPD

Drainage Area	(acres)	104	--->	0.1625 sq.mi.
Runoff Curve Number	(CN)	74		
Time of Concentration,Tc	(hrs)	.66		
Rainfall Distribution	(Type)	II		
Pond and Swamp Areas	(%)	1	--->	1.0 acres

	Storm #1	Storm #2	Storm #3
Frequency (years)	25		
Rainfall, P, 24-hr (in)	4.7		
Initial Abstraction, Ia (in)	0.703	0.703	0.703
Ia/p Ratio	0.150	0.000	0.000
Unit Discharge, * qu (csm/in)	436	0	0
Runoff, Q (in)	2.13	0.00	0.00
Pond & Swamp Adjustment Factor	0.87	0.87	0.87
PEAK DISCHARGE, qp (cfs)	131	0	0

Summary of Computations for qu

Ia/p	#1	0.100	0.000	0.000
C0	#1	2.553	0.000	0.000
C1	#1	-0.615	0.000	0.000
C2	#1	-0.164	0.000	0.000
qu (csm)	#1	455.922	0.000	0.000
Ia/p	#2	0.300	0.000	0.000
C0	#2	2.465	0.000	0.000
C1	#2	-0.623	0.000	0.000
C2	#2	-0.117	0.000	0.000
qu (csm)	#2	374.861	0.000	0.000
* qu (csm)		436	0	0

* Interpolated for computed Ia/p ratio (between Ia/p #1 & Ia/p #2)
If computed Ia/p exceeds Ia/p limits, bounding limit for Ia/p is use

$$\log(qu) = C0 + (C1 * \log(Tc)) + (C2 * (\log(Tc))^2)$$

qp (cfs) = qu(csm) * Area(sq.mi.) * Q(in.) * (Pond & Swamp Adj.)

Quick TR-55 Version: 5.46 S/N:

>>>>> DETENTION STORAGE ESTIMATE <<<<<

DETENTION STORAGE ESTIMATE
POND 3 - SOUTHEAST FEMP
FEMP

CALCULATED
DISK FILE: c:\qtr55\POND3 .DET

Drainage Area	(acres)	104	0.1625 sq.mi.
Rainfall Distribution	(Type)	II	

	Storm #1	Storm #2	Storm #3
Frequency (years)	25		
Peak Inflow, qi (cfs)	~~130~~ 131		
Inflow Runoff, Q (in)	2.13		
Peak Outflow, qo (cfs)	0		
qo/qi Ratio	0.000	0.000	0.000
* Vs/Vr Ratio	0.682	0.000	0.000
Inflow Volume, Vr (ac-ft)	18.5	0.0	0.0
STORAGE VOLUME, Vs (ac-ft)	12.6	0.0	0.0

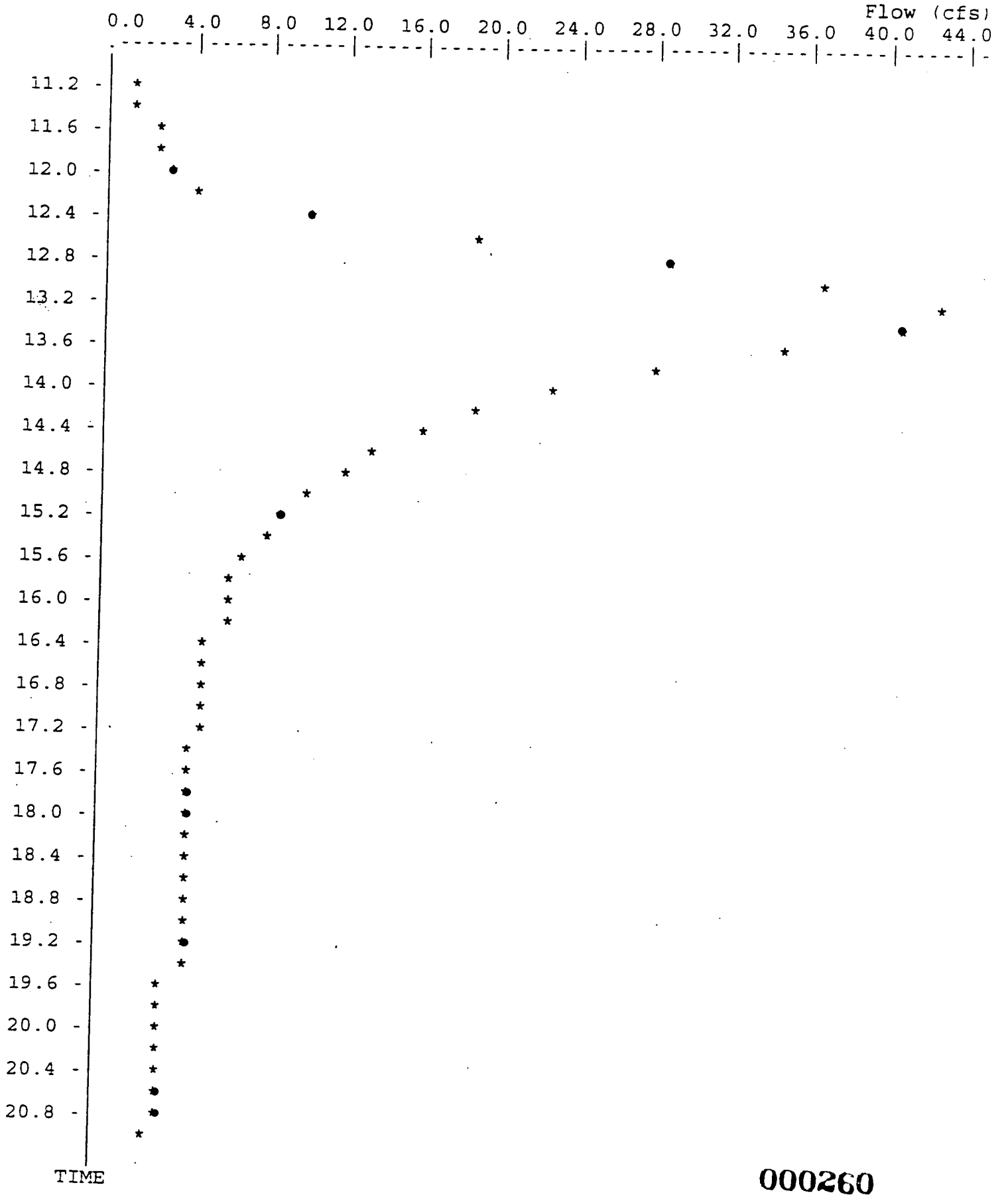
Summary of Volume Computations

C0	0.682	0.682	0.682
C1	-1.430	-1.430	-1.430
C2	1.640	1.640	1.640
C3	-0.804	-0.804	-0.804
* Vs/Vr	0.682	0.000	0.000

$$* \quad Vs/Vr = C0 + (C1*(qo/qi)) + (C2*(qo/qi)^2) + (C3*(qo/qi)^3)$$

Quick TR-55 Version: 5.46 S/N:
Plotted: 06-09-1997 16:59:27

8091



Quick TR-55 Version: 5.46 S/N:

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-09-1997 16:51:16
Watershed file: --> C:\QTR55\POND4 .MOP
Hydrograph file: --> C:\QTR55\POND4-25.HYD

TABULAR HYDROGRAPH
POND 4 - RETENTION POND
FEMP

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input	Ia/p used
SUBBASIN K	8.70	74.0	0.50	1.00	4.70	2.13	I.15	.15
SUBBASIN J	40.60	74.0	1.50	0.00	4.70	2.13	I.15	.15

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 49.30 acres or 0.07703 sq.mi
Peak discharge = 43 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
SUBBASIN K	0.62	0.86	0.50	1.00	Yes	--
SUBBASIN J	1.58	0.00	1.50	0.00	Yes	--

* Travel time from subarea outfall to composite watershed outfall point.

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-09-1997 16:51:16
Watershed file: --> C:\QTR55\POND4 .MOP
Hydrograph file: --> C:\QTR55\POND4-25.HYD

TABULAR HYDROGRAPH
POND 4 - RETENTION POND
FEMP

>>>> Summary of Subarea Times to Peak <<<<

Subarea	Peak Discharge at Composite Outfall (cfs)	Time to Peak at Composite Outfall (hrs)
SUBBASIN K	10	13.4
SUBBASIN J	35	13.2
Composite Watershed	43	13.2

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-09-1997 16:51:16
Watershed file: --> C:\QTR55\POND4 .MOP
Hydrograph file: --> C:\QTR55\POND4-25.HYD

TABULAR HYDROGRAPH
POND 4 - RETENTION POND
FEMP

Composite Hydrograph Summary (cfs)

Subarea Description	11.0 hr	11.3 hr	11.6 hr	11.9 hr	12.0 hr	12.1 hr	12.2 hr	12.3 hr	12.4 hr
SUBBASIN K	0	0	0	0	0	0	0	1	1
SUBBASIN J	1	1	2	2	3	3	4	6	9
Total (cfs)	1	1	2	2	3	3	4	7	10

Subarea Description	12.5 hr	12.6 hr	12.7 hr	12.8 hr	13.0 hr	13.2 hr	13.4 hr	13.6 hr	13.8 hr
SUBBASIN K	1	1	1	2	5	8	10	9	7
SUBBASIN J	13	18	22	27	32	35	31	26	21
Total (cfs)	14	19	23	29	37	43	41	35	28

Subarea Description	14.0 hr	14.3 hr	14.6 hr	15.0 hr	15.5 hr	16.0 hr	16.5 hr	17.0 hr	17.5 hr
SUBBASIN K	5	3	2	2	1	1	1	1	1
SUBBASIN J	18	14	11	8	6	5	4	4	3
Total (cfs)	23	17	13	10	7	6	5	5	4

Subarea Description	18.0 hr	19.0 hr	20.0 hr	22.0 hr	26.0 hr
SUBBASIN K	1	1	1	0	0
SUBBASIN J	3	3	2	2	0

Total (cfs)	4	4	3	2	0

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-09-1997 16:51:16
Watershed file: --> C:\QTR55\POND4 .MOP
Hydrograph file: --> C:\QTR55\POND4-25.HYD

TABULAR HYDROGRAPH
POND 4 - RETENTION POND
FEMP

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
11.0	1	14.8	12
11.1	1	14.9	11
11.2	1	15.0	10
11.3	1	15.1	9
11.4	1	15.2	9
11.5	2	15.3	8
11.6	2	15.4	8
11.7	2	15.5	7
11.8	2	15.6	7
11.9	2	15.7	7
12.0	3	15.8	6
12.1	3	15.9	6
12.2	4	16.0	6
12.3	7	16.1	6
12.4	10	16.2	6
12.5	14	16.3	5
12.6	19	16.4	5
12.7	23	16.5	5
12.8	29	16.6	5
12.9	33	16.7	5
13.0	37	16.8	5
13.1	40	16.9	5
13.2	43	17.0	5
13.3	42	17.1	5
13.4	41	17.2	5
13.5	38	17.3	4
13.6	35	17.4	4
13.7	32	17.5	4
13.8	28	17.6	4
13.9	26	17.7	4
14.0	23	17.8	4
14.1	21	17.9	4
14.2	19	18.0	4
14.3	17	18.1	4
14.4	16	18.2	4
14.5	14	18.3	4

14.6	13	18.4	4
14.7	12	18.5	4

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 06-09-1997 16:51:16
Watershed file: --> C:\QTR55\POND4 .MOP
Hydrograph file: --> C:\QTR55\POND4-25.HYD

TABULAR HYDROGRAPH
POND 4 - RETENTION POND
FEMP

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
18.6	4	22.4	2
18.7	4	22.5	2
18.8	4	22.6	2
18.9	4	22.7	2
19.0	4	22.8	2
19.1	4	22.9	2
19.2	4	23.0	2
19.3	4	23.1	1
19.4	4	23.2	1
19.5	4	23.3	1
19.6	3	23.4	1
19.7	3	23.5	1
19.8	3	23.6	1
19.9	3	23.7	1
20.0	3	23.8	1
20.1	3	23.9	1
20.2	3	24.0	1
20.3	3	24.1	1
20.4	3	24.2	1
20.5	3	24.3	1
20.6	3	24.4	1
20.7	3	24.5	1
20.8	3	24.6	1
20.9	3	24.7	1
21.0	2	24.8	1
21.1	2	24.9	1
21.2	2	25.0	0
21.3	2	25.1	0
21.4	2	25.2	0
21.5	2	25.3	0
21.6	2	25.4	0
21.7	2	25.5	0
21.8	2	25.6	0
21.9	2	25.7	0
22.0	2	25.8	0
22.1	2	25.9	0
22.2	2		
22.3	2		

Quick TR-55 Ver.5.46 S/N:
Executed: 16:32:57 06-09-1997

SCS RUNOFF CURVE NUMBER
POND 4 - RETENTION POND
FEMP

RUNOFF CURVE NUMBER SUMMARY

Subarea Description	Area (acres)	CN (weighted)
K	8.70	74
SUBBASIN J	40.60	74

Quick TR-55 Ver.5.46 S/N:
Executed: 16:32:57 06-09-1997

SCS RUNOFF CURVE NUMBER
POND 4 - RETENTION POND
FEMP

RUNOFF CURVE NUMBER DATA

::

Composite Area: K

SURFACE DESCRIPTION	AREA (acres)	CN	
GRASS	8.70	74	
COMPOSITE AREA --->	8.70	74.0	(74)

::

Composite Area: SUBBASIN J

SURFACE DESCRIPTION	AREA (acres)	CN	
GRASS	40.60	74	
COMPOSITE AREA --->	40.60	74.0	(74)

::

Quick TR-55 Ver.5.46 S/N:
Executed: 16:23:41 06-09-1997 c:\qtr55\POND4.TCT

SUMMARY SHEET FOR Tc or Tt COMPUTATIONS
(Solved for Time using TR-55 Methods)

POND 4 - RETENTION POND
TIME OF CONCENTRATION
FEMP

Subarea descr.	Tc or Tt	Time (hrs)
SUBBASIN K	Tc	0.62
SUBBASIN J	Tc	1.58

Quick TR-55 Ver.5.46 S/N:
Executed: 16:23:41 06-09-1997 c:\qtr55\POND4.TCT

POND 4 - RETENTION POND
TIME OF CONCENTRATION
FEMP

Tc COMPUTATIONS FOR: SUBBASIN K

SHEET FLOW (Applicable to Tc only)

Segment ID			
Surface description		GRASS	
Manning's roughness coeff., n		0.3000	
Flow length, L (total < or = 300)	ft	580.0	
Two-yr 24-hr rainfall, P2	in	2.900	
Land slope, s	ft/ft	0.1480	
$T = \frac{.007 \bullet (n*L)^{0.8}}{P2^{0.5} \bullet s^{0.4}}$	hrs	0.55	= 0.55

SHALLOW CONCENTRATED FLOW

Segment ID			
Surface (paved or unpaved)?			
Flow length, L	ft	0.0	
Watercourse slope, s	ft/ft	0.0000	
$Avg.V = Csf * (s)^{0.5}$	ft/s	0.0000	
where: Unpaved Csf = 16.1345			
Paved Csf = 20.3282			
T = L / (3600*V)	hrs	0.00	= 0.00

CHANNEL FLOW

Segment ID			
Cross Sectional Flow Area, a	sq.ft	16.00	
Wetted perimeter, Pw	ft	11.30	
Hydraulic radius, r = a/Pw	ft	1.416	
Channel slope, s	ft/ft	0.0050	
Manning's roughness coeff., n		0.0340	
$V = \frac{1.49 \bullet r^{2/3} * s^{1/2}}{n}$	ft/s	3.9074	
Flow length, L	ft	1020	
T = L / (3600*V)	hrs	0.07	= 0.07

::

TOTAL TIME (hrs) 0.62

Quick TR-55 Ver.5.46 S/N:
Executed: 16:23:41 06-09-1997 c:\qtr55\POND4.TCT

POND 4 - RETENTION POND
TIME OF CONCENTRATION
FEMP

Tc COMPUTATIONS FOR: SUBBASIN J

SHEET FLOW (Applicable to Tc only)

Segment ID			
Surface description		GRASS	
Manning's roughness coeff., n		0.3000	
Flow length, L (total < or = 300)	ft	300.0	
Two-yr 24-hr rainfall, P2	in	2.900	
Land slope, s	ft/ft	0.0050	
$T = \frac{.007 \cdot (n*L)^{0.8}}{P2^{0.5} * s^{0.4}}$	hrs	1.25	= 1.25

SHALLOW CONCENTRATED FLOW

Segment ID			
Surface (paved or unpaved)?		Unpaved	
Flow length, L	ft	600.0	
Watercourse slope, s	ft/ft	0.0010	
$Avg.V = Csf * (s)^{0.5}$	ft/s	0.5102	
where: Unpaved Csf = 16.1345			
Paved Csf = 20.3282			
T = L / (3600*V)	hrs	0.33	= 0.33

CHANNEL FLOW

Segment ID			
Cross Sectional Flow Area, a	sq.ft	0.00	
Wetted perimeter, Pw	ft	0.00	
Hydraulic radius, r = a/Pw	ft	0.000	
Channel slope, s	ft/ft	0.0000	
Manning's roughness coeff., n		0.0000	
$V = \frac{1.49 * r^{2/3} \cdot s^{1/2}}{n}$	ft/s	0.0000	
Flow length, L	ft	0	
T = L / (3600*V)	hrs	0.00	= 0.0

::

TOTAL TIME (hrs) 1.58

Quick TR-55 Ver.5.46 S/N:
Executed: 16:30:29 06-09-1997

SUMMARY SHEET FOR Tc or Tt COMPUTATIONS
(Solved for Time using Length/Velocity)

POND 4 - RETENTION POND
TRAVEL TIME
FEMP

Subarea descr.	Tc or Tt	Time (hrs)
K	Tt	0.86
SUBBASIN J	Tt	0.00

Quick TR-55 Ver.5.46 S/N:
Executed: 16:30:29 06-09-1997

POND 4 - RETENTION POND
TRAVEL TIME
FEMP

Tc or Tt DATA
::

Subarea: K DESCRIPTION	LENGTH (feet)	VELOCITY (ft/sec)	TIME minutes		hours
CHANNEL THROUGH SUBAREA J	1580	0.51	51.6	=	0.86

	minutes		hours
TOTAL Tt --->	51.6	=	0.86

::::::::::::::::::::::::::::::::::::

Subarea: SUBBASIN J DESCRIPTION	LENGTH (feet)	VELOCITY (ft/sec)	TIME minutes		hours
OUTFALL AT RETENTION POND	0	0.00	0.0	=	0.

	minutes		hours
TOTAL Tt --->	0.0	=	0.00

::::::::::::::::::::::::::::::::::::

Quick TR-55 Version: 5.46 S/N:

8091

>>>>> GRAPHICAL PEAK DISCHARGE METHOD <<<<<

GRAPHICAL PEAK DISCHATGE
POND 4 -RETEMTION POND
FEMP

CALCULATED
DISK FILE: c:\qtr55\POND4 .GPD

Drainage Area	(acres)	49.3	--->	0.0770 sq.mi.
Runoff Curve Number	(CN)	74		
Time of Concentration,Tc	(hrs)	1.48		
Rainfall Distribution	(Type)	II		
Pond and Swamp Areas	(%)	1	--->	0.5 acres

	Storm #1	Storm #2	Storm #3
Frequency (years)	25		
Rainfall, P, 24-hr (in)	4.7		
Initial Abstraction, Ia (in)	0.703	0.703	0.703
Ia/p Ratio	0.150	0.000	0.000
Unit Discharge, * qu (csm/in)	265	0	0
Runoff, Q (in)	2.13	0.00	0.00
Pond & Swamp Adjustment Factor	0.87	0.87	0.87
PEAK DISCHARGE, qp (cfs)	38	0	0

Summary of Computations for qu

Ia/p	#1	0.100	0.000	0.000
C0	#1	2.553	0.000	0.000
C1	#1	-0.615	0.000	0.000
C2	#1	-0.164	0.000	0.000
qu (csm)	#1	277.807	0.000	0.000
Ia/p	#2	0.300	0.000	0.000
C0	#2	2.465	0.000	0.000
C1	#2	-0.623	0.000	0.000
C2	#2	-0.117	0.000	0.000
qu (csm)	#2	226.956	0.000	0.000
* qu (csm)		265	0	0

* Interpolated for computed Ia/p ratio (between Ia/p #1 & Ia/p #2)
If computed Ia/p exceeds Ia/p limits, bounding limit for Ia/p is used.

$$\log(qu) = C0 + (C1 * \log(Tc)) + (C2 * (\log(Tc))^2)$$

qp (cfs) = qu(csm) * Area(sq.mi.) * Q(in.) * (Pond & Swamp Adj.)

Quick TR-55 Version: 5.46 S/N:

>>>>> DETENTION STORAGE ESTIMATE <<<<<

DETENTION STORAGE ESTIMATE
POND 4 - RETENTION POND
FEMP

CALCULATED
DISK FILE: c:\qtr55\POND4 .DET

Drainage Area	(acres)	49.3	0.0770 sq.mi.
Rainfall Distribution	(Type)	II	

	Storm #1	Storm #2	Storm #3
Frequency (years)	25		
Peak Inflow, qi (cfs)	4.7		
Inflow Runoff, Q (in)	2.13		
Peak Outflow, qo (cfs)	0		
qo/qi Ratio	0.000	0.000	0.000
* Vs/Vr Ratio	0.682	0.000	0.000
Inflow Volume, Vr (ac-ft)	8.8	0.0	0.0
STORAGE VOLUME, Vs (ac-ft)	6.0	0.0	0.0

Summary of Volume Computations

C0	0.682	0.682	0.682
C1	-1.430	-1.430	-1.430
C2	1.640	1.640	1.640
C3	-0.804	-0.804	-0.804
* Vs/Vr	0.682	0.000	0.000

$$* \quad Vs/Vr = C0 + (C1*(qo/qi)) + (C2*(qo/qi)^2) + (C3*(qo/qi)^3)$$

APPENDIX C

ROUTING CALCULATIONS UNDER NORMAL CONDITIONS

BROWN & ROOT ENVIRONMENTAL

Table C-1
POND ROUTING UNDER NORMAL CONDITIONS
POND 1 (NORTHEAST OF FEMP)

Hydraulic Conductivity of Pond Liner (cm/sec) = 7.23E-07
Thickness of Pond Liner (f 3
Pond Bottom Elev (ft) = 555
Drainage Area (ft^2) 5,550,300

Pond 1 Overflow El = 573

Pond overflow at storage (ft^3): 4445400

POND 1

Year	Month	Rainfall Depth (inch)	Rainfall Vol. Into Pond (ft³)	Runoff Depth (inch)	Runoff Vol. Into Pond (ft³)	Total Inflow I (ft³)	Pond Elevation (ft)	Pond Area (ft^2)	GW Elev. (ft)	Pond Storage S (ft³)	Infiltration Rate (ft)	Total Infiltration (ft³)	Monthly Evapo. (inch)	Total Evapo. (ft³)	Pond Overflow (ft³)/day	Total Out flow O (ft³)
1	1	3.66	1.46E+05	1.242	5.74E+05	7.20E+05	571.38	4.78E+05	520	3.60E+06	3.36E-01	1.61E+05	0.527	2.10E+04	0.00E+00	1.82E+05
1	2	2.98	1.29E+05	2.125	9.83E+05	1.11E+06	572.41	5.18E+05	520	4.14E+06	3.57E-01	1.85E+05	1.620	6.99E+04	0.00E+00	2.55E+05
1	3	3.67	1.65E+05	0.945	4.37E+05	6.02E+05	573.00	5.41E+05	520	4.45E+06	3.69E-01	1.99E+05	2.673	1.20E+05	1.83E+04	6.70E+05
1	4	3.55	1.54E+05	0.053	2.45E+04	1.79E+05	572.49	5.21E+05	520	4.16E+06	3.58E-01	1.87E+05	4.437	1.93E+05	0.00E+00	3.79E+05
1	5	3.78	1.59E+05	0.121	5.60E+04	2.15E+05	572.10	5.06E+05	520	3.98E+06	3.51E-01	1.77E+05	5.076	2.14E+05	0.00E+00	3.91E+05
1	6	3.59	1.48E+05	0.191	8.83E+04	2.36E+05	571.76	4.93E+05	520	3.80E+06	3.44E-01	1.69E+05	6.098	2.51E+05	0.00E+00	4.20E+05
1	7	4.09	1.63E+05	0.473	2.19E+05	3.82E+05	571.41	4.80E+05	520	3.62E+06	3.36E-01	1.61E+05	5.905	2.36E+05	0.00E+00	3.97E+05
1	8	2.8	1.12E+05	0.125	5.78E+04	1.69E+05	571.38	4.79E+05	520	3.60E+06	3.36E-01	1.61E+05	5.039	2.01E+05	0.00E+00	3.62E+05
1	9	2.59	1.00E+05	0.087	4.02E+04	1.40E+05	571.01	4.64E+05	520	3.41E+06	3.28E-01	1.52E+05	4.036	1.56E+05	0.00E+00	3.09E+05
1	10	2.11	7.95E+04	0.016	7.40E+03	8.69E+04	570.69	4.52E+05	520	3.24E+06	3.22E-01	1.45E+05	2.593	9.77E+04	0.00E+00	2.43E+05
1	11	3.01	1.10E+05	0.057	2.64E+04	1.37E+05	570.39	4.41E+05	520	3.09E+06	3.15E-01	1.39E+05	1.558	5.72E+04	0.00E+00	1.96E+05
1	12	2.86	1.04E+05	0.187	8.65E+04	1.90E+05	570.28	4.36E+05	520	3.03E+06	3.13E-01	1.37E+05	0.494	1.80E+04	0.00E+00	1.55E+05
2	13	3.66	1.34E+05	1.242	5.74E+05	7.08E+05	570.35	4.39E+05	520	3.06E+06	3.15E-01	1.38E+05	0.527	1.93E+04	0.00E+00	1.57E+05
2	14	2.98	1.19E+05	2.125	9.83E+05	1.10E+06	571.40	4.79E+05	520	3.61E+06	3.36E-01	1.61E+05	1.620	6.47E+04	0.00E+00	2.26E+05
2	15	3.67	1.65E+05	0.945	4.37E+05	6.02E+05	573.00	5.41E+05	520	4.45E+06	3.69E-01	1.99E+05	2.673	1.20E+05	1.46E+03	3.64E+05
2	16	3.55	1.60E+05	0.053	2.45E+04	1.84E+05	573.00	5.41E+05	520	4.45E+06	3.69E-01	1.99E+05	4.437	2.00E+05	7.96E+03	6.36E+05
2	17	3.78	1.60E+05	0.121	5.60E+04	2.16E+05	572.13	5.07E+05	520	3.99E+06	3.51E-01	1.76E+05	5.076	2.15E+05	0.00E+00	3.93E+05
2	18	3.59	1.48E+05	0.191	8.83E+04	2.36E+05	571.79	4.94E+05	520	3.81E+06	3.44E-01	1.70E+05	6.098	2.51E+05	0.00E+00	4.21E+05
2	19	4.09	1.64E+05	0.473	2.19E+05	3.83E+05	571.44	4.81E+05	520	3.63E+06	3.37E-01	1.62E+05	5.905	2.36E+05	0.00E+00	3.98E+05
2	20	2.8	1.12E+05	0.125	5.78E+04	1.70E+05	571.41	4.79E+05	520	3.61E+06	3.36E-01	1.61E+05	5.039	2.01E+05	0.00E+00	3.62E+05
2	21	2.59	1.00E+05	0.087	4.02E+04	1.41E+05	571.04	4.65E+05	520	3.42E+06	3.29E-01	1.53E+05	4.036	1.56E+05	0.00E+00	3.09E+05
2	22	2.11	7.96E+04	0.016	7.40E+03	8.70E+04	570.71	4.53E+05	520	3.25E+06	3.22E-01	1.46E+05	2.593	9.79E+04	0.00E+00	2.44E+05
2	23	3.01	1.11E+05	0.057	2.64E+04	1.37E+05	570.41	4.41E+05	520	3.10E+06	3.16E-01	1.39E+05	1.558	5.73E+04	0.00E+00	1.97E+05
2	24	2.86	1.04E+05	0.187	8.65E+04	1.91E+05	570.30	4.37E+05	520	3.04E+06	3.14E-01	1.37E+05	0.494	1.80E+04	0.00E+00	1.55E+05
3	25	3.66	1.34E+05	1.242	5.74E+05	7.09E+05	570.37	4.40E+05	520	3.07E+06	3.15E-01	1.38E+05	0.527	1.93E+04	0.00E+00	1.58E+05
3	26	2.98	1.19E+05	2.125	9.83E+05	1.10E+06	571.42	4.80E+05	520	3.62E+06	3.37E-01	1.62E+05	1.620	6.48E+04	0.00E+00	2.26E+05

POND 1

Year	Month	Rainfall Depth (inch)	Rainfall Vol. into Pond (ft³)	Runoff Depth (inch)	Runoff Vol. into Pond (ft³)	Total Inflow I (ft³)	Pond Elevation (ft)	Pond Area (ft^2)	GW Elev. (ft)	Pond Storage S (ft³)	Infiltration Rate (ft)	Total Infiltration (ft³)	Monthly Evapo. (inch)	Total Evapo. (ft³)	Pond Overflow (ft³)/day	Total Out flow O (ft³)
3	27	3.67	1.65E+05	0.945	4.37E+05	6.02E+05	573.00	5.41E+05	520	4.45E+06	3.69E-01	1.99E+05	2.673	1.20E+05	1.77E+03	3.73E+05
3	28	3.55	1.60E+05	0.053	2.45E+04	1.84E+05	573.00	5.41E+05	520	4.45E+06	3.69E-01	1.99E+05	4.437	2.00E+05	7.65E+03	6.29E+05
3	29	3.78	1.60E+05	0.121	5.60E+04	2.16E+05	572.15	5.06E+05	520	4.00E+06	3.51E-01	1.78E+05	5.076	2.15E+05	0.00E+00	3.93E+05
3	30	3.59	1.48E+05	0.191	8.83E+04	2.36E+05	571.81	4.95E+05	520	3.82E+06	3.44E-01	1.70E+05	6.098	2.51E+05	0.00E+00	4.22E+05
3	31	4.09	1.64E+05	0.473	2.19E+05	3.83E+05	571.45	4.81E+05	520	3.64E+06	3.37E-01	1.62E+05	5.905	2.37E+05	0.00E+00	3.99E+05
3	32	2.8	1.12E+05	0.125	5.78E+04	1.70E+05	571.42	4.80E+05	520	3.62E+06	3.37E-01	1.62E+05	5.039	2.02E+05	0.00E+00	3.63E+05
3	33	2.59	1.01E+05	0.087	4.02E+04	1.41E+05	571.05	4.66E+05	520	3.43E+06	3.29E-01	1.53E+05	4.036	1.57E+05	0.00E+00	3.10E+05
3	34	2.11	7.97E+04	0.018	7.40E+03	8.71E+04	570.73	4.53E+05	520	3.26E+06	3.22E-01	1.46E+05	2.593	9.80E+04	0.00E+00	2.44E+05
3	35	3.01	1.11E+05	0.057	2.84E+04	1.37E+05	570.42	4.42E+05	520	3.10E+06	3.16E-01	1.40E+05	1.558	5.73E+04	0.00E+00	1.97E+05
3	36	2.86	1.04E+05	0.187	8.65E+04	1.91E+05	570.31	4.37E+05	520	3.04E+06	3.14E-01	1.37E+05	0.494	1.80E+04	0.00E+00	1.55E+05
4	37	3.68	1.34E+05	1.242	5.74E+05	7.09E+05	570.38	4.40E+05	520	3.08E+06	3.15E-01	1.39E+05	0.527	1.93E+04	0.00E+00	1.58E+05
4	38	2.98	1.19E+05	2.125	9.83E+05	1.10E+06	571.43	4.81E+05	520	3.63E+06	3.37E-01	1.62E+05	1.620	6.49E+04	0.00E+00	2.27E+05
4	39	3.67	1.65E+05	0.945	4.37E+05	6.02E+05	573.00	5.41E+05	520	4.45E+06	3.69E-01	1.99E+05	2.673	1.20E+05	1.96E+03	3.79E+05
4	40	3.55	1.60E+05	0.053	2.45E+04	1.84E+05	573.00	5.41E+05	520	4.45E+06	3.69E-01	1.99E+05	4.437	2.00E+05	7.46E+03	6.23E+05
4	41	3.78	1.60E+05	0.121	5.60E+04	2.16E+05	572.16	5.08E+05	520	4.01E+06	3.52E-01	1.79E+05	5.076	2.15E+05	0.00E+00	3.94E+05
4	42	3.59	1.48E+05	0.191	8.83E+04	2.37E+05	571.82	4.95E+05	520	3.83E+06	3.45E-01	1.71E+05	6.098	2.52E+05	0.00E+00	4.22E+05
4	43	4.09	1.64E+05	0.473	2.19E+05	3.83E+05	571.46	4.82E+05	520	3.64E+06	3.37E-01	1.62E+05	5.905	2.37E+05	0.00E+00	3.99E+05
4	44	2.8	1.12E+05	0.125	5.78E+04	1.70E+05	571.43	4.80E+05	520	3.63E+06	3.37E-01	1.62E+05	5.039	2.02E+05	0.00E+00	3.63E+05
4	45	2.59	1.01E+05	0.087	4.02E+04	1.41E+05	571.06	4.66E+05	520	3.43E+06	3.29E-01	1.53E+05	4.036	1.57E+05	0.00E+00	3.10E+05
4	46	2.11	7.98E+04	0.018	7.40E+03	8.72E+04	570.73	4.54E+05	520	3.26E+06	3.22E-01	1.46E+05	2.593	9.80E+04	0.00E+00	2.44E+05
4	47	3.01	1.11E+05	0.057	2.84E+04	1.37E+05	570.43	4.42E+05	520	3.11E+06	3.16E-01	1.40E+05	1.558	5.74E+04	0.00E+00	1.97E+05
4	48	2.86	1.04E+05	0.187	8.65E+04	1.91E+05	570.32	4.38E+05	520	3.05E+06	3.14E-01	1.37E+05	0.494	1.80E+04	0.00E+00	1.55E+05

Table C-2
POND ROUTING
POND 2 (SOUTH OF PADR) - FEMP

BROWN & ROOT ENVIRONMENTAL

8091

Hydraulic Conductivity of Pond Liner (cm/sec) = 7 23E-07
Thickness of Pond Liner (ft = 3
Pond Bottom Elev (ft) = 550
Drainage Area (ft^2) 4753800

Pond 2 Overflow El = 573

Pond overflow at storage (ft^3) 10669000

POND 2

Year	Month	Rainfall Depth (inch)	Rainfall Vol. Into Pond (ft³)	Runoff Depth (inch)	Runoff Into Pond (ft³)	Total Inflow I (ft³)	Pond Elevation (ft)	Pond Area (ft^2)	GW Elev. (ft)	Pond Storage S (ft³)	Infiltration Rate (ft)	Total Infiltration (ft³)	Monthly Evapo. (inch)	Total Evapo. (ft³)	Pond Overflow (ft³)/day	Total Out flow O (ft³)
1	1	3 66	1.65E+05	1.242	4.92E+05	6.57E+05	564.11	5.41E+05	520	4.70E+06	2.89E-01	1.56E+05	0 527	2 37E+04	0 00E+00	1.80E+05
1	2	2 98	1 39E+05	2.125	8 42E+05	9 81E+05	565 04	5.60E+05	520	5.18E+06	3.08E-01	1.73E+05	1 620	7 56E+04	0 00E+00	2 48E+05
1	3	3 67	1 78E+05	0 945	3 74E+05	5 53E+05	566 25	5 83E+05	520	5 91E+06	3 33E-01	1 94E+05	2 673	1 30E+05	0 00E+00	3 24E+05
1	4	3 55	1 75E+05	0 053	2 10E+04	1.96E+05	566.63	5 90E+05	520	6.14E+06	3.41E-01	2 01E+05	4 437	2 18E+05	0 00E+00	4 19E+05
1	5	3 78	1 84E+05	0 121	4 79E+04	2.32E+05	566.26	5.83E+05	520	5.91E+06	3.33E-01	1.94E+05	5 076	2 47E+05	0 00E+00	4.41E+05
1	6	3 59	1 73E+05	0 191	7 57E+04	2 48E+05	565 91	5.77E+05	520	5.71E+06	3.26E-01	1.88E+05	6 098	2 93E+05	0.00E+00	4 81E+05
1	7	4 09	1 94E+05	0 473	1.87E+05	3.81E+05	565.53	5.69E+05	520	5.47E+06	3.18E-01	1.81E+05	5 905	2.80E+05	0 00E+00	4 61E+05
1	8	2 8	1 32E+05	0 125	4 95E+04	1.82E+05	565.40	5.67E+05	520	5.39E+06	3.16E-01	1.79E+05	5.039	2 38E+05	0 00E+00	4.17E+05
1	9	2 59	1 21E+05	0 087	3 45E+04	1.55E+05	565.01	5.60E+05	520	5.16E+06	3.08E-01	1.72E+05	4.036	1 88E+05	0 00E+00	3 60E+05
1	10	2 11	9 69E+04	0 016	6 34E+03	1 03E+05	564.61	5.51E+05	520	4.95E+06	2.99E-01	1.65E+05	2.593	1 19E+05	0 00E+00	2 84E+05
1	11	3 01	1 36E+05	0 057	2 26E+04	1 59E+05	564.25	5.44E+05	520	4.77E+06	2.92E-01	1.59E+05	1 558	7 06E+04	0 00E+00	2 29E+05
1	12	2 86	1 29E+05	0 187	7 41E+04	2 03E+05	564.11	5.41E+05	520	4.70E+06	2.89E-01	1.57E+05	0 494	2 23E+04	0 00E+00	1 79E+05
2	13	3 66	1 65E+05	1.242	4 92E+05	6 57E+05	564.16	5.42E+05	520	4.72E+06	2.90E-01	1 57E+05	0.527	2.38E+04	0 00E+00	1 81E+05
2	14	2 98	1 39E+05	2 125	8 42E+05	9 81E+05	565.08	5.61E+05	520	5.20E+06	3.09E-01	1 73E+05	1 620	7 57E+04	0 00E+00	2 49E+05
2	15	3 67	1.79E+05	0.945	3.74E+05	5 53E+05	566.29	5.84E+05	520	5.93E+06	3.34E-01	1.95E+05	2 673	1.30E+05	0 00E+00	3 25E+05
2	16	3 55	1 75E+05	0 053	2.10E+04	1.96E+05	566.66	5.91E+05	520	6.16E+06	3.42E-01	2 02E+05	4 437	2 18E+05	0.00E+00	4 20E+05
2	17	3 78	1 84E+05	0 121	4 79E+04	2 32E+05	566.29	5 84E+05	520	5.94E+06	3.34E-01	1 95E+05	5 076	2 47E+05	0 00E+00	4 42E+05
2	18	3 59	1 73E+05	0 191	7.57E+04	2 48E+05	565.95	5 77E+05	520	5.73E+06	3.27E-01	1 89E+05	6 098	2 93E+05	0 00E+00	4 82E+05
2	19	4 09	1 94E+05	0 473	1 87E+05	3 82E+05	565.56	5.70E+05	520	5.49E+06	3.19E-01	1.82E+05	5 905	2 80E+05	0 00E+00	4 62E+05
2	20	2 8	1 32E+05	0 125	4 95E+04	1 82E+05	565.43	5.68E+05	520	5.41E+06	3.16E-01	1.79E+05	5 039	2.38E+05	0 00E+00	4.18E+05
2	21	2 59	1 21E+05	0.087	3.45E+04	1 55E+05	565.04	5.60E+05	520	5.18E+06	3.08E-01	1.73E+05	4 036	1 88E+05	0 00E+00	3 61E+05
2	22	2 11	9.71E+04	0.016	6.34E+03	1 03E+05	564.64	5.52E+05	520	4.97E+06	3.00E-01	1 66E+05	2 593	1 19E+05	0 00E+00	2 85E+05
2	23	3 01	1 37E+05	0 057	2 26E+04	1 59E+05	564 29	5.45E+05	520	4 79E+06	2.93E-01	1 59E+05	1 558	7 07E+04	0 00E+00	2 30E+05

000280

POND 2

Year	Month	Rainfall Depth (inch)	Rainfall Vol. Into Pond (ft³)	Runoff Depth (inch)	Runoff Into Pond (ft³)	Total Inflow I (ft³)	Pond Elevation (ft)	Pond Area (ft^2)	GW Elev. (ft)	Pond Storage S (ft³)	Infiltration Rate (ft)	Total Infiltration (ft³)	Monthly Evapo. (inch)	Total Evapo. (ft³)	Pond Overflow (ft³)/day	Total Out flow O (ft³)
2	24	2.86	1.29E+05	0.187	7.41E+04	2.03E+05	564.15	5.42E+05	520	4.72E+06	2.90E-01	1.57E+05	0.494	2.23E+04	0.00E+00	1.79E+05
3	25	3.66	1.66E+05	1.242	4.92E+05	6.58E+05	564.19	5.43E+05	520	4.74E+06	2.91E-01	1.58E+05	0.527	2.38E+04	0.00E+00	1.82E+05
3	26	2.98	1.39E+05	2.125	8.42E+05	9.81E+05	565.11	5.61E+05	520	5.22E+06	3.10E-01	1.74E+05	1.620	7.58E+04	0.00E+00	2.50E+05
3	27	3.67	1.79E+05	0.945	3.74E+05	5.53E+05	566.32	5.84E+05	520	5.95E+06	3.34E-01	1.95E+05	2.673	1.30E+05	0.00E+00	3.25E+05
3	28	3.55	1.75E+05	0.053	2.10E+04	1.96E+05	566.69	5.91E+05	520	6.18E+06	3.42E-01	2.02E+05	4.437	2.19E+05	0.00E+00	4.21E+05
3	29	3.78	1.84E+05	0.121	4.79E+04	2.32E+05	566.32	5.84E+05	520	5.95E+06	3.34E-01	1.95E+05	5.076	2.47E+05	0.00E+00	4.43E+05
3	30	3.59	1.73E+05	0.191	7.57E+04	2.49E+05	565.97	5.78E+05	520	5.74E+06	3.27E-01	1.89E+05	6.098	2.94E+05	0.00E+00	4.83E+05
3	31	4.09	1.94E+05	0.473	1.87E+05	3.82E+05	565.59	5.70E+05	520	5.51E+06	3.19E-01	1.82E+05	5.905	2.81E+05	0.00E+00	4.63E+05
3	32	2.8	1.33E+05	0.125	4.95E+04	1.82E+05	565.45	5.68E+05	520	5.43E+06	3.17E-01	1.80E+05	5.039	2.38E+05	0.00E+00	4.18E+05
3	33	2.59	1.21E+05	0.087	3.45E+04	1.55E+05	565.06	5.61E+05	520	5.19E+06	3.09E-01	1.73E+05	4.036	1.89E+05	0.00E+00	3.62E+05
3	34	2.11	9.72E+04	0.016	6.34E+03	1.04E+05	564.67	5.53E+05	520	4.98E+06	3.01E-01	1.66E+05	2.593	1.19E+05	0.00E+00	2.86E+05
3	35	3.01	1.37E+05	0.057	2.26E+04	1.59E+05	564.31	5.45E+05	520	4.80E+06	2.93E-01	1.60E+05	1.558	7.08E+04	0.00E+00	2.31E+05
3	36	2.86	1.29E+05	0.187	7.41E+04	2.03E+05	564.17	5.42E+05	520	4.73E+06	2.90E-01	1.58E+05	0.494	2.23E+04	0.00E+00	1.80E+05
4	37	3.66	1.66E+05	1.242	4.92E+05	6.58E+05	564.22	5.43E+05	520	4.75E+06	2.91E-01	1.58E+05	0.527	2.38E+04	0.00E+00	1.82E+05
4	38	2.98	1.40E+05	2.125	8.42E+05	9.81E+05	565.13	5.62E+05	520	5.23E+06	3.10E-01	1.74E+05	1.620	7.58E+04	0.00E+00	2.50E+05
4	39	3.67	1.79E+05	0.945	3.74E+05	5.53E+05	566.33	5.85E+05	520	5.96E+06	3.35E-01	1.96E+05	2.673	1.30E+05	0.00E+00	3.26E+05
4	40	3.55	1.75E+05	0.053	2.10E+04	1.96E+05	566.71	5.92E+05	520	6.19E+06	3.42E-01	2.03E+05	4.437	2.19E+05	0.00E+00	4.21E+05
4	41	3.78	1.84E+05	0.121	4.79E+04	2.32E+05	566.34	5.85E+05	520	5.96E+06	3.35E-01	1.96E+05	5.076	2.47E+05	0.00E+00	4.43E+05
4	42	3.59	1.73E+05	0.191	7.57E+04	2.49E+05	565.99	5.78E+05	520	5.75E+06	3.28E-01	1.89E+05	6.098	2.94E+05	0.00E+00	4.83E+05
4	43	4.09	1.95E+05	0.473	1.87E+05	3.82E+05	565.60	5.71E+05	520	5.52E+06	3.20E-01	1.83E+05	5.905	2.81E+05	0.00E+00	4.63E+05
4	44	2.8	1.33E+05	0.125	4.95E+04	1.82E+05	565.47	5.68E+05	520	5.44E+06	3.17E-01	1.80E+05	5.039	2.39E+05	0.00E+00	4.19E+05
4	45	2.59	1.21E+05	0.087	3.45E+04	1.56E+05	565.08	5.61E+05	520	5.20E+06	3.09E-01	1.73E+05	4.036	1.89E+05	0.00E+00	3.62E+05
4	46	2.11	9.72E+04	0.016	6.34E+03	1.04E+05	564.69	5.53E+05	520	4.99E+06	3.01E-01	1.66E+05	2.593	1.20E+05	0.00E+00	2.86E+05
4	47	3.01	1.37E+05	0.057	2.26E+04	1.59E+05	564.33	5.46E+05	520	4.81E+06	2.94E-01	1.60E+05	1.558	7.08E+04	0.00E+00	2.31E+05
4	48	2.86	1.29E+05	0.187	7.41E+04	2.03E+05	564.19	5.43E+05	520	4.74E+06	2.91E-01	1.58E+05	0.494	2.24E+04	0.00E+00	1.80E+05

Table C-3
POND ROUTING UNDER NORMAL CONDITIONS
POND 3 (SOUTHEAST OF FEMP, BORROWED AREA)

BROWN & ROOT ENVIRONMENTAL

Hydraulic Conductivity of Pond Liner (cm/sec) = 7.23E-07
Thickness of Pond Liner (ft 3
Pond Bottom Elev (ft) = 565
Drainage Area (ft^2) 4528350

Pond 3 Overflow El = 578

Pond overflow at storage (ft^3) 1931500

POND 3

Year	Month	Rainfall Depth (inch)	Rainfall Vol. Into Pond (ft³)	Runoff Depth (inch)	Runoff Vol. Into Pond (ft³)	Total Inflow I (ft³)	Pond Elevation (ft)	Pond Area (ft^2)	GW Elev. (ft)	Pond Storage S (ft³)	Infiltration Rate (ft)	Total Infiltration (ft³)	Monthly Evapo. (inch)	Total Evapo. (ft³)	Pond Overflow (ft³/Day	Total Out flow O (ft³)
1	1	3.66	1.04E+05	1.242	4.69E+05	5.73E+05	576.93	3.42E+05	520	1.50E+06	2.44E-01	8.37E+04	0.527	1.50E+04	0.00E+00	9.87E+04
1	2	2.98	1.12E+05	2.125	8.02E+05	9.14E+05	578.00	4.53E+05	520	1.93E+06	2.66E-01	1.21E+05	1.620	6.11E+04	1.43E+03	2.25E+05
1	3	3.67	1.39E+05	0.945	3.57E+05	4.95E+05	578.00	4.53E+05	520	1.93E+06	2.66E-01	1.21E+05	2.673	1.01E+05	2.30E+04	9.11E+05
1	4	3.55	1.02E+05	0.053	2.00E+04	1.22E+05	576.96	3.46E+05	520	1.52E+06	2.45E-01	8.49E+04	4.437	1.28E+05	0.00E+00	2.13E+05
1	5	3.78	1.02E+05	0.121	4.57E+04	1.47E+05	576.74	3.23E+05	520	1.42E+06	2.41E-01	7.77E+04	5.076	1.37E+05	0.00E+00	2.14E+05
1	6	3.59	9.15E+04	0.191	7.21E+04	1.64E+05	576.57	3.06E+05	520	1.36E+06	2.37E-01	7.26E+04	6.098	1.55E+05	0.00E+00	2.28E+05
1	7	4.09	9.87E+04	0.473	1.78E+05	2.77E+05	576.41	2.90E+05	520	1.29E+06	2.34E-01	6.77E+04	5.905	1.42E+05	0.00E+00	2.10E+05
1	8	2.8	7.16E+04	0.125	4.72E+04	1.19E+05	576.58	3.07E+05	520	1.36E+06	2.37E-01	7.28E+04	5.039	1.29E+05	0.00E+00	2.02E+05
1	9	2.59	6.16E+04	0.087	3.28E+04	9.44E+04	576.37	2.85E+05	520	1.28E+06	2.33E-01	6.65E+04	4.036	9.60E+04	0.00E+00	1.63E+05
1	10	2.11	4.71E+04	0.016	6.04E+03	5.32E+04	576.20	2.68E+05	520	1.21E+06	2.30E-01	6.15E+04	2.593	5.79E+04	0.00E+00	1.19E+05
1	11	3.01	6.30E+04	0.057	2.15E+04	8.45E+04	576.04	2.51E+05	520	1.14E+06	2.26E-01	5.68E+04	1.558	3.26E+04	0.00E+00	8.94E+04
1	12	2.86	5.95E+04	0.187	7.06E+04	1.30E+05	576.02	2.50E+05	520	1.14E+06	2.26E-01	5.64E+04	0.494	1.03E+04	0.00E+00	6.67E+04
2	13	3.66	8.11E+04	1.242	4.69E+05	5.50E+05	576.18	2.66E+05	520	1.20E+06	2.29E-01	6.10E+04	0.527	1.17E+04	0.00E+00	7.26E+04
2	14	2.98	9.64E+04	2.125	8.02E+05	8.98E+05	577.37	3.88E+05	520	1.68E+06	2.54E-01	9.84E+04	1.620	5.24E+04	0.00E+00	1.51E+05
2	15	3.67	1.39E+05	0.945	3.57E+05	4.95E+05	578.00	4.53E+05	520	1.93E+06	2.66E-01	1.21E+05	2.673	1.01E+05	1.65E+04	7.16E+05
2	16	3.55	1.17E+05	0.053	2.00E+04	1.37E+05	577.45	3.96E+05	520	1.71E+06	2.55E-01	1.01E+05	4.437	1.46E+05	0.00E+00	2.48E+05
2	17	3.78	1.16E+05	0.121	4.57E+04	1.62E+05	577.17	3.68E+05	520	1.60E+06	2.50E-01	9.18E+04	5.076	1.56E+05	0.00E+00	2.47E+05
2	18	3.59	1.03E+05	0.191	7.21E+04	1.76E+05	576.96	3.46E+05	520	1.51E+06	2.45E-01	8.48E+04	6.098	1.76E+05	0.00E+00	2.61E+05
2	19	4.09	1.10E+05	0.473	1.78E+05	2.89E+05	576.75	3.24E+05	520	1.43E+06	2.41E-01	7.81E+04	5.905	1.60E+05	0.00E+00	2.38E+05
2	20	2.8	7.87E+04	0.125	4.72E+04	1.26E+05	576.88	3.37E+05	520	1.48E+06	2.43E-01	8.21E+04	5.039	1.42E+05	0.00E+00	2.24E+05
2	21	2.59	6.74E+04	0.087	3.28E+04	1.00E+05	576.63	3.12E+05	520	1.38E+06	2.38E-01	7.45E+04	4.036	1.05E+05	0.00E+00	1.79E+05
2	22	2.11	5.13E+04	0.016	6.04E+03	5.74E+04	576.44	2.92E+05	520	1.30E+06	2.34E-01	6.84E+04	2.593	6.31E+04	0.00E+00	1.32E+05
2	23	3.01	6.85E+04	0.057	2.15E+04	9.00E+04	576.25	2.73E+05	520	1.23E+06	2.31E-01	6.29E+04	1.558	3.54E+04	0.00E+00	9.84E+04

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POND 3

Year	Month	Rainfall Depth (inch)	Rainfall Vol. Into Pond (ft³)	Runoff Depth (inch)	Runoff Vol. Into Pond (ft³)	Total Inflow I (ft³)	Pond Elevation (ft)	Pond Area (ft^2)	GW Elev. (ft)	Pond Storage S (ft³)	Infiltration Rate (ft)	Total Infiltration (ft³)	Monthly Evapo. (inch)	Total Evapo. (ft³)	Pond Overflow (ft³)/Day	Total Out flow O (ft³)
2	24	2.86	6.46E+04	0.187	7.06E+04	1.35E+05	576.23	2.71E+05	520	1.22E+06	2.30E-01	6.23E+04	0.494	1.12E+04	0.00E+00	7.35E+04
3	25	3.66	8.74E+04	1.242	4.69E+05	5.56E+05	576.38	2.87E+05	520	1.28E+06	2.33E-01	6.69E+04	0.527	1.26E+04	0.00E+00	7.95E+04
3	26	2.98	1.01E+05	2.125	8.02E+05	9.03E+05	577.57	4.09E+05	520	1.76E+06	2.58E-01	1.05E+05	1.620	5.52E+04	0.00E+00	1.60E+05
3	27	3.67	1.39E+05	0.945	3.57E+05	4.95E+05	578.00	4.53E+05	520	1.93E+06	2.66E-01	1.21E+05	2.673	1.01E+05	1.90E+04	7.92E+05
3	28	3.55	1.11E+05	0.053	2.00E+04	1.31E+05	577.26	3.77E+05	520	1.63E+06	2.51E-01	9.47E+04	4.437	1.39E+05	0.00E+00	2.34E+05
3	29	3.78	1.10E+05	0.121	4.57E+04	1.56E+05	577.01	3.51E+05	520	1.53E+06	2.46E-01	8.63E+04	5.076	1.48E+05	0.00E+00	2.35E+05
3	30	3.59	9.89E+04	0.191	7.21E+04	1.71E+05	576.81	3.31E+05	520	1.45E+06	2.42E-01	8.00E+04	6.098	1.68E+05	0.00E+00	2.48E+05
3	31	4.09	1.06E+05	0.473	1.78E+05	2.84E+05	576.62	3.11E+05	520	1.38E+06	2.38E-01	7.40E+04	5.905	1.53E+05	0.00E+00	2.27E+05
3	32	2.8	7.60E+04	0.125	4.72E+04	1.23E+05	576.76	3.26E+05	520	1.43E+06	2.41E-01	7.85E+04	5.039	1.37E+05	0.00E+00	2.15E+05
3	33	2.59	6.52E+04	0.087	3.28E+04	9.80E+04	576.53	3.02E+05	520	1.34E+06	2.36E-01	7.14E+04	4.036	1.02E+05	0.00E+00	1.73E+05
3	34	2.11	4.97E+04	0.016	6.04E+03	5.58E+04	576.35	2.83E+05	520	1.27E+06	2.33E-01	6.58E+04	2.593	6.11E+04	0.00E+00	1.27E+05
3	35	3.01	6.64E+04	0.057	2.15E+04	8.79E+04	576.17	2.65E+05	520	1.20E+06	2.29E-01	6.06E+04	1.558	3.43E+04	0.00E+00	9.49E+04
3	36	2.86	6.26E+04	0.187	7.06E+04	1.33E+05	576.15	2.63E+05	520	1.19E+06	2.29E-01	6.01E+04	0.494	1.08E+04	0.00E+00	7.09E+04
4	37	3.66	8.50E+04	1.242	4.69E+05	5.54E+05	576.31	2.79E+05	520	1.25E+06	2.32E-01	6.46E+04	0.527	1.22E+04	0.00E+00	7.68E+04
4	38	2.98	9.95E+04	2.125	8.02E+05	9.01E+05	577.49	4.01E+05	520	1.73E+06	2.56E-01	1.03E+05	1.620	5.41E+04	0.00E+00	1.57E+05
4	39	3.67	1.39E+05	0.945	3.57E+05	4.95E+05	578.00	4.53E+05	520	1.93E+06	2.66E-01	1.21E+05	2.673	1.01E+05	1.80E+04	7.63E+05
4	40	3.55	1.14E+05	0.053	2.00E+04	1.34E+05	577.33	3.84E+05	520	1.66E+06	2.53E-01	9.71E+04	4.437	1.42E+05	0.00E+00	2.39E+05
4	41	3.78	1.13E+05	0.121	4.57E+04	1.58E+05	577.07	3.57E+05	520	1.56E+06	2.47E-01	8.84E+04	5.076	1.51E+05	0.00E+00	2.39E+05
4	42	3.59	1.01E+05	0.191	7.21E+04	1.73E+05	576.87	3.36E+05	520	1.48E+06	2.43E-01	8.18E+04	6.098	1.71E+05	0.00E+00	2.53E+05
4	43	4.09	1.08E+05	0.473	1.78E+05	2.86E+05	576.67	3.16E+05	520	1.40E+06	2.39E-01	7.56E+04	5.905	1.55E+05	0.00E+00	2.31E+05
4	44	2.8	7.70E+04	0.125	4.72E+04	1.24E+05	576.81	3.30E+05	520	1.45E+06	2.42E-01	7.99E+04	5.039	1.39E+05	0.00E+00	2.18E+05
4	45	2.59	6.60E+04	0.087	3.28E+04	9.89E+04	576.57	3.06E+05	520	1.36E+06	2.37E-01	7.25E+04	4.036	1.03E+05	0.00E+00	1.75E+05
4	46	2.11	5.03E+04	0.016	6.04E+03	5.64E+04	576.38	2.86E+05	520	1.28E+06	2.33E-01	6.68E+04	2.593	6.19E+04	0.00E+00	1.29E+05
4	47	3.01	6.72E+04	0.057	2.15E+04	8.87E+04	576.20	2.68E+05	520	1.21E+06	2.30E-01	6.15E+04	1.558	3.48E+04	0.00E+00	9.62E+04
4	48	2.86	6.34E+04	0.187	7.06E+04	1.34E+05	576.18	2.66E+05	520	1.20E+06	2.29E-01	6.09E+04	0.494	1.10E+04	0.00E+00	7.19E+04

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Table C-4
POND ROUTING UNDER NORMAL CONDITIONS
POND 4 (STORMWATER RETENTION POND) - FEMP

BROWN & ROOT ENVIRONMENTAL

Hydraulic Conductivity of Pond Liner (cm/sec) = 7.23E-07
Thickness of Pond Liner (ft) = 3
Pond Bottom Elev. (ft) = 535
Drainage Area (ft^2) 2146500

Pond 4 Overflow El = 560

Pond overflow at storage (ft^3) 2550000

POND 4

Year	Month	Rainfall Depth (inch)	Rainfall Vol. Into Pond (ft³)	Runoff Depth (inch)	Runoff Vol. Into Pond (ft³)	Inflow from Pond 2 (ft³)	Total Inflow I (ft³)	Pond Elevation (ft)	Pond Area (ft^2)	GW Elev. (ft)	Pond Storage S (ft³)	Infiltration Rate (ft)	Total Infiltration (ft³)	Monthly Evapo. (inch)	Total Evapo. (ft³)	Pond Overflow (ft³/day	Total Out flow O (ft³)
1	1	3.66	4.45E+04	1.242	2.22E+05	0.00E+00	2.67E+05	556.05	1.46E+05	520	2.00E+06	4.31E-01	6.30E+04	0.527	6.41E+03	0.00E+00	6.94E+04
1	2	2.98	3.66E+04	2.125	3.80E+05	0.00E+00	4.19E+05	557.47	1.55E+05	520	2.20E+06	4.60E-01	7.16E+04	1.620	2.10E+04	0.00E+00	9.26E+04
1	3	3.67	5.23E+04	0.945	1.69E+05	0.00E+00	2.21E+05	559.81	1.71E+05	520	2.52E+06	5.09E-01	8.70E+04	2.673	3.81E+04	0.00E+00	1.25E+05
1	4	3.55	5.10E+04	0.053	9.48E+03	0.00E+00	6.05E+04	560.00	1.72E+05	520	2.55E+06	5.12E-01	8.83E+04	4.437	6.37E+04	2.32E+03	2.22E+05
1	5	3.78	5.19E+04	0.121	2.16E+04	0.00E+00	7.35E+04	558.85	1.65E+05	520	2.39E+06	4.89E-01	8.05E+04	5.076	6.96E+04	0.00E+00	1.50E+05
1	6	3.59	4.82E+04	0.191	3.42E+04	0.00E+00	8.23E+04	558.29	1.61E+05	520	2.31E+06	4.77E-01	7.69E+04	6.098	8.18E+04	0.00E+00	1.59E+05
1	7	4.09	5.36E+04	0.473	8.46E+04	0.00E+00	1.38E+05	557.75	1.57E+05	520	2.24E+06	4.66E-01	7.33E+04	5.905	7.74E+04	0.00E+00	1.51E+05
1	8	2.8	3.66E+04	0.125	2.24E+04	0.00E+00	5.89E+04	557.66	1.57E+05	520	2.22E+06	4.64E-01	7.28E+04	5.039	6.58E+04	0.00E+00	1.39E+05
1	9	2.59	3.30E+04	0.087	1.56E+04	0.00E+00	4.86E+04	557.08	1.53E+05	520	2.14E+06	4.53E-01	6.92E+04	4.036	5.14E+04	0.00E+00	1.21E+05
1	10	2.11	2.63E+04	0.016	2.86E+03	0.00E+00	2.91E+04	556.56	1.49E+05	520	2.07E+06	4.42E-01	6.61E+04	2.593	3.23E+04	0.00E+00	9.84E+04
1	11	3.01	3.67E+04	0.057	1.02E+04	0.00E+00	4.69E+04	556.07	1.46E+05	520	2.00E+06	4.32E-01	6.31E+04	1.558	1.90E+04	0.00E+00	8.21E+04
1	12	2.86	3.44E+04	0.187	3.34E+04	0.00E+00	6.79E+04	555.81	1.44E+05	520	1.97E+06	4.27E-01	6.16E+04	0.494	5.95E+03	0.00E+00	6.76E+04
2	13	3.66	4.41E+04	1.242	2.22E+05	0.00E+00	2.66E+05	555.82	1.44E+05	520	1.97E+06	4.27E-01	6.16E+04	0.527	6.34E+03	0.00E+00	6.80E+04
2	14	2.98	3.82E+04	2.125	3.80E+05	0.00E+00	4.18E+05	557.24	1.54E+05	520	2.17E+06	4.56E-01	7.02E+04	1.620	2.08E+04	0.00E+00	9.10E+04
2	15	3.67	5.19E+04	0.945	1.69E+05	0.00E+00	2.21E+05	559.60	1.70E+05	520	2.49E+06	5.04E-01	8.55E+04	2.673	3.78E+04	0.00E+00	1.23E+05
2	16	3.55	5.10E+04	0.053	9.48E+03	0.00E+00	6.05E+04	560.00	1.72E+05	520	2.55E+06	5.12E-01	8.83E+04	4.437	6.37E+04	1.35E+03	1.93E+05
2	17	3.78	5.23E+04	0.121	2.16E+04	0.00E+00	7.40E+04	559.05	1.66E+05	520	2.42E+06	4.93E-01	8.19E+04	5.076	7.02E+04	0.00E+00	1.52E+05
2	18	3.59	4.86E+04	0.191	3.42E+04	0.00E+00	8.27E+04	558.49	1.62E+05	520	2.34E+06	4.81E-01	7.81E+04	6.098	8.25E+04	0.00E+00	1.61E+05
2	19	4.09	5.40E+04	0.473	8.46E+04	0.00E+00	1.39E+05	557.93	1.59E+05	520	2.26E+06	4.70E-01	7.45E+04	5.905	7.80E+04	0.00E+00	1.53E+05
2	20	2.8	3.66E+04	0.125	2.24E+04	0.00E+00	5.92E+04	557.63	1.58E+05	520	2.25E+06	4.68E-01	7.39E+04	5.039	6.63E+04	0.00E+00	1.40E+05
2	21	2.59	3.32E+04	0.087	1.56E+04	0.00E+00	4.88E+04	557.25	1.54E+05	520	2.17E+06	4.56E-01	7.02E+04	4.036	5.18E+04	0.00E+00	1.22E+05
2	22	2.11	2.65E+04	0.016	2.86E+03	0.00E+00	2.93E+04	556.72	1.51E+05	520	2.09E+06	4.45E-01	6.70E+04	2.593	3.25E+04	0.00E+00	9.95E+04
2	23	3.01	3.69E+04	0.057	1.02E+04	0.00E+00	4.71E+04	556.22	1.47E+05	520	2.02E+06	4.35E-01	6.40E+04	1.558	1.91E+04	0.00E+00	8.31E+04
2	24	2.86	3.47E+04	0.187	3.34E+04	0.00E+00	6.81E+04	555.96	1.45E+05	520	1.99E+06	4.30E-01	6.25E+04	0.494	5.99E+03	0.00E+00	6.85E+04
3	25	3.66	4.44E+04	1.242	2.22E+05	0.00E+00	2.67E+05	555.96	1.45E+05	520	1.99E+06	4.29E-01	6.25E+04	0.527	6.38E+03	0.00E+00	6.88E+04
3	26	2.98	3.85E+04	2.125	3.80E+05	0.00E+00	4.19E+05	557.38	1.55E+05	520	2.18E+06	4.59E-01	7.10E+04	1.620	2.09E+04	0.00E+00	9.19E+04
3	27	3.67	5.22E+04	0.945	1.69E+05	0.00E+00	2.21E+05	559.73	1.71E+05	520	2.51E+06	5.07E-01	8.64E+04	2.673	3.80E+04	0.00E+00	1.24E+05
3	28	3.55	5.10E+04	0.053	9.48E+03	0.00E+00	6.05E+04	560.00	1.72E+05	520	2.55E+06	5.12E-01	8.83E+04	4.437	6.37E+04	1.94E+03	2.10E+05
3	29	3.78	5.20E+04	0.121	2.16E+04	0.00E+00	7.37E+04	558.93	1.65E+05	520	2.40E+06	4.90E-01	8.10E+04	5.076	6.99E+04	0.00E+00	1.51E+05

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POND 4

Year	Month	Rainfall Depth (inch)	Rainfall Vol. Into Pond (ft^3)	Runoff Depth (inch)	Runoff Vol. Into Pond (ft^3)	Inflow from Pond 2 (ft^3)	Total Inflow I (ft^3)	Pond Elevation (ft)	Pond Area (ft^2)	GW Elev. (ft)	Pond Storage S (ft^3)	Infiltration Rate (ft)	Total Infiltration (ft^3)	Monthly Evapo. (inch)	Total Evapo. (ft^3)	Pond Overflow (ft^3/day	Total Out flow O (ft^3)
3	30	3.59	4.83E+04	0.191	3.42E+04	0.00E+00	8.25E+04	558.37	1.62E+05	520	2.32E+06	4.79E-01	7.74E+04	6.098	8.21E+04	0.00E+00	1.59E+05
3	31	4.09	5.38E+04	0.473	8.46E+04	0.00E+00	1.38E+05	557.82	1.58E+05	520	2.25E+06	4.68E-01	7.38E+04	5.905	7.77E+04	0.00E+00	1.51E+05
3	32	2.8	3.67E+04	0.125	2.24E+04	0.00E+00	5.90E+04	557.73	1.57E+05	520	2.23E+06	4.66E-01	7.32E+04	5.039	6.60E+04	0.00E+00	1.39E+05
3	33	2.59	3.31E+04	0.087	1.56E+04	0.00E+00	4.87E+04	557.15	1.53E+05	520	2.15E+06	4.54E-01	6.96E+04	4.036	5.16E+04	0.00E+00	1.21E+05
3	34	2.11	2.64E+04	0.016	2.86E+03	0.00E+00	2.92E+04	556.63	1.50E+05	520	2.08E+06	4.43E-01	6.64E+04	2.593	3.24E+04	0.00E+00	9.88E+04
3	35	3.01	3.68E+04	0.057	1.02E+04	0.00E+00	4.70E+04	556.13	1.47E+05	520	2.01E+06	4.33E-01	6.35E+04	1.558	1.90E+04	0.00E+00	8.25E+04
3	36	2.86	3.45E+04	0.187	3.34E+04	0.00E+00	6.80E+04	555.87	1.45E+05	520	1.98E+06	4.28E-01	6.20E+04	0.494	5.97E+03	0.00E+00	6.79E+04
4	37	3.66	4.42E+04	1.242	2.22E+05	0.00E+00	2.66E+05	555.87	1.45E+05	520	1.98E+06	4.28E-01	6.20E+04	0.527	6.36E+03	0.00E+00	6.83E+04
4	38	2.98	3.83E+04	2.125	3.80E+05	0.00E+00	4.18E+05	557.30	1.54E+05	520	2.17E+06	4.57E-01	7.05E+04	1.620	2.08E+04	0.00E+00	9.14E+04
4	39	3.67	5.20E+04	0.945	1.69E+05	0.00E+00	2.21E+05	559.65	1.70E+05	520	2.50E+06	5.05E-01	8.59E+04	2.673	3.79E+04	0.00E+00	1.24E+05
4	40	3.55	5.10E+04	0.053	9.48E+03	0.00E+00	6.05E+04	560.00	1.72E+05	520	2.55E+06	5.12E-01	8.83E+04	4.437	6.37E+04	1.59E+03	2.00E+05
4	41	3.78	5.22E+04	0.121	2.16E+04	0.00E+00	7.38E+04	559.00	1.66E+05	520	2.41E+06	4.92E-01	8.15E+04	5.076	7.01E+04	0.00E+00	1.52E+05
4	42	3.59	4.85E+04	0.191	3.42E+04	0.00E+00	8.26E+04	558.44	1.62E+05	520	2.33E+06	4.60E-01	7.78E+04	6.098	8.23E+04	0.00E+00	1.60E+05
4	43	4.09	5.39E+04	0.473	8.46E+04	0.00E+00	1.39E+05	557.89	1.58E+05	520	2.26E+06	4.69E-01	7.42E+04	5.905	7.79E+04	0.00E+00	1.52E+05
4	44	2.8	3.68E+04	0.125	2.24E+04	0.00E+00	5.91E+04	557.79	1.58E+05	520	2.24E+06	4.67E-01	7.36E+04	5.039	6.62E+04	0.00E+00	1.40E+05
4	45	2.59	3.32E+04	0.087	1.56E+04	0.00E+00	4.87E+04	557.21	1.54E+05	520	2.16E+06	4.55E-01	7.00E+04	4.036	5.17E+04	0.00E+00	1.22E+05
4	46	2.11	2.64E+04	0.016	2.86E+03	0.00E+00	2.93E+04	556.68	1.50E+05	520	2.09E+06	4.44E-01	6.68E+04	2.593	3.25E+04	0.00E+00	9.93E+04
4	47	3.01	3.69E+04	0.057	1.02E+04	0.00E+00	4.70E+04	556.18	1.47E+05	520	2.02E+06	4.34E-01	6.38E+04	1.558	1.91E+04	0.00E+00	8.29E+04
4	48	2.86	3.46E+04	0.187	3.34E+04	0.00E+00	6.81E+04	555.92	1.45E+05	520	1.98E+06	4.29E-01	6.23E+04	0.494	5.98E+03	0.00E+00	6.82E+04

APPENDIX D

ROUTING CALCULATIONS UNDER EXTREME CONDITIONS

TABLE D-1
POND ROUTING UNDER EXTREME CONDITIONS
POND 1 (NORTHEAST OF FEMP)
25-YEAR FREQUENCY AND 24 HOUR DURATION STORM

Initial Pond Storage 4.45E+06 ft^3 Initial Pond Elevation 573 feet
Time Step= 360 second
Pond Overflow El.= 573 feet
Weir Width = 5 feet

POND 1

Time (hour)	Time Step dt (min)	Inflow Rates I (ft^3/sec)	Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
11	0	0		0.0	0	4.45E+06	573.00
11.1	6	3	1080	0.0	0	4.45E+06	573.00
11.2	6	4	1440	0.0	1	4.45E+06	573.01
11.3	6	4	1440	0.0	2	4.45E+06	573.01
11.4	6	4	1440	0.0	4	4.45E+06	573.01
11.5	6	5	1800	0.0	7	4.45E+06	573.01
11.6	6	5	1800	0.0	10	4.45E+06	573.02
11.7	6	6	2160	0.0	14	4.46E+06	573.02
11.8	6	8	2880	0.1	19	4.46E+06	573.03
11.9	6	9	3240	0.1	27	4.46E+06	573.03
12	6	9	3240	0.1	36	4.47E+06	573.04
12.1	6	11	3960	0.1	47	4.47E+06	573.05
12.2	6	13	4680	0.2	61	4.47E+06	573.06
12.3	6	21	7560	0.2	78	4.48E+06	573.07
12.4	6	34	12240	0.3	111	4.49E+06	573.09
12.5	6	57	20520	0.5	170	4.51E+06	573.13
12.6	6	83	29880	0.8	287	4.54E+06	573.19
12.7	6	109	39240	1.4	489	4.58E+06	573.26
12.8	6	125	45000	2.2	804	4.63E+06	573.35
12.9	6	127	45720	3.4	1221	4.67E+06	573.43
13	6	129	46440	4.7	1697	4.72E+06	573.52
13.1	6	122	43920	6.2	2224	4.76E+06	573.60
13.2	6	114	41040	7.7	2757	4.80E+06	573.67
13.3	6	103	37080	9.1	3279	4.83E+06	573.74
13.4	6	92	33120	10.5	3764	4.86E+06	573.79
13.5	6	82	29520	11.7	4203	4.88E+06	573.84
13.6	6	72	25920	12.8	4594	4.91E+06	573.88
13.7	6	63	22680	13.7	4933	4.92E+06	573.92
13.8	6	55	19800	14.5	5221	4.94E+06	573.95
13.9	6	49	17640	15.2	5461	4.95E+06	573.97
14	6	43	15480	15.7	5665	4.96E+06	573.99
14.1	6	39	14040	16.2	5831	4.97E+06	574.00
14.2	6	35	12600	16.6	5971	4.98E+06	574.02

POND 1

Time (hour)	Time Step dt (min)	Inflow Rates I (ft^3/sec)	Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
14.3	6	31	11160	16.9	6085	4.98E+06	574.03
14.4	6	29	10440	17.1	6172	4.98E+06	574.03
14.5	6	26	9360	17.4	6246	4.99E+06	574.04
14.6	6	24	8640	17.5	6300	4.99E+06	574.04
14.7	6	23	8280	17.6	6341	4.99E+06	574.05
14.8	6	22	7920	17.7	6375	4.99E+06	574.05
14.9	6	20	7200	17.8	6402	4.99E+06	574.05
15	6	19	6840	17.8	6416	4.99E+06	574.05
15.1	6	18	6480	17.8	6424	4.99E+06	574.05
15.2	6	18	6480	17.8	6425	4.99E+06	574.05
15.3	6	17	6120	17.8	6426	4.99E+06	574.05
15.4	6	17	6120	17.8	6420	4.99E+06	574.05
15.5	6	16	5760	17.8	6415	4.99E+06	574.05
15.6	6	16	5760	17.8	6403	4.99E+06	574.05
15.7	6	16	5760	17.8	6392	4.99E+06	574.05
15.8	6	15	5400	17.7	6381	4.99E+06	574.05
15.9	6	15	5400	17.7	6364	4.99E+06	574.05
16	6	15	5400	17.6	6347	4.99E+06	574.0
16.1	6	15	5400	17.6	6331	4.99E+06	574.0
16.2	6	14	5040	17.5	6314	4.99E+06	574.04
16.3	6	14	5040	17.5	6292	4.99E+06	574.04
16.4	6	13	4680	17.4	6270	4.98E+06	574.03
16.5	6	13	4680	17.3	6243	4.98E+06	574.03
16.6	6	13	4680	17.3	6216	4.98E+06	574.03
16.7	6	12	4320	17.2	6189	4.98E+06	574.02
16.8	6	12	4320	17.1	6157	4.98E+06	574.02
16.9	6	11	3960	17.0	6125	4.98E+06	574.02
17	6	11	3960	16.9	6088	4.97E+06	574.01
17.1	6	11	3960	16.8	6051	4.97E+06	574.01
17.2	6	11	3960	16.7	6015	4.97E+06	574.00
17.3	6	11	3960	16.6	5980	4.97E+06	574.00
17.4	6	11	3960	16.5	5945	4.96E+06	574.00
17.5	6	11	3960	16.4	5911	4.96E+06	573.99
17.6	6	11	3960	16.3	5878	4.96E+06	573.99
17.7	6	10	3600	16.2	5845	4.96E+06	573.99
17.8	6	10	3600	16.1	5807	4.96E+06	573.98
17.9	6	10	3600	16.0	5770	4.95E+06	573.98
18	6	10	3600	15.9	5733	4.95E+06	573.97
18.1	6	10	3600	15.8	5697	4.95E+06	573.97
18.2	6	10	3600	15.7	5662	4.95E+06	573.96
18.3	6	9	3240	15.6	5627	4.95E+06	573.96
18.4	6	9	3240	15.5	5587	4.94E+06	573.9
18.5	6	9	3240	15.4	5548	4.94E+06	573.95
18.6	6	9	3240	15.3	5509	4.94E+06	573.95
18.7	6	9	3240	15.2	5472	4.94E+06	573.94

POND 1

Time (hour)	Time Step dt (min)	Inflow Rates I (ft^3/sec)	Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
18.8	6	8	2880	15.1	5435	4.93E+06	573.94
18.9	6	8	2880	15.0	5392	4.93E+06	573.93
19	6	8	2880	14.9	5351	4.93E+06	573.93
19.1	6	8	2880	14.8	5310	4.93E+06	573.92
19.2	6	8	2880	14.6	5270	4.92E+06	573.92
19.3	6	8	2880	14.5	5231	4.92E+06	573.91
19.4	6	8	2880	14.4	5192	4.92E+06	573.91
19.5	6	8	2880	14.3	5155	4.92E+06	573.91
19.6	6	7	2520	14.2	5118	4.91E+06	573.90
19.7	6	7	2520	14.1	5076	4.91E+06	573.90
19.8	6	7	2520	14.0	5034	4.91E+06	573.89
19.9	6	7	2520	13.9	4994	4.91E+06	573.89
20	6	7	2520	13.8	4954	4.90E+06	573.88
20.1	6	7	2520	13.7	4915	4.90E+06	573.88
20.2	6	7	2520	13.5	4876	4.90E+06	573.87
20.3	6	7	2520	13.4	4839	4.90E+06	573.87
20.4	6	7	2520	13.3	4802	4.90E+06	573.86
20.5	6	6	2160	13.2	4765	4.89E+06	573.86
20.6	6	6	2160	13.1	4724	4.89E+06	573.85
20.7	6	6	2160	13.0	4683	4.89E+06	573.85
20.8	6	6	2160	12.9	4644	4.89E+06	573.84
20.9	6	6	2160	12.8	4605	4.88E+06	573.84
21	6	6	2160	12.7	4566	4.88E+06	573.83
21.1	6	6	2160	12.6	4529	4.88E+06	573.83
21.2	6	6	2160	12.5	4492	4.88E+06	573.83
21.3	6	6	2160	12.4	4456	4.87E+06	573.82
21.4	6	6	2160	12.3	4420	4.87E+06	573.82
21.5	6	6	2160	12.2	4385	4.87E+06	573.81
21.6	6	5	1800	12.1	4351	4.87E+06	573.81
21.7	6	5	1800	12.0	4311	4.86E+06	573.80
21.8	6	5	1800	11.9	4273	4.86E+06	573.80
21.9	6	5	1800	11.8	4235	4.86E+06	573.79
22	6	5	1800	11.7	4198	4.86E+06	573.79
22.1	6	5	1800	11.6	4162	4.85E+06	573.78
22.2	6	5	1800	11.5	4126	4.85E+06	573.78
22.3	6	5	1800	11.4	4091	4.85E+06	573.78
22.4	6	4	1440	11.3	4056	4.85E+06	573.77
22.5	6	4	1440	11.2	4017	4.84E+06	573.77
22.6	6	4	1440	11.1	3978	4.84E+06	573.76
22.7	6	4	1440	10.9	3940	4.84E+06	573.76
22.8	6	4	1440	10.8	3903	4.84E+06	573.75
22.9	6	4	1440	10.7	3867	4.83E+06	573.75
23	6	4	1440	10.6	3831	4.83E+06	573.74
23.1	6	4	1440	10.5	3795	4.83E+06	573.74
23.2	6	4	1440	10.4	3761	4.83E+06	573.73

POND 1

Time (hour)	Time Step dt (min)	Inflow Rates I (ft^3/sec)	Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
23.3	6	3	1080	10.4	3727	4.82E+06	573.73
23.4	6	3	1080	10.2	3688	4.82E+06	573.72
23.5	6	3	1080	10.1	3650	4.82E+06	573.72
23.6	6	3	1080	10.0	3613	4.82E+06	573.71
23.7	6	3	1080	9.9	3576	4.81E+06	573.71
23.8	6	3	1080	9.8	3540	4.81E+06	573.70
23.9	6	3	1080	9.7	3505	4.81E+06	573.70
24	6	2	720	9.6	3470	4.81E+06	573.69
24.1	6	2	720	9.5	3431	4.80E+06	573.69
24.2	6	2	720	9.4	3393	4.80E+06	573.68
24.3	6	2	720	9.3	3355	4.80E+06	573.68
24.4	6	2	720	9.2	3318	4.80E+06	573.67
24.5	6	2	720	9.1	3281	4.79E+06	573.67
24.6	6	2	720	9.0	3245	4.79E+06	573.66
24.7	6	2	720	8.9	3210	4.79E+06	573.66
24.8	6	2	720	8.8	3175	4.79E+06	573.65
24.9	6	1	360	8.7	3141	4.78E+06	573.65
25	6	1	360	8.6	3103	4.78E+06	573.[illegible]
25.1	6	1	360	8.5	3065	4.78E+06	573.[illegible]
25.2	6	1	360	8.4	3028	4.78E+06	573.63
25.3	6	1	360	8.3	2992	4.77E+06	573.63
25.4	6	1	360	8.2	2956	4.77E+06	573.62
25.5	6	1	360	8.1	2921	4.77E+06	573.62
30.5	300	0	0	8.0	144340	4.62E+06	573.34
35.5	300	0	0	3.3	59220	4.56E+06	573.23
40.5	300	0	0	1.8	32275	4.53E+06	573.17
45.5	300	0	0	1.1	20055	4.51E+06	573.13
50.5	300	0	0	0.7	13499	4.50E+06	573.10
55.5	300	0	0	0.5	9600	4.49E+06	573.08
65.5	600	0	0	0.4	14218	4.47E+06	573.06
75.5	600	0	0	0.2	7827	4.47E+06	573.04
85.5	600	0	0	0.1	4891	4.46E+06	573.03
95.5	600	0	0	0.1	3304	4.46E+06	573.03
105.5	600	0	0	0.1	2356	4.46E+06	573.02
115.5	600	0	0	0.0	1748	4.45E+06	573.02
125.5	600	0	0	0.0	1338	4.45E+06	573.01

Total volume of flow (ft^3)= Inflow = 9.38E+05 Outflow 8.72E+05

000290

TABLE D-2
POND ROUTING UNDER EXTREME CONDITIONS
POND 2 (NORTHWEST OF FEMP)
25-YEAR FREQUENCY AND 24 HOUR DURATION STORM

Initial Pond Storage 5.96E+06 ft^3 Initial Pond Elevation 566.33 feet
Time Step= 360 second
Pond Overflow El.= 573 feet
Weir Width = 5 feet

POND 2

Time (hour)	Time Step dt (min)	Inflow Rates I (ft^3/sec)	Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
10.9		0		0.0	0	5.96E+06	566.33
11	6	2	720	0.0	0	5.96E+06	566.33
11.1	6	3	1080	0.0	0	5.96E+06	566.34
11.2	6	3	1080	0.0	0	5.96E+06	566.34
11.3	6	4	1440	0.0	0	5.96E+06	566.34
11.4	6	4	1440	0.0	0	5.97E+06	566.34
11.5	6	4	1440	0.0	0	5.97E+06	566.34
11.6	6	4	1440	0.0	0	5.97E+06	566.35
11.7	6	5	1800	0.0	0	5.97E+06	566.35
11.8	6	5	1800	0.0	0	5.97E+06	566.35
11.9	6	6	2160	0.0	0	5.97E+06	566.36
12	6	7	2520	0.0	0	5.98E+06	566.36
12.1	6	8	2880	0.0	0	5.98E+06	566.37
12.2	6	10	3600	0.0	0	5.98E+06	566.37
12.3	6	15	5400	0.0	0	5.99E+06	566.38
12.4	6	22	7920	0.0	0	6.00E+06	566.39
12.5	6	36	12960	0.0	0	6.01E+06	566.41
12.6	6	54	19440	0.0	0	6.03E+06	566.45
12.7	6	77	27720	0.0	0	6.06E+06	566.49
12.8	6	98	35280	0.0	0	6.09E+06	566.55
12.9	6	108	38880	0.0	0	6.13E+06	566.61
13	6	117	42120	0.0	0	6.17E+06	566.68
13.1	6	112	40320	0.0	0	6.21E+06	566.75
13.2	6	107	38520	0.0	0	6.25E+06	566.81
13.3	6	94	33840	0.0	0	6.29E+06	566.87
13.4	6	82	29520	0.0	0	6.32E+06	566.92
13.5	6	72	25920	0.0	0	6.34E+06	566.96
13.6	6	62	22320	0.0	0	6.36E+06	567.00
13.7	6	54	19440	0.0	0	6.38E+06	567.03
13.8	6	47	16920	0.0	0	6.40E+06	567.06
13.9	6	42	15120	0.0	0	6.42E+06	567.08
14	6	38	13680	0.0	0	6.43E+06	567.11
14.1	6	35	12600	0.0	0	6.44E+06	567.13

POND 2

Time (hour)	Time Step dt (min)	Inflow Rates I (ft^3/sec)	Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
14.2	6	32	11520	0.0	0	6.45E+06	567.15
14.3	6	29	10440	0.0	0	6.46E+06	567.16
14.4	6	27	9720	0.0	0	6.47E+06	567.18
14.5	6	26	9360	0.0	0	6.48E+06	567.19
14.6	6	24	8640	0.0	0	6.49E+06	567.21
14.7	6	23	8280	0.0	0	6.50E+06	567.22
14.8	6	22	7920	0.0	0	6.51E+06	567.24
14.9	6	20	7200	0.0	0	6.51E+06	567.25
15	6	19	6840	0.0	0	6.52E+06	567.26
15.1	6	18	6480	0.0	0	6.53E+06	567.27
15.2	6	17	6120	0.0	0	6.53E+06	567.28
15.3	6	17	6120	0.0	0	6.54E+06	567.29
15.4	6	16	5760	0.0	0	6.55E+06	567.30
15.5	6	15	5400	0.0	0	6.55E+06	567.31
15.6	6	15	5400	0.0	0	6.56E+06	567.32
15.7	6	14	5040	0.0	0	6.56E+06	567.32
15.8	6	14	5040	0.0	0	6.57E+06	567.33
15.9	6	13	4680	0.0	0	6.57E+06	567
16	6	13	4680	0.0	0	6.58E+06	567.
16.1	6	13	4680	0.0	0	6.58E+06	567.36
16.2	6	12	4320	0.0	0	6.58E+06	567.36
16.3	6	12	4320	0.0	0	6.59E+06	567.37
16.4	6	11	3960	0.0	0	6.59E+06	567.38
16.5	6	11	3960	0.0	0	6.60E+06	567.38
16.6	6	11	3960	0.0	0	6.60E+06	567.39
16.7	6	10	3600	0.0	0	6.60E+06	567.40
16.8	6	10	3600	0.0	0	6.61E+06	567.40
16.9	6	9	3240	0.0	0	6.61E+06	567.41
17	6	9	3240	0.0	0	6.61E+06	567.41
17.1	6	9	3240	0.0	0	6.62E+06	567.42
17.2	6	9	3240	0.0	0	6.62E+06	567.42
17.3	6	9	3240	0.0	0	6.62E+06	567.43
17.4	6	9	3240	0.0	0	6.63E+06	567.43
17.5	6	9	3240	0.0	0	6.63E+06	567.44
17.6	6	9	3240	0.0	0	6.63E+06	567.44
17.7	6	9	3240	0.0	0	6.64E+06	567.45
17.8	6	8	2880	0.0	0	6.64E+06	567.45
17.9	6	8	2880	0.0	0	6.64E+06	567.46
18	6	8	2880	0.0	0	6.65E+06	567.46
18.1	6	8	2880	0.0	0	6.65E+06	567.47
18.2	6	8	2880	0.0	0	6.65E+06	567
18.3	6	8	2880	0.0	0	6.65E+06	567
18.4	6	8	2880	0.0	0	6.66E+06	567.48
18.5	6	8	2880	0.0	0	6.66E+06	567.49
18.6	6	7	2520	0.0	0	6.66E+06	567.49

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POND 2

Time (hour)	Time Step dt (min)	Inflow Rates I (ft^3/sec)	Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
18.7	6	7	2520	0.0	0	6.67E+06	567.50
18.8	6	7	2520	0.0	0	6.67E+06	567.50
18.9	6	7	2520	0.0	0	6.67E+06	567.50
19	6	7	2520	0.0	0	6.67E+06	567.51
19.1	6	7	2520	0.0	0	6.68E+06	567.51
19.2	6	7	2520	0.0	0	6.68E+06	567.52
19.3	6	7	2520	0.0	0	6.68E+06	567.52
19.4	6	7	2520	0.0	0	6.68E+06	567.53
19.5	6	6	2160	0.0	0	6.69E+06	567.53
19.6	6	6	2160	0.0	0	6.69E+06	567.53
19.7	6	6	2160	0.0	0	6.69E+06	567.54
19.8	6	6	2160	0.0	0	6.69E+06	567.54
19.9	6	6	2160	0.0	0	6.69E+06	567.54
20	6	6	2160	0.0	0	6.70E+06	567.55
20.1	6	6	2160	0.0	0	6.70E+06	567.55
20.2	6	6	2160	0.0	0	6.70E+06	567.55
20.3	6	6	2160	0.0	0	6.70E+06	567.56
20.4	6	6	2160	0.0	0	6.70E+06	567.56
20.5	6	6	2160	0.0	0	6.71E+06	567.56
20.6	6	6	2160	0.0	0	6.71E+06	567.57
20.7	6	6	2160	0.0	0	6.71E+06	567.57
20.8	6	6	2160	0.0	0	6.71E+06	567.58
20.9	6	6	2160	0.0	0	6.72E+06	567.58
21	6	6	2160	0.0	0	6.72E+06	567.58
21.1	6	5	1800	0.0	0	6.72E+06	567.59
21.2	6	5	1800	0.0	0	6.72E+06	567.59
21.3	6	5	1800	0.0	0	6.72E+06	567.59
21.4	6	5	1800	0.0	0	6.73E+06	567.59
21.5	6	5	1800	0.0	0	6.73E+06	567.60
21.6	6	5	1800	0.0	0	6.73E+06	567.60
21.7	6	5	1800	0.0	0	6.73E+06	567.60
21.8	6	5	1800	0.0	0	6.73E+06	567.61
21.9	6	5	1800	0.0	0	6.73E+06	567.61
22	6	5	1800	0.0	0	6.74E+06	567.61
22.1	6	5	1800	0.0	0	6.74E+06	567.61
22.2	6	5	1800	0.0	0	6.74E+06	567.62
22.3	6	5	1800	0.0	0	6.74E+06	567.62
22.4	6	4	1440	0.0	0	6.74E+06	567.62
22.5	6	4	1440	0.0	0	6.74E+06	567.63
22.6	6	4	1440	0.0	0	6.75E+06	567.63
22.7	6	4	1440	0.0	0	6.75E+06	567.63
22.8	6	4	1440	0.0	0	6.75E+06	567.63
22.9	6	4	1440	0.0	0	6.75E+06	567.64
23	6	4	1440	0.0	0	6.75E+06	567.64
23.1	6	4	1440	0.0	0	6.75E+06	567.64

POND 2

Time (hour)	Time Step dt (min)	Inflow Rates I (ft^3/sec)	Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
23.2	6	4	1440	0.0	0	6.75E+06	567.64
23.3	6	3	1080	0.0	0	6.76E+06	567.64
23.4	6	3	1080	0.0	0	6.76E+06	567.65
23.5	6	3	1080	0.0	0	6.76E+06	567.65
23.6	6	3	1080	0.0	0	6.76E+06	567.65
23.7	6	3	1080	0.0	0	6.76E+06	567.65
23.8	6	3	1080	0.0	0	6.76E+06	567.65
23.9	6	3	1080	0.0	0	6.76E+06	567.65
24	6	2	720	0.0	0	6.76E+06	567.66
24.1	6	2	720	0.0	0	6.76E+06	567.66
24.2	6	2	720	0.0	0	6.76E+06	567.66
24.3	6	2	720	0.0	0	6.76E+06	567.66
24.4	6	2	720	0.0	0	6.77E+06	567.66
24.5	6	2	720	0.0	0	6.77E+06	567.66
24.6	6	2	720	0.0	0	6.77E+06	567.66
24.7	6	2	720	0.0	0	6.77E+06	567.66
24.8	6	2	720	0.0	0	6.77E+06	567.67
24.9	6	1	360	0.0	0	6.77E+06	567
25	6	1	360	0.0	0	6.77E+06	567
25.1	6	1	360	0.0	0	6.77E+06	567.67
25.2	6	1	360	0.0	0	6.77E+06	567.67
25.3	6	1	360	0.0	0	6.77E+06	567.67
25.4	6	1	360	0.0	0	6.77E+06	567.67
25.5	6	1	360	0.0	0	6.77E+06	567.67
30.5	300	0	0	0.0	0	6.77E+06	567.67
35.5	300	0	0	0.0	0	6.77E+06	567.67
40.5	300	0	0	0.0	0	6.77E+06	567.67
45.5	300	0	0	0.0	0	6.77E+06	567.67
50.5	300	0	0	0.0	0	6.77E+06	567.67
55.5	300	0	0	0.0	0	6.77E+06	567.67
65.5	600	0	0	0.0	0	6.77E+06	567.67
75.5	600	0	0	0.0	0	6.77E+06	567.67
85.5	600	0	0	0.0	0	6.77E+06	567.67
95.5	600	0	0	0.0	0	6.77E+06	567.67
105.5	600	0	0	0.0	0	6.77E+06	567.67
115.5	600	0	0	0.0	0	6.77E+06	567.67
125.5	600	0	0	0.0	0	6.77E+06	567.67

Total volume of flow (ft^3) Inflow = 8.11E+05 Outflow = 0.00E+00

TABLE D-3
POND ROUTING UNDER EXTREME CONDITIONS
POND 3 (SOUTHEAST OF FEMP, BORROWED AREA)
25-YEAR FREQUENCY AND 24 HOUR DURATION STORM

Initial Pond Storage 1.93E+06 ft^3 Initial Pond Elevation 578.00 feet
Time Step= 360 second
Pond Overflow El.= 578 feet Pond 3 overflow to SSOD
Weir Width = 5 feet

POND 3

Time (hour)	Time Step dt (min)	Inflow Rates I (ft^3/sec)	Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
11	0	0		0.0	0	1.93E+06	578.00
11.1	6	3	1080	0.0	0	1.93E+06	578.00
11.2	6	4	1440	0.0	0	1.93E+06	578.00
11.3	6	4	1440	0.0	1	1.93E+06	578.01
11.4	6	5	1800	0.0	3	1.94E+06	578.01
11.5	6	5	1800	0.0	7	1.94E+06	578.02
11.6	6	6	2160	0.0	12	1.94E+06	578.02
11.7	6	7	2520	0.1	18	1.94E+06	578.03
11.8	6	7	2520	0.1	27	1.94E+06	578.03
11.9	6	8	2880	0.1	37	1.95E+06	578.04
12	6	12	4320	0.1	49	1.95E+06	578.05
12.1	6	20	7200	0.2	69	1.96E+06	578.07
12.2	6	32	11520	0.3	108	1.97E+06	578.10
12.3	6	53	19080	0.5	181	1.99E+06	578.14
12.4	6	72	25920	0.9	327	2.01E+06	578.21
12.5	6	87	31320	1.6	565	2.05E+06	578.29
12.6	6	93	33480	2.5	904	2.08E+06	578.37
12.7	6	94	33840	3.7	1316	2.11E+06	578.45
12.8	6	95	34200	4.9	1777	2.14E+06	578.53
12.9	6	92	33120	6.3	2279	2.17E+06	578.60
13	6	90	32400	7.8	2794	2.20E+06	578.68
13.1	6	82	29520	9.2	3321	2.23E+06	578.74
13.2	6	75	27000	10.6	3811	2.25E+06	578.80
13.3	6	67	24120	11.8	4263	2.27E+06	578.85
13.4	6	60	21600	13.0	4664	2.29E+06	578.89
13.5	6	54	19440	13.9	5015	2.30E+06	578.93
13.6	6	47	16920	14.8	5321	2.32E+06	578.96
13.7	6	42	15120	15.5	5571	2.33E+06	578.98
13.8	6	37	13320	16.1	5780	2.33E+06	579.00
13.9	6	34	12240	16.5	5946	2.34E+06	579.02
14	6	31	11160	16.9	6087	2.34E+06	579.03
14.1	6	29	10440	17.2	6200	2.35E+06	579.04
14.2	6	26	9360	17.5	6296	2.35E+06	579.05

POND 3

Time (hour)	Time Step dt (min)	Inflow Rates I (ft^3/sec)	Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
14.3	6	24	8640	17.7	6366	2.35E+06	579.05
14.4	6	23	8280	17.8	6417	2.36E+06	579.06
14.5	6	21	7560	17.9	6460	2.36E+06	579.06
14.6	6	20	7200	18.0	6485	2.36E+06	579.06
14.7	6	19	6840	18.1	6501	2.36E+06	579.06
14.8	6	18	6480	18.1	6509	2.36E+06	579.06
14.9	6	16	5760	18.1	6508	2.36E+06	579.06
15	6	15	5400	18.0	6491	2.36E+06	579.06
15.1	6	15	5400	18.0	6466	2.35E+06	579.06
15.2	6	14	5040	17.9	6442	2.35E+06	579.05
15.3	6	14	5040	17.8	6410	2.35E+06	579.05
15.4	6	13	4680	17.7	6379	2.35E+06	579.04
15.5	6	13	4680	17.6	6340	2.35E+06	579.04
15.6	6	13	4680	17.5	6303	2.35E+06	579.04
15.7	6	13	4680	17.4	6266	2.35E+06	579.03
15.8	6	12	4320	17.3	6230	2.34E+06	579.03
15.9	6	12	4320	17.2	6187	2.34E+06	579.02
16	6	12	4320	17.1	6145	2.34E+06	579.[illegible]
16.1	6	12	4320	17.0	6104	2.34E+06	579.[illegible]
16.2	6	11	3960	16.8	6064	2.34E+06	579.01
16.3	6	11	3960	16.7	6017	2.33E+06	579.00
16.4	6	10	3600	16.6	5972	2.33E+06	579.00
16.5	6	10	3600	16.4	5919	2.33E+06	578.99
16.6	6	10	3600	16.3	5868	2.33E+06	578.99
16.7	6	10	3600	16.2	5818	2.32E+06	578.98
16.8	6	9	3240	16.0	5769	2.32E+06	578.97
16.9	6	9	3240	15.9	5713	2.32E+06	578.97
17	6	9	3240	15.7	5659	2.32E+06	578.96
17.1	6	9	3240	15.6	5606	2.32E+06	578.96
17.2	6	9	3240	15.4	5555	2.31E+06	578.95
17.3	6	9	3240	15.3	5505	2.31E+06	578.94
17.4	6	9	3240	15.2	5456	2.31E+06	578.94
17.5	6	9	3240	15.0	5408	2.31E+06	578.93
17.6	6	9	3240	14.9	5361	2.30E+06	578.93
17.7	6	9	3240	14.8	5316	2.30E+06	578.92
17.8	6	9	3240	14.6	5272	2.30E+06	578.92
17.9	6	9	3240	14.5	5228	2.30E+06	578.91
18	6	9	3240	14.4	5186	2.30E+06	578.91
18.1	6	9	3240	14.3	5145	2.29E+06	578.90
18.2	6	9	3240	14.2	5105	2.29E+06	578.90
18.3	6	8	2880	14.1	5065	2.29E+06	578.8[illegible]
18.4	6	8	2880	13.9	5019	2.29E+06	578.[illegible]
18.5	6	8	2880	13.8	4975	2.29E+06	578.88
18.6	6	8	2880	13.7	4931	2.28E+06	578.88
18.7	6	8	2880	13.6	4888	2.28E+06	578.87

POND 3

Time (hour)	Time Step dt (min)	Inflow Rates I (ft^3/sec)	Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
18.8	6	7	2520	13.5	4846	2.28E+06	578.87
18.9	6	7	2520	13.3	4798	2.28E+06	578.86
19	6	7	2520	13.2	4751	2.27E+06	578.86
19.1	6	7	2520	13.1	4705	2.27E+06	578.85
19.2	6	7	2520	12.9	4661	2.27E+06	578.85
19.3	6	6	2160	12.8	4617	2.27E+06	578.84
19.4	6	6	2160	12.7	4567	2.27E+06	578.83
19.5	6	6	2160	12.5	4518	2.26E+06	578.83
19.6	6	6	2160	12.4	4470	2.26E+06	578.82
19.7	6	6	2160	12.3	4424	2.26E+06	578.82
19.8	6	5	1800	12.2	4378	2.26E+06	578.81
19.9	6	5	1800	12.0	4327	2.25E+06	578.80
20	6	5	1800	11.9	4276	2.25E+06	578.80
20.1	6	5	1800	11.7	4227	2.25E+06	578.79
20.2	6	5	1800	11.6	4179	2.25E+06	578.79
20.3	6	5	1800	11.5	4132	2.24E+06	578.78
20.4	6	5	1800	11.4	4086	2.24E+06	578.77
20.5	6	5	1800	11.2	4042	2.24E+06	578.77
20.6	6	5	1800	11.1	3998	2.24E+06	578.76
20.7	6	5	1800	11.0	3955	2.24E+06	578.76
20.8	6	5	1800	10.9	3914	2.23E+06	578.75
20.9	6	5	1800	10.8	3873	2.23E+06	578.75
21	6	5	1800	10.6	3833	2.23E+06	578.74
21.1	6	5	1800	10.5	3794	2.23E+06	578.74
21.2	6	5	1800	10.4	3756	2.22E+06	578.73
21.3	6	5	1800	10.3	3719	2.22E+06	578.73
21.4	6	5	1800	10.2	3682	2.22E+06	578.72
21.5	6	5	1800	10.1	3647	2.22E+06	578.72
21.6	6	5	1800	10.0	3612	2.22E+06	578.71
21.7	6	5	1800	9.9	3578	2.22E+06	578.71
21.8	6	5	1800	9.8	3545	2.21E+06	578.70
21.9	6	5	1800	9.8	3512	2.21E+06	578.70
22	6	5	1800	9.7	3480	2.21E+06	578.70
22.1	6	5	1800	9.6	3449	2.21E+06	578.69
22.2	6	5	1800	9.5	3419	2.21E+06	578.69
22.3	6	5	1800	9.4	3389	2.21E+06	578.68
22.4	6	4	1440	9.3	3360	2.20E+06	578.68
22.5	6	4	1440	9.2	3324	2.20E+06	578.67
22.6	6	4	1440	9.1	3290	2.20E+06	578.67
22.7	6	4	1440	9.0	3256	2.20E+06	578.67
22.8	6	4	1440	9.0	3223	2.20E+06	578.66
22.9	6	4	1440	8.9	3191	2.19E+06	578.66
23	6	4	1440	8.8	3160	2.19E+06	578.65
23.1	6	4	1440	8.7	3129	2.19E+06	578.65
23.2	6	4	1440	8.6	3099	2.19E+06	578.64

POND 3

Time (hour)	Time Step dt (min)	Inflow Rates I (ft^3/sec)	Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
23.3	6	3	1080	8.5	3069	2.19E+06	578.64
23.4	6	3	1080	8.4	3034	2.19E+06	578.63
23.5	6	3	1080	8.3	2999	2.18E+06	578.63
23.6	6	3	1080	8.2	2965	2.18E+06	578.62
23.7	6	3	1080	8.1	2932	2.18E+06	578.62
23.8	6	3	1080	8.1	2900	2.18E+06	578.62
23.9	6	3	1080	8.0	2868	2.18E+06	578.61
24	6	2	720	7.9	2837	2.17E+06	578.61
24.1	6	2	720	7.8	2800	2.17E+06	578.60
24.2	6	2	720	7.7	2764	2.17E+06	578.60
24.3	6	2	720	7.6	2729	2.17E+06	578.59
24.4	6	2	720	7.5	2695	2.17E+06	578.59
24.5	6	2	720	7.4	2661	2.16E+06	578.58
24.6	6	2	720	7.3	2628	2.16E+06	578.58
24.7	6	2	720	7.2	2596	2.16E+06	578.57
24.8	6	2	720	7.1	2565	2.16E+06	578.57
24.9	6	1	360	7.0	2534	2.16E+06	578.56
25	6	1	360	6.9	2497	2.15E+06	578.
25.1	6	1	360	6.8	2462	2.15E+06	578.
25.2	6	1	360	6.7	2427	2.15E+06	578.55
25.3	6	1	360	6.6	2393	2.15E+06	578.54
25.4	6	1	360	6.6	2360	2.15E+06	578.54
25.5	6	1	360	6.5	2327	2.14E+06	578.53
25.6	6	0	0	6.4	2296	2.14E+06	578.52
26.5	60	0	0	6.4	22956	2.12E+06	578.47
31.5	300	0	0	5.4	96731	2.02E+06	578.23
36.5	300	0	0	1.8	33273	1.99E+06	578.15
41.5	300	0	0	1.0	17168	1.97E+06	578.11
46.5	300	0	0	0.6	10356	1.96E+06	578.08
51.5	300	0	0	0.4	6838	1.96E+06	578.06
61.5	600	0	0	0.3	9594	1.95E+06	578.04
71.5	600	0	0	0.1	4751	1.94E+06	578.03
81.5	600	0	0	0.1	2807	1.94E+06	578.02
91.5	600	0	0	0.1	1829	1.94E+06	578.02
101.5	600	0	0	0.0	1271	1.94E+06	578.01
111.5	600	0	0	0.0	926	1.94E+06	578.01
121.5	600	0	0	0.0	698	1.93E+06	578.01

Total volume of flow (ft^3) Inflow = 7.87E+05 Outflow= 7.45E+05

TABLE D-4
POND ROUTING UNDER EXTREME CONDITIONS
POND 4 (RETENTION POND- SOUTHWEST OF FEMP)
25-YEAR FREQUENCY AND 24 HOUR DURATION STORM
FEMP

Initial Pond Storage 2.55E+06 ft^3 Initial Pond Elevation 560.00 feet
Time Step= 360 second
Pond Overflow El.= 560 feet
Weir Width = 20 feet

POND 4

Time (hour)	Time Step dt (min)	Storm Inflow Rates (ft^3/sec)	Inflow from Pond 2 (ft^3/sec)	Total Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
11	0	0	0	0	0.0	0	2.55E+06	560.00
11.1	6	1	0	360	0.0	4	2.55E+06	560.00
11.2	6	1	0	360	0.0	7	2.55E+06	560.01
11.3	6	1	0	360	0.0	11	2.55E+06	560.01
11.4	6	1	0	360	0.0	15	2.55E+06	560.01
11.5	6	2	0	720	0.1	20	2.55E+06	560.01
11.6	6	2	0	720	0.1	30	2.55E+06	560.01
11.7	6	2	0	720	0.1	42	2.55E+06	560.02
11.8	6	2	0	720	0.2	54	2.55E+06	560.02
11.9	6	2	0	720	0.2	68	2.55E+06	560.02
12	6	3	0	1080	0.2	82	2.56E+06	560.03
12.1	6	3	0	1080	0.3	105	2.56E+06	560.03
12.2	6	4	0	1440	0.4	129	2.56E+06	560.04
12.3	6	7	0	2520	0.5	164	2.56E+06	560.05
12.4	6	10	0	3600	0.7	234	2.56E+06	560.06
12.5	6	14	0	5040	1.0	347	2.57E+06	560.08
12.6	6	19	0	6840	1.5	529	2.57E+06	560.11
12.7	6	23	0	8280	2.2	809	2.58E+06	560.14
12.8	6	29	0	10440	3.3	1189	2.59E+06	560.17
12.9	6	33	0	11880	4.8	1722	2.60E+06	560.22
13	6	37	0	13320	6.6	2378	2.61E+06	560.26
13.1	6	40	0	14400	8.8	3160	2.62E+06	560.31
13.2	6	43	0	15480	11.2	4037	2.64E+06	560.35
13.3	6	42	0	15120	13.9	5000	2.65E+06	560.40
13.4	6	41	0	14760	16.4	5908	2.65E+06	560.43
13.5	6	38	0	13680	18.7	6742	2.66E+06	560.46
13.6	6	35	0	12600	20.6	7421	2.67E+06	560.48
13.7	6	32	0	11520	22.1	7942	2.67E+06	560.50
13.8	6	28	0	10080	23.1	8308	2.67E+06	560.50
13.9	6	26	0	9360	23.6	8492	2.67E+06	560.51
14	6	23	0	8280	23.8	8582	2.67E+06	560.51
14.1	6	21	0	7560	23.8	8551	2.67E+06	560.50
14.2	6	19	0	6840	23.5	8448	2.67E+06	560.50

POND 4

Time (hour)	Time Step dt (min)	Storm Inflow Rates (ft^3/sec)	Inflow from Pond 2 (ft^3/sec)	Total Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
14.3	6	17	0	6120	23.0	8281	2.67E+06	560.49
14.4	6	16	0	5760	22.4	8060	2.67E+06	560.48
14.5	6	14	0	5040	21.7	7826	2.66E+06	560.47
14.6	6	13	0	4680	21.0	7545	2.66E+06	560.45
14.7	6	12	0	4320	20.2	7261	2.66E+06	560.44
14.8	6	12	0	4320	19.4	6973	2.65E+06	560.43
14.9	6	11	0	3960	18.7	6716	2.65E+06	560.42
15	6	10	0	3600	17.9	6453	2.65E+06	560.41
15.1	6	9	0	3240	17.2	6184	2.65E+06	560.40
15.2	6	9	0	3240	16.4	5910	2.64E+06	560.38
15.3	6	8	0	2880	15.7	5666	2.64E+06	560.37
15.4	6	8	0	2880	15.0	5415	2.64E+06	560.36
15.5	6	7	0	2520	14.4	5190	2.63E+06	560.35
15.6	6	7	0	2520	13.8	4956	2.63E+06	560.34
15.7	6	7	0	2520	13.2	4746	2.63E+06	560.33
15.8	6	6	0	2160	12.7	4556	2.63E+06	560.32
15.9	6	6	0	2160	12.1	4355	2.63E+06	560.31
16	6	6	0	2160	11.6	4174	2.62E+06	[illegible]
16.1	6	6	0	2160	11.1	4010	2.62E+06	[illegible]
16.2	6	6	0	2160	10.7	3861	2.62E+06	560.29
16.3	6	5	0	1800	10.3	3726	2.62E+06	560.28
16.4	6	5	0	1800	9.9	3575	2.62E+06	560.28
16.5	6	5	0	1800	9.5	3437	2.61E+06	560.27
16.6	6	5	0	1800	9.2	3312	2.61E+06	560.26
16.7	6	5	0	1800	8.9	3198	2.61E+06	560.26
16.8	6	5	0	1800	8.6	3093	2.61E+06	560.25
16.9	6	5	0	1800	8.3	2998	2.61E+06	560.25
17	6	5	0	1800	8.1	2910	2.61E+06	560.24
17.1	6	5	0	1800	7.9	2830	2.61E+06	560.24
17.2	6	5	0	1800	7.7	2756	2.61E+06	560.23
17.3	6	4	0	1440	7.5	2688	2.60E+06	560.23
17.4	6	4	0	1440	7.2	2600	2.60E+06	560.22
17.5	6	4	0	1440	7.0	2519	2.60E+06	560.22
17.6	6	4	0	1440	6.8	2445	2.60E+06	560.22
17.7	6	4	0	1440	6.6	2376	2.60E+06	560.21
17.8	6	4	0	1440	6.4	2313	2.60E+06	560.21
17.9	6	4	0	1440	6.3	2254	2.60E+06	560.20
18	6	4	0	1440	6.1	2200	2.60E+06	560.20
18.1	6	4	0	1440	6.0	2150	2.60E+06	560.20
18.2	6	4	0	1440	5.8	2103	2.60E+06	560.20
18.3	6	4	0	1440	5.7	2060	2.60E+06	[illegible]
18.4	6	4	0	1440	5.6	2020	2.60E+06	[illegible]
18.5	6	4	0	1440	5.5	1983	2.60E+06	560.19
18.6	6	4	0	1440	5.4	1948	2.59E+06	560.19
18.7	6	4	0	1440	5.3	1916	2.59E+06	560.18

POND 4

Time (hour)	Time Step dt (min)	Storm Inflow Rates (ft^3/sec)	Inflow from Pond 2 (ft^3/sec)	Total Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Pond Stage (ft)
18.8	6	4	0	1440	5.2	1886	2.59E+06	560.18
18.9	6	4	0	1440	5.2	1858	2.59E+06	560.18
19	6	4	0	1440	5.1	1832	2.59E+06	560.18
19.1	6	4	0	1440	5.0	1807	2.59E+06	560.18
19.2	6	4	0	1440	5.0	1784	2.59E+06	560.18
19.3	6	4	0	1440	4.9	1763	2.59E+06	560.18
19.4	6	4	0	1440	4.8	1743	2.59E+06	560.17
19.5	6	4	0	1440	4.8	1725	2.59E+06	560.17
19.6	6	3	0	1080	4.7	1707	2.59E+06	560.17
19.7	6	3	0	1080	4.6	1669	2.59E+06	560.17
19.8	6	3	0	1080	4.5	1634	2.59E+06	560.17
19.9	6	3	0	1080	4.4	1601	2.59E+06	560.16
20	6	3	0	1080	4.4	1570	2.59E+06	560.16
20.1	6	3	0	1080	4.3	1541	2.59E+06	560.16
20.2	6	3	0	1080	4.2	1514	2.59E+06	560.16
20.3	6	3	0	1080	4.1	1488	2.59E+06	560.16
20.4	6	3	0	1080	4.1	1465	2.59E+06	560.15
20.5	6	3	0	1080	4.0	1443	2.59E+06	560.15
20.6	6	3	0	1080	3.9	1422	2.59E+06	560.15
20.7	6	3	0	1080	3.9	1402	2.59E+06	560.15
20.8	6	3	0	1080	3.8	1384	2.59E+06	560.15
20.9	6	3	0	1080	3.8	1367	2.59E+06	560.15
21	6	2	0	720	3.8	1350	2.58E+06	560.15
21.1	6	2	0	720	3.7	1315	2.58E+06	560.14
21.2	6	2	0	720	3.6	1282	2.58E+06	560.14
21.3	6	2	0	720	3.5	1251	2.58E+06	560.14
21.4	6	2	0	720	3.4	1222	2.58E+06	560.14
21.5	6	2	0	720	3.3	1195	2.58E+06	560.13
21.6	6	2	0	720	3.2	1169	2.58E+06	560.13
21.7	6	2	0	720	3.2	1145	2.58E+06	560.13
21.8	6	2	0	720	3.1	1122	2.58E+06	560.13
21.9	6	2	0	720	3.1	1101	2.58E+06	560.13
22	6	2	0	720	3.0	1081	2.58E+06	560.13
22.1	6	2	0	720	3.0	1062	2.58E+06	560.12
22.2	6	2	0	720	2.9	1045	2.58E+06	560.12
22.3	6	2	0	720	2.9	1028	2.58E+06	560.12
22.4	6	2	0	720	2.8	1012	2.58E+06	560.12
22.5	6	2	0	720	2.8	997	2.58E+06	560.12
22.6	6	2	0	720	2.7	983	2.58E+06	560.12
22.7	6	2	0	720	2.7	970	2.58E+06	560.12
22.8	6	2	0	720	2.7	957	2.58E+06	560.12
22.9	6	2	0	720	2.6	945	2.58E+06	560.12
23	6	2	0	720	2.6	934	2.58E+06	560.11
23.1	6	1	0	360	2.6	923	2.58E+06	560.11
23.2	6	1	0	360	2.5	896	2.58E+06	560.11

POND 4

Time (hour)	Time Step dt (min)	Storm Inflow Rates (ft^3/sec)	Inflow from Pond 2 (ft^3/sec)	Total Inflow Volume I*dt (ft^3)	Outflow from Weir O (ft^3/sec)	Outflow Volume O*dt (ft^3)	Pond Storage S (ft^3)	Po.. Stage (ft)
23.3	6	1	0	360	2.4	869	2.58E+06	560.11
23.4	6	1	0	360	2.3	845	2.58E+06	560.11
23.5	6	1	0	360	2.3	822	2.57E+06	560.10
23.6	6	1	0	360	2.2	800	2.57E+06	560.10
23.7	6	1	0	360	2.2	779	2.57E+06	560.10
23.8	6	1	0	360	2.1	759	2.57E+06	560.10
23.9	6	1	0	360	2.1	741	2.57E+06	560.10
24	6	1	0	360	2.0	723	2.57E+06	560.10
24.1	6	1	0	360	2.0	707	2.57E+06	560.09
24.2	6	1	0	360	1.9	691	2.57E+06	560.09
24.3	6	1	0	360	1.9	676	2.57E+06	560.09
24.4	6	1	0	360	1.8	662	2.57E+06	560.09
24.5	6	1	0	360	1.8	649	2.57E+06	560.09
24.6	6	1	0	360	1.8	636	2.57E+06	560.09
24.7	6	1	0	360	1.7	624	2.57E+06	560.09
24.8	6	1	0	360	1.7	613	2.57E+06	560.09
24.9	6	1	0	360	1.7	602	2.57E+06	560.09
25	6	0	0	0	1.6	591	2.57E+06	5[illegible]
25.1	6	0	0	0	1.6	566	2.57E+06	5[illegible]
25.2	6	0	0	0	1.5	542	2.57E+06	560.[illegible]
25.3	6	0	0	0	1.4	520	2.57E+06	560.08
25.4	6	0	0	0	1.4	499	2.57E+06	560.07
25.5	6	0	0	0	1.3	479	2.57E+06	560.07
25.6	6	0	0	0	1.3	460	2.57E+06	560.07
26.5	54	0	0	0	1.2	3977	2.56E+06	560.05
31.5	300	0	0	0	0.8	14844	2.55E+06	559.99
36.5	300	0	0	0	0.0	0	2.55E+06	559.99
41.5	300	0	0	0	0.0	0	2.55E+06	559.99
46.5	300	0	0	0	0.0	0	2.55E+06	559.99
51.5	300	0	0	0	0.0	0	2.55E+06	559.99
61.5	600	0	0	0	0.0	0	2.55E+06	559.99
71.5	600	0	0	0	0.0	0	2.55E+06	559.99
81.5	600	0	0	0	0.0	0	2.55E+06	559.99
91.5	600	0	0	0	0.0	0	2.55E+06	559.99
101.5	600	0	0	0	0.0	0	2.55E+06	559.99
111.5	600	0	0	0	0.0	0	2.55E+06	559.99
121.5	600	0	0	0	0.0	0	2.55E+06	559.99

Total volume of flow (ft^3)= Inflow = 3.67E+05 Outflow 3.69E+05