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U.S. EPA Clean Lakes Program, Phase I Diagnostic-Feasibility Study of the Upper St. Johns River Chain of Lakes Volume II - Feasibility Study

by

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ABSTRACT

Research was conducted, as part of a U.S. EPA Clean Lakes Phase I Study to define feasible methodologies for reversing the ecological decline of lakes of the upper St. Johns River basin. Ecological problems addressed included declines in the populations of fish, waterfowl and wading birds; alteration of the community structure of floodplain vegetation; soil subsidence; acceleration of sedimentation in one basin lake; and degradation of water quality. These conditions primarily resulted from altered surface water hydrology and loss of wetland habit and may have been augmented by pollutant loads from borrow canals and agricultural pumps. Due to the large area affected and the magnitude of corrective measures required, the most feasible means of restoration appears to be the federally funded water control project, the Upper Basin Project (UBP) to be constructed by the U. S. Army Corps of Engineers with the St. Johns River Water Management District as local sponsor. Various designs and operation schedules for the UBP were developed and tested in order to allow ecological restoration while still meeting the flood control and water supply objectives of the UBP. In order to satisfy environmental goals, the UBP will employ a semi-structural approach to water management in which the flood control and water supply objectives of the project will be met to the extent practical through wetland acquisition and restoration. The

ecological decline of lakes in the basin will be ameliorated by the UBP through restoration of floodplain wetlands, to the extent practical, and through improvement of the hydrologic regime of existing wetlands.

Computer simulations of the proposed project indicate that previously developed wetlands can not feasibly be restored to their pre-development condition because of severe subsidence. The hydrologic regime of existing wetlands, however, will be improved by the creation of artificial water storage areas, extenuation of interbasin diversion, and operation of the projects structural components. The project should also enhance the water quality of the river and its lakes through segregating agricultural discharges from the river system and restoring sheetflow.

INTRODUCTION

In its pristine state, the upper St. Johns River consisted of a chain of shallow lakes lying within a large floodplain marsh. As an integral component of a riverine, lacustrine and palustrine ecosystem, the wetlands of the upper St. Johns directly affect the integrity of the lakes. In 1912 - 1914 a road was constructed across the marsh north of the headwater lake, Blue Cypress Lake. This marked the beginning of physical and hydrological alteration of the floodplain, primarily to support agricultural development. Since construction of the road, the remnants of which form the Fellsmere Grade, the floodplain and river have been segmented by other roads and by dams, drained through channelization and through the diversion of water to the coast, and managed to support pasture, citrus and vegetable agriculture (Figure 1). The loss of floodplain storage, the channelization of the floodplain, and the interbasin diversion of water created a water supply problem during dry periods whereas the placement of valuable agricultural lands within the natural floodplain created a potential for economic damage from floods during wet periods.

In order to address these water management problems, a federal flood control project was authorized by congress in 1962. Construction of the Upper Basin Project (UBP) was initiated by the U.S. Army Corps of Engineers (COE) in 1969 (with the Central and Southern Florida Flood Control District acting as local sponsor), but was halted in 1972

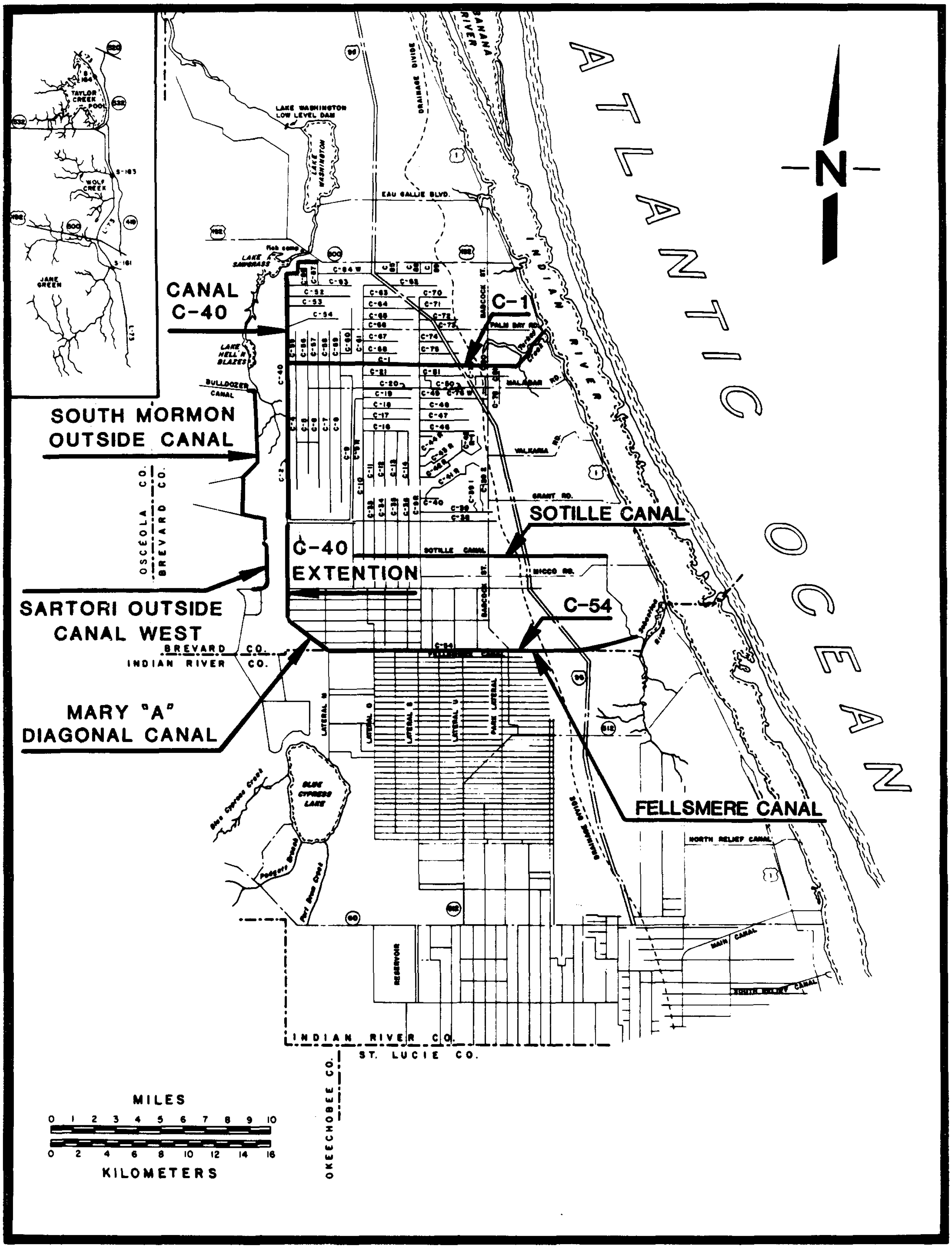

FIGURE 1. Physical Features of the Upper St. Johns

due to environmental concerns. These concerns stemmed from a growing awareness of the natural values of the river and its floodplain and from recognition of the devastating impacts to upland swamps which would result from the construction of upland impoundments proposed by the Corps.

On October 27, 1976, the St. Johns River Water Management District (District) assumed local sponsorship of the UBP. As empowered and mandated by the Florida Water Resources Act of 1972, the District expanded the project objectives to include the preservation, and in some areas the restoration, of natural resources such as vegetation, fish and wildlife. Thus the project had to be redesigned to accomplish ecological goals in addition to the original economic goals.

Since 1972, when the original UBP was halted, ecological understanding of the basin has grown considerably (Cox et al., 1976, 1982; Belanger et al., 1976; Lowe et al., 1984). It is now apparent that development of the floodplain has had detrimental ecological effects on the basin's lakes including declines in the populations of fish, waterfowl and wading birds; alteration of the community structure of floodplain vegetation; soil subsidence; acceleration of sedimentation rates in Lake Hell 'n Blazes; and degradation of water quality (Lowe, et al., 1984). In order to define specific methodologies for reversal of these trends the District conducted research under a U.S. EPA Clean Lakes Diagnostic/Feasibility grant to the Florida

Department of Environmental Regulation. Part of this work, the diagnostic study, was designed to elucidate suspected types and causes of ecological harm (Lowe et al., 1984). The results of this diagnostic study were then utilized to develop restoration goals. These goals, and feasible means of attaining them, are the subject of this paper which documents the results of the feasibility portion of the Clean Lakes study.

RESTORATION CONCEPTS

Maintenance of Status Quo

Before the goals and means of an ecological restoration of the basin are discussed, it is valuable to consider what would be required to maintain the status quo and what the ecological implications of such a strategy might be. Maintenance of status quo is the minimum effort acceptable for management of the upper basin but is not synonymous with doing nothing. Development of the basin continues to reduce the acreage of floodplain wetland and intensify the use of previously developed lands. Maintenance of the status quo would therefore necessitate public land acquisition and regulation of hydrologic modifications on private lands.

In recognition of the intense development pressure in the basin, the St. Johns River Water Management District has been actively acquiring floodplain for several years. This process was greatly facilitated by the passage of Senate Bill #520 in June of 1981 (Save Our Rivers Program). This legislation sets aside funds, generated from taxes on land sales, for the purchase of privately owned floodplain. It is predicted that 75-80 million dollars will be generated state-wide over the life of the Save Our Rivers Program (10 years). As part of a program to maintain status quo, land acquisition would be limited to undeveloped wetlands.

In addition to land acquisition, effective regulation of surface water consumption, routing and storage, would be essential to maintenance of the basin's hydrologic regime.

The District has exercised regulatory jurisdiction in the basin since January 1, 1977. As a result of improved understanding of the basin, the old rules regarding surface water use have been revised to provide for more effective regulation of surface waters under both high and low flow conditions.

Refinement and enforcement of rules and acquisition of undeveloped lands will not improve existing environmental conditions and under existing conditions the deleterious ecological trends presently in progress may continue until an equilibrium is attained. The time required for stabilization of these trends and the state of the basin at equilibrium cannot be accurately predicted. It appears, however, that the basin will have lost most of the recreational, hydrological and ecological values it once had in abundance. Considering the high regional value of the river and the associated lakes and the evidence for continuing ecological decline (Lowe et al., 1984), maintenance of the existing system cannot be considered an acceptable approach to river and lake management for public benefits.

Restoration Goals

What would be required for an ecological restoration? Most of the ecological degradation apparently stems from the dramatic loss and hydrologic alteration of floodplain wetlands. Consequently, restoration of these wetlands in terms of both their areal extent and hydrology would be the primary restoration goal. Concomitantly, the potential for water quality degradation from channelization and from pumped agricultural discharges should be mitigated. Because of the magnitude of land acquisition and construction required to satisfy these goals it is clear that the most feasible means for achieving them is the federally funded UBP. This means, however, that these ecological goals must be met without incurring a significant loss of the flood control and water supply benefits of the project. This can be accomplished through a semi-structural approach to water management in which flood control and water supply objectives of the project are met to the extent practicable through the non-structural avenues of wetland acquisition and restoration. The required regulation of surface water flows cannot be achieved solely through non-structural means however, and some structural regulation would be required. The basic elements of a semi-structural project would thus include: 1) augmentation of floodplain storage through restoration of floodplain wetlands, 2) structural extenuation of the diversion of water to the Atlantic Coastal Basin (interbasin diversion), 3) structural elimination of channelization and restoration of sheetflow, and 4) construction and regulation of new water conveyance and water storage structures.

THE PROPOSED PROJECT

Reversal of the ecological decline within the upper basin lakes requires a restoration of the hydrology on the once vast floodplain wetlands. In a system that has been subjected to such intense development restoration of a desirable hydrologic regime can only be accomplished through structural means. The specific structural components are discussed below following a general description of the system.

Historically, the focus of water management in the basin has been flood protection. Consequently, extensive drainage works have impaired the natural water storage function of the floodplain marshes. In the UBP areas designated as marsh conservation areas, which will be located south of the Fellsmere Grade (Figure 10), will compensate for this lost storage. Water input to these areas will be from direct rainfall and surface flow from the western uplands. Water entering the Ft. Drum Marsh Conservation Area (FDMCA) will sheet-flow north into and through the Blue Cypress Marsh Conservation Area (BCMCA) (Figure 10), and thence through regulated structures into the restored marshes north of the Fellsmere Grade.

Water draining from areas south of the Florida Turnpike and east of the marsh conservation areas (MCAs) will be segregated from the MCAs and the main flow of the river. Storage of runoff from these lands will be provided by two water management areas (WMAs) (Figure 10) which will be interconnected by a canal system . WMAs will be regulated for flood control and supplemental irrigation. Water from these areas will be released into the St. Johns via S-96B or into the Indian River via S-96.

Flows into the marshes of Brevard County will be regulated in order to maintain a minimum base-flow and to attenuate floods. During floods controlled releases from the WMAs will be made through both S-1 and S-96B and inflow from the primary western upland tributary, Jane Green Creek, will be regulated by S-161 and S-161A (Figure 5).

Base-flows in the wetlands north of the Fellsmere Grade will be maintained by the release of water from the BCMCA. These discharges will be regulated so as to optimize the hydrologic regime of the downstream marsh.

Many of the ecological problems associated with the lakes north of the Fellsmere Grade are the result of an altered hydrologic regime on the basin's wetlands. By providing compensating storage and by regulating flows, the project will restore the values of the marsh to the lakes. Secondarily, the storage facilities associated with the project will segregate poorer quality agricultural water and thereby enhance the water quality of receiving lakes.

Success of the project in mitigating the ecological problems of the basin lakes is dependent upon the successful implementation of the many complex components of the system. Presented in more detail below are the independent components of this comprehensive project.

Floodplain Restoration

Approximately 56,600 acres of developed annual floodplain would be purchased under the proposed project (Figure 2). All of these lands are in private ownership and most have been hydrologically isolated from the river and lakes by levees. Most of these lands will be managed in a manner designed to restore the natural flora and fauna of the floodplain. Certain areas (parcels 83-2, 83-7, 82-16, and 82-18), however, will become impoundments (WMAs) designed to provide the additional storage necessary for flood control and irrigation benefits. Water depths and hydroperiods in these areas may be greater than those experienced by natural floodplain wetlands and, consequently, it is doubtful that natural habitat will be restored, or in one case (parcel 82-18) maintained.

Interbasin Diversion

Four canals account for most interbasin diversion; C-54, Fellsmere Main, Sotille, and Melbourne-Tillman (Figure 3). Discharge from C-54 is controlled by two structures S-96 and S-157 (Figure 3). In the 1962 U. S. Army Corps of Engineers' project these structures would have released water only during a storm event with a recurrence interval greater than 25 years. Under the current proposal the frequency of discharge would not change, but there would be a reduction in discharge volume and rate. All discharges through C-54 would be from an artificial storage area, St. Johns Water Management Area (SJWMA; described below).

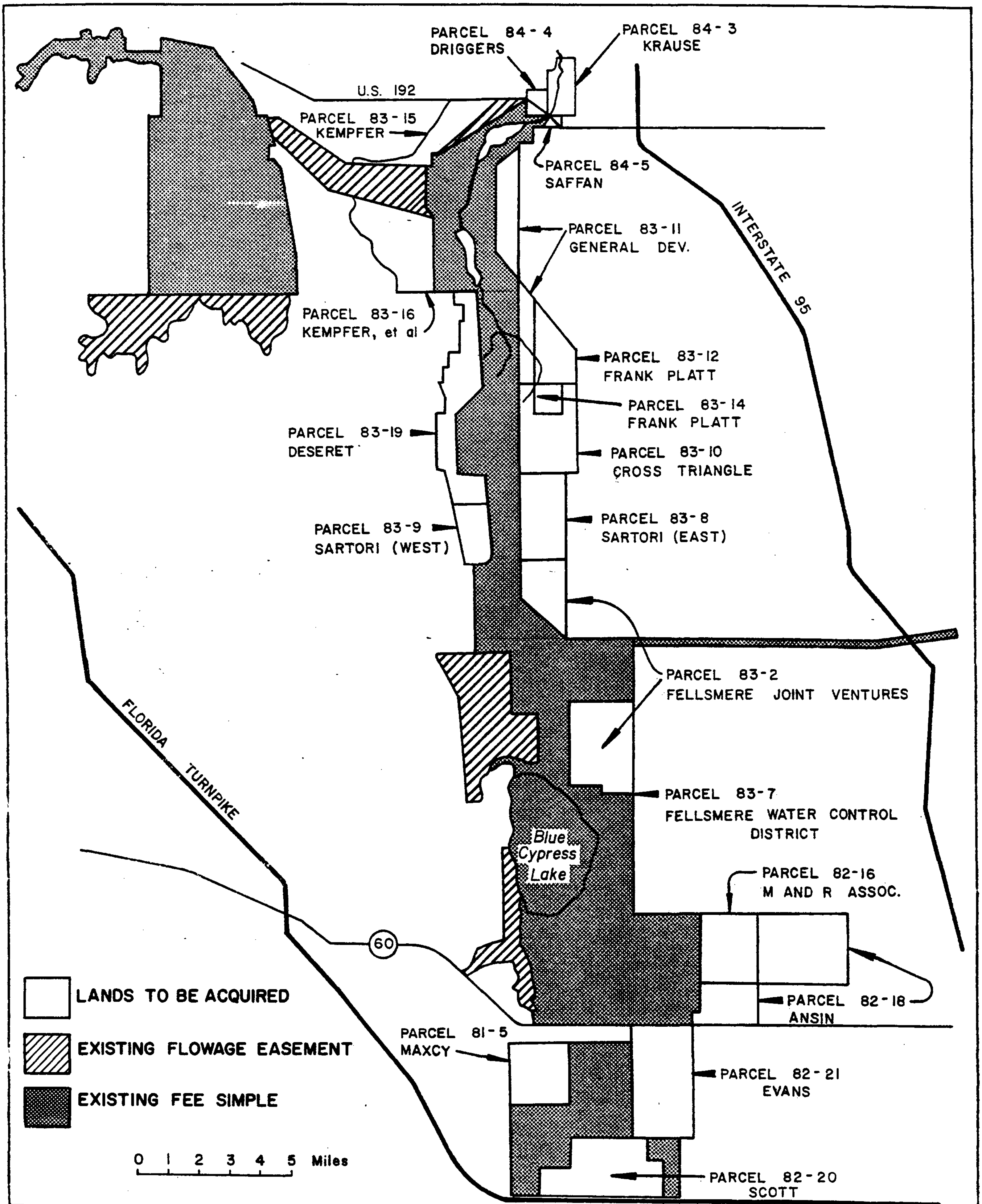

FIGURE 2. RECOMMENDED LAND ACQUISITION

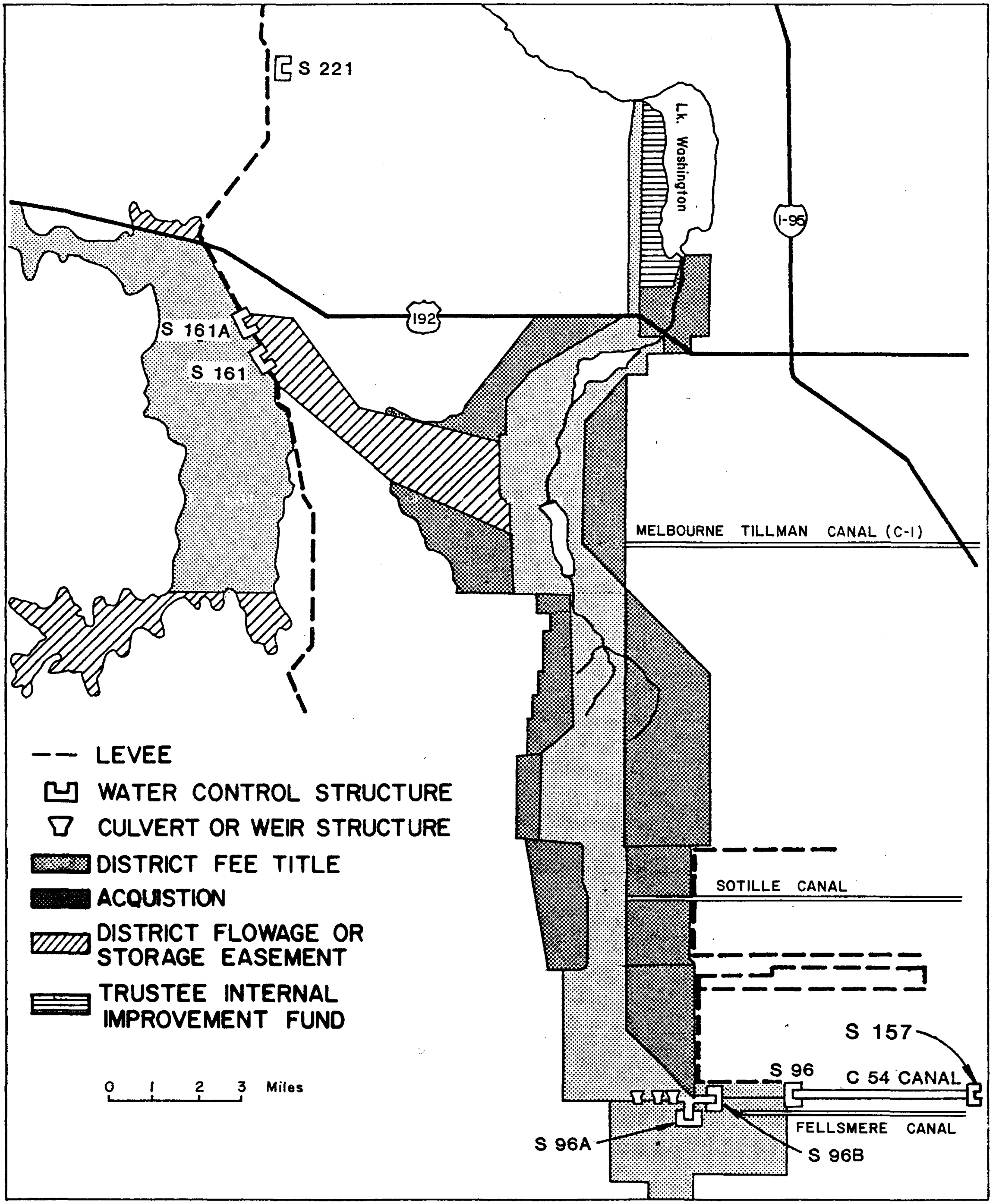

FIGURE 3. MAJOR INTER-BASIN DIVERSION CANALS

Maximum discharge capabilities from SJWMA would be 6000 cfs of which 2000 cfs would be conveyed downstream if downstream stages were acceptable (Figure 4).

Elimination of the interbasin diversion of stormwater is not feasible because, based on the projected total volume of discharge out of C-54 during a 100-year storm, more than 40,000 acre/feet of additional storage would be required. Assuming a suitable storage area of such size was identified, the combined cost of land acquisition and construction of a detention facility would likely exceed the projected benefits in that the additional storage would be utilized only during very infrequent and severe storms during which the affected coastal ecosystems would already be stressed.

Compensating storage could be obtained by storing water at greater than normal depths in the marsh but this would be ecologically undesirable. Preliminary calculations based on the volume of water to be stored during the 100-year storm using available storage indicate that stages would have to be increased in excess of 1.4 feet. These excessively high stages would probably be more deleterious to the wetland ecosystem than would the loss of water to coastal drainage.

As part of the 1962 U. S. Army Corps of Engineers' project, contractual agreements were entered into between the South Florida Water Management District and the owners of lands adjacent to and north of C-54. Through these agreements the landowners were provided drainage rights into

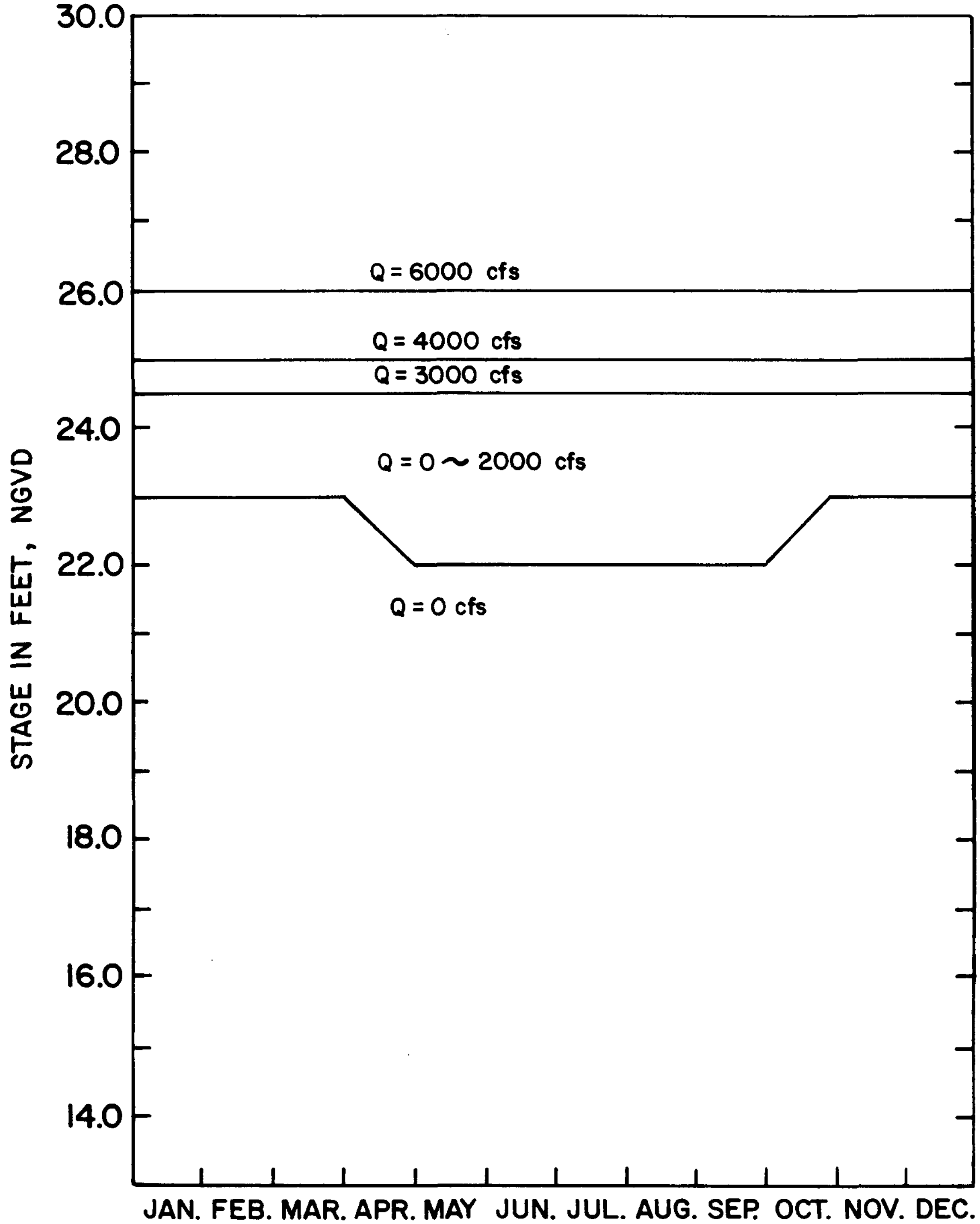

FIGURE 4. DISCHARGE SCHEDULE FOR ST. JOHNS WATER MANAGEMENT AREA

C-54 up to a maximum of 1,000 cfs. Due to non-regulated drainage from lands north of C-54, discharges to the coast occur in the absence of structure operation. This is because when the water level in C-54 exceeds 16 ft. NGVD the eastern structure (S-157) is overtopped. The mean discharge rate for the period of record is 71.0 cfs. The District has been working to eliminate this loss of water through the regulatory process. Results from this work have been positive and it is anticipated that this chronic diversion of water to the coast will be eliminated.

Fellsmere Main Canal (FMC), located immediately south of C-54, is a privately owned and maintained flood relief canal which runs parallel to C-54 (Figure 3). Flows to FMC are primarily from agricultural lands to the immediate south with a watershed of greater than 75 sq. miles. Based on discharge records since September 1969, FMC has diverted large volumes of water to the coastal basin even during drought periods. Average discharge has been 177.0 cfs with a range of 22.7 - 2030.0 cfs. It is anticipated that the owner of the canal will bear the responsibility for reducing this loss of water. This effort would be integrated into the overall basin project by storing the returned water in a proposed detention area.

The Sotille Canal (Figure 1) diverts water from a drainage area of approximately 25.8 sq. miles. A means of reducing interbasin diversion through this canal has been negotiated with landowners. Drainage works are currently being re-designed to route stormwater through detention basins prior to gravity discharge to the St. Johns River Marsh. Regulatory constraints were imposed on discharges from the detention area to prevent undesirable effects on the hydrology of the receiving waters.

Melbourne-Tillman Water Control District's primary drainage canal (C-1) is located approximately 4.5 miles south of U.S. 192. The canal extends east 10 miles from the St. Johns River Marsh to Turkey Creek. The drainage basin for C-1 is about 99.8 sq. miles, of which approximately 95 square miles naturally flowed to the St. Johns basin. Average daily discharge for C-1 over the period of record is 147 cfs. Consideration is being given to returning a portion of the water from C-1 to the St. Johns River during low flow periods. Because there is a flood proofing levee at the west end of C-1 and because the elevation gradient of C-1 causes gravity discharge to the coast, water can be returned to the St. Johns only by pumping. Benefits associated with various pumped discharges are currently under evaluation for determining cost/benefit relationships. Of primary concern are operation and maintenance costs for the pumps.

Channelization

Restoration of sheetflow in the basin requires controlled dispersal of water across the breadth of the marsh at the Fellsmere Grade and the plugging of borrow ditches. To facilitate the dispersion of water across the marsh, improvements to the Fellsmere Grade are proposed. Across the total length of the Grade, approximately 5 miles, the crest elevation will be raised to 30.0 feet, NGVD. Discharges from the Blue Cypress Marsh Conservation Area (described below) will be dispersed into the downstream marsh through a set of new weir/culvert structures. Three overflow weirs are proposed with a width of 135 feet and a crest elevation of 25.0 feet, NGVD. Three 72-inch culverts, one at each weir, will be constructed at marsh ground level for maintaining minimum downstream flows.

Under existing conditions, water flow between the Fellsmere Grade and Three-Forks Run is through borrow canals. These canals were created in the construction of privately owned levees and serve as significant conveyance systems during periods of low flow. To facilitate sheetflow and prevent overdrainage of the marsh, plugging of these canals is proposed. The major canals which would be plugged include Canal 40, south Mormon Outside Canal, Sartori Outside Canal West, Mary "A" Diagonal Canal and Canal 40 Extension (Figure 1). The design and location of the plugs have not been determined at this time.

<u>New Storage and Conveyance Structures</u>

Diminished surface water storage, resulting from floodplain encroachment, is largely responsible for the hydrologic problems of the lakes. As previously stated, a major element of the restoration plan for the lakes is to

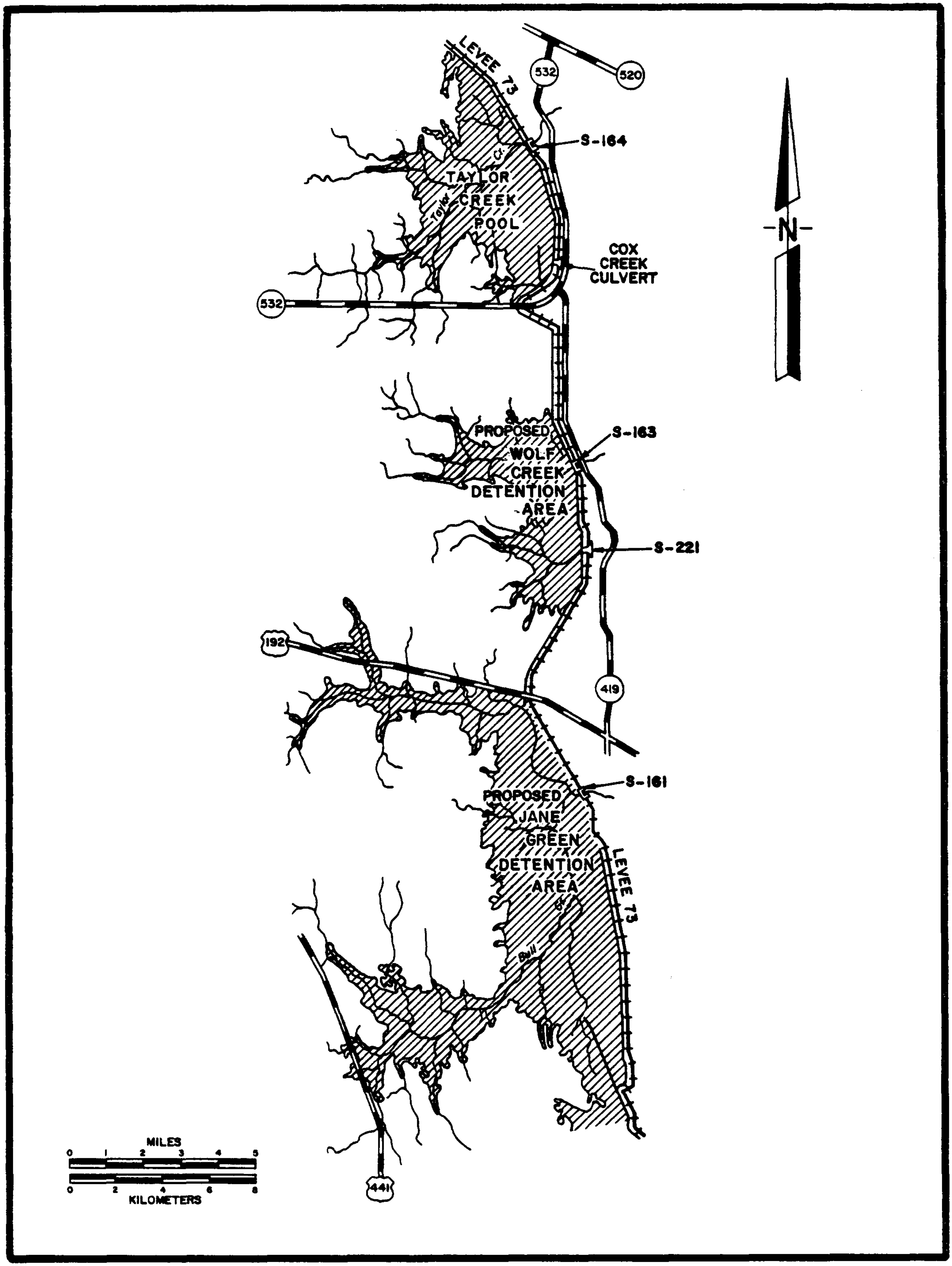

FIGURE 5. EXISTING AND PROPOSED UPLAND DETENTION WORKS

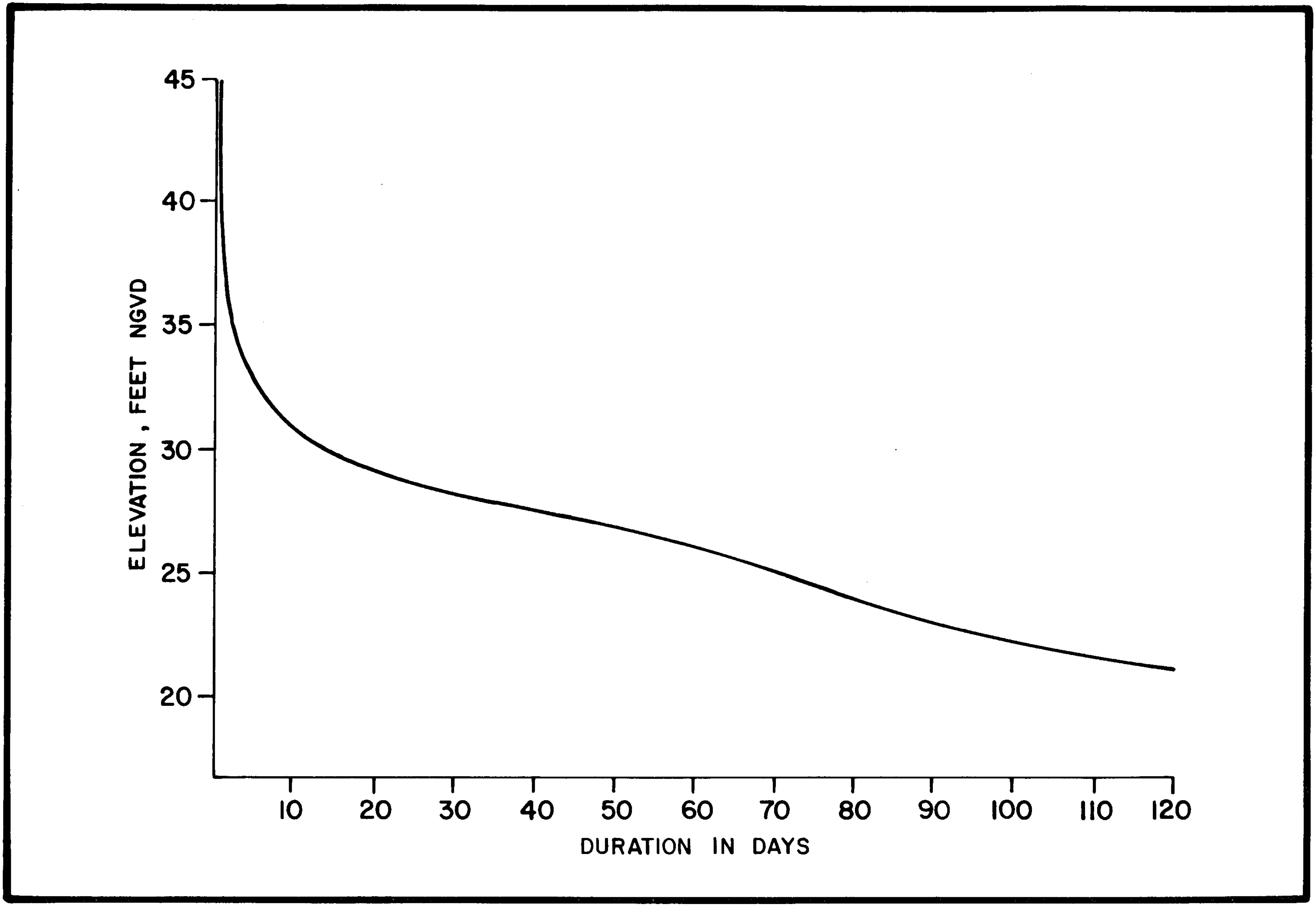

FIGURE 6. INUNDATION CONSTRAINTS FOR JANE GREEN DETENTION AREA - DORMANT SEASON (NOVEMBER 1 - MARCH 15)

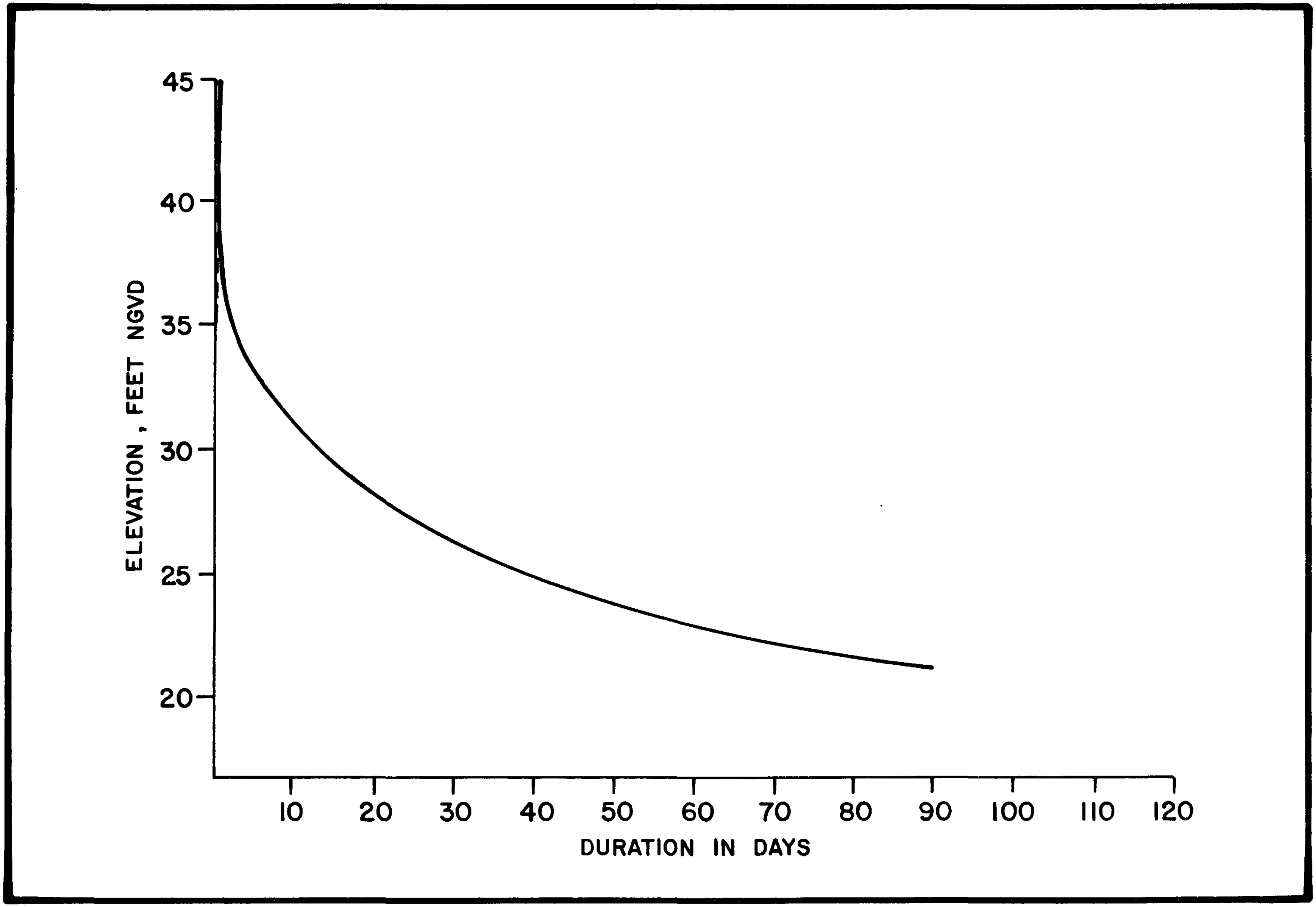

FIGURE 7. INUNDATION CONSTRAINTS FOR JANE GREEN DETENTION AREA - GROWING SEASON (MARCH 16 - OCTOBER 31)

compensate for the loss of floodplain storage. Upland storage of stormwater, through construction of detention/retention structures along the flowways of 5 upland tributaries, was the proposed means of compensation for loss of valley storage in the 1962 project. This approach was criticized because of the devastating effect of impoundment on the riparian hardwood ecosystems of the tributaries; but Taylor and Cox Creeks, the northern most tributaries, were permanently impounded prior to cessation of construction in 1972. Impoundment of these tributaries has resulted in the creation of an open water ecosystem.

Under the proposed plan, water storage in the remaining tributaries will be constrained so as to minimize harm to the associated riparian ecosystem. Extensive investigations of the riparian wetlands of Jane Green Creek (Figure 5) have been conducted. The distribution of plant communities with respect to elevation was studied through analysis of aerial photographs and through stratified random sampling along four transects (Biagiotti-Griggs and Girardin, 1980; Biagiotti-Griggs, 1982). The objectives of these investigations were: 1) to define the impact of impoundment, 2) to recommend constraints which would maximize flood control benefits without damaging the forested riparian ecosystem, and 3) to establish baseline conditions to enable detection of impacts during and after inundation. Based on these investigations a regulation schedule was developed which allows temporary storage of stormwater (Figures 6 and 7).

Similar analyses were conducted on the other tributaries subject to impoundment, Wolf and Pennywash Creeks. The recommended regulation schedules are presented in Figures 8 and 9. Gaps in levee 73 currently maintain an unrestricted base-flow through the levee. Recent simulations of flood routings indicate that these upland storage areas are less important for flood control north of Lake Washington than was previously thought. Therefore, these gaps can be maintained as part of the project.

Detention of stormwater in the upland tributaries reduces storm peaks but does not conserve water for maintenance of low flow, this requires increased storage in the St. Johns River floodplain. The storage capacity of the floodplain will be increased by construction of water management areas (WMAs) and marsh conservation areas (MCAs).

Two WMAs, both located south of the Fellsmere Grade, are planned; the Blue Cypress WMA (BCWMA; 9,680 acres) southeast of Blue Cypress Lake, and the St. Johns WMA (SJWMA; 6,200 acres) located immediately northeast of the lake between the Fellsmere Grade and Zigzag Canal (Figure 10). The WMAs will maximize storage per unit area in order to buffer the hydrologic effects of floods and periods of low rainfall.

During storms, water discharged from surrounding agricultural lands east of the river and south of the Fellsmere Grade will be contained in the WMAs. Under existing conditions a portion of the stormwater is pumped to the

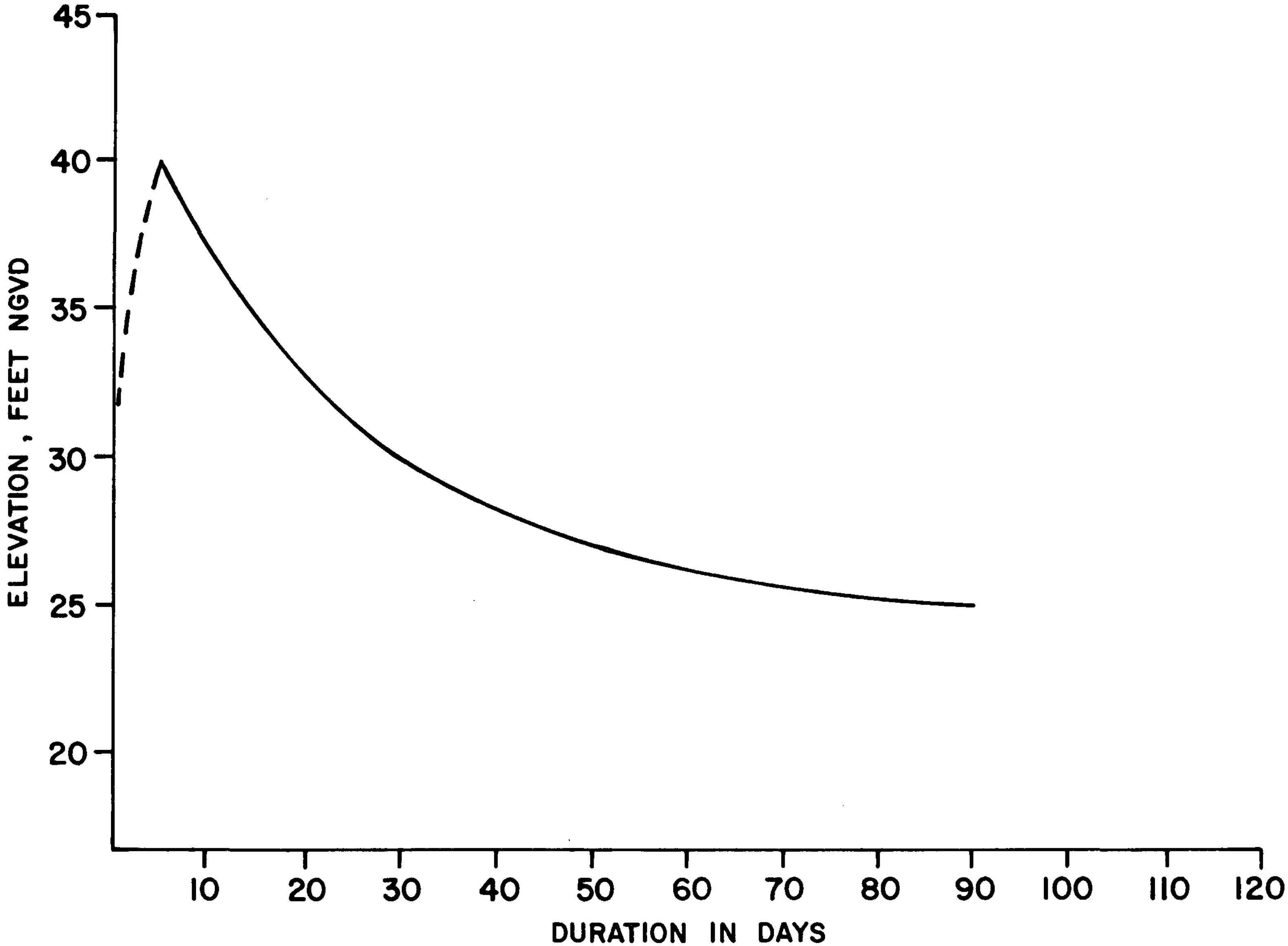

FIGURE 8. INUNDATION CONSTRAINTS FOR WOLF CREEK DETENTION AREA - GROWING SEASON (MARCH 16 - OCTOBER 31)

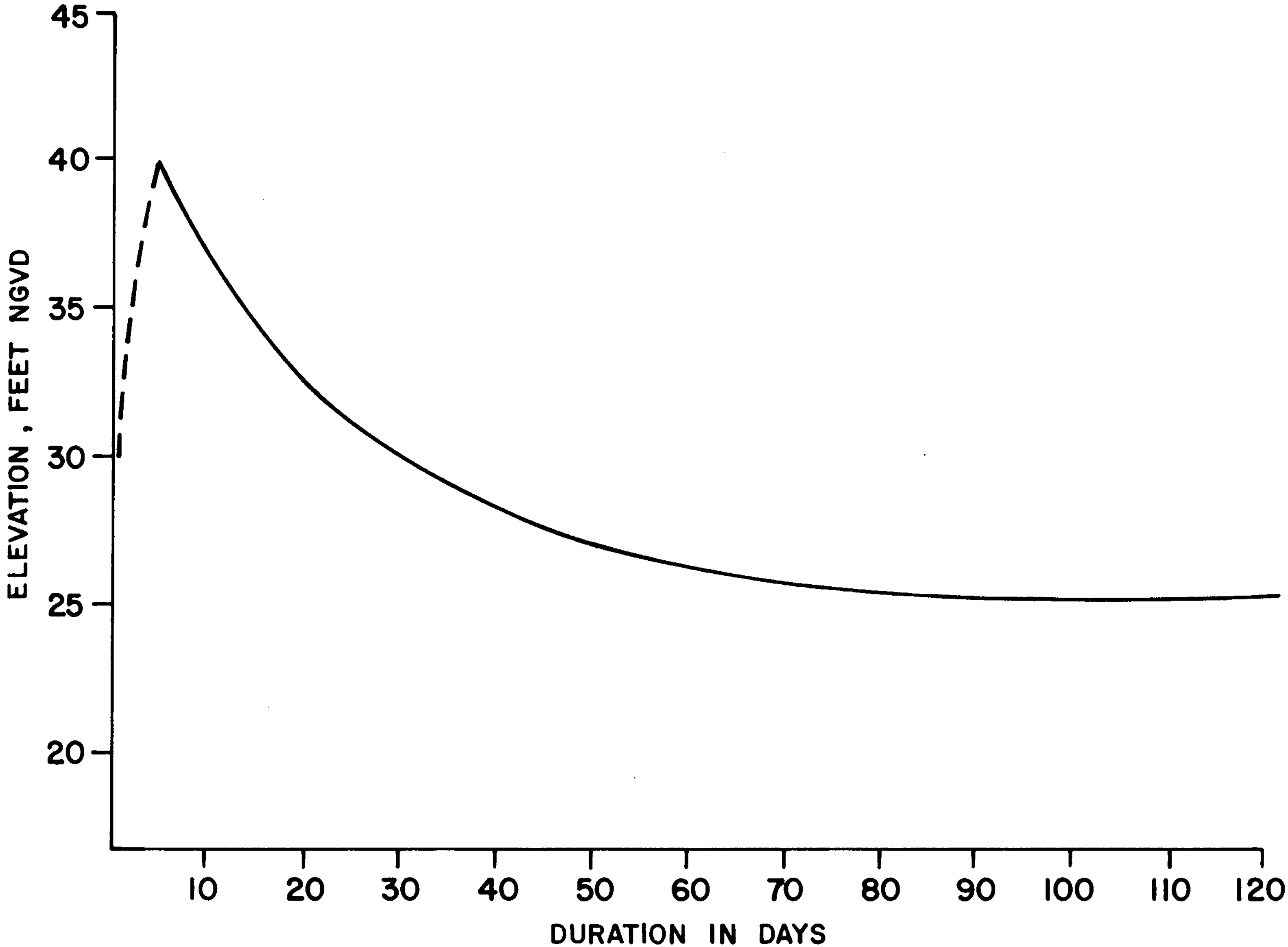

FIGURE 9. INUNDATION CONSTRAINTS FOR WOLF CREEK DETENTION AREA - DORMANT SEASON (NOVEMBER 1 - MARCH 15)

river. This rapid delivery of water to the receiving basin results in both water quality and quantity problems. Detention of agricultural discharges in the WMAs will reduce the rate and magnitude of flood peaks and reduce water column concentrations of suspended solids, turbidity and BOD.

The WMAs will also increase dry season minimum flow rates by reducing both the average and maximum rates of water conveyance downstream and the quantity of water lost through interbasin diversion. Release from the WMAs will be regulated to optimize the balance between downstream flow requirements and irrigation demands. In addition, irrigation demands on Blue Cypress Lake will be reduced because water for irrigation will be available in the WMAs. This will allow more high quality water to be released from the lake to augment downstream flows.

In addition to the two WMAs, there will be two MCAs: Fort Drum MCA (FDMCA; 18,040 acres) situated south of Highway 60 and Blue Cypress MCA (BCWMA; 39,600 acres) situated between the Fellsmere Grade and Highway 60 (Figure 10). Operation of the MCAs will accomplish three objectives: 1) storage of stormwater originating in the western portion of the basin, 2) regulation of discharges to areas north of the Fellsmere Grade for improvement of dry season stages, and 3) maintenance of the relatively high ecological quality of the marsh south of the Fellsmere Grade.

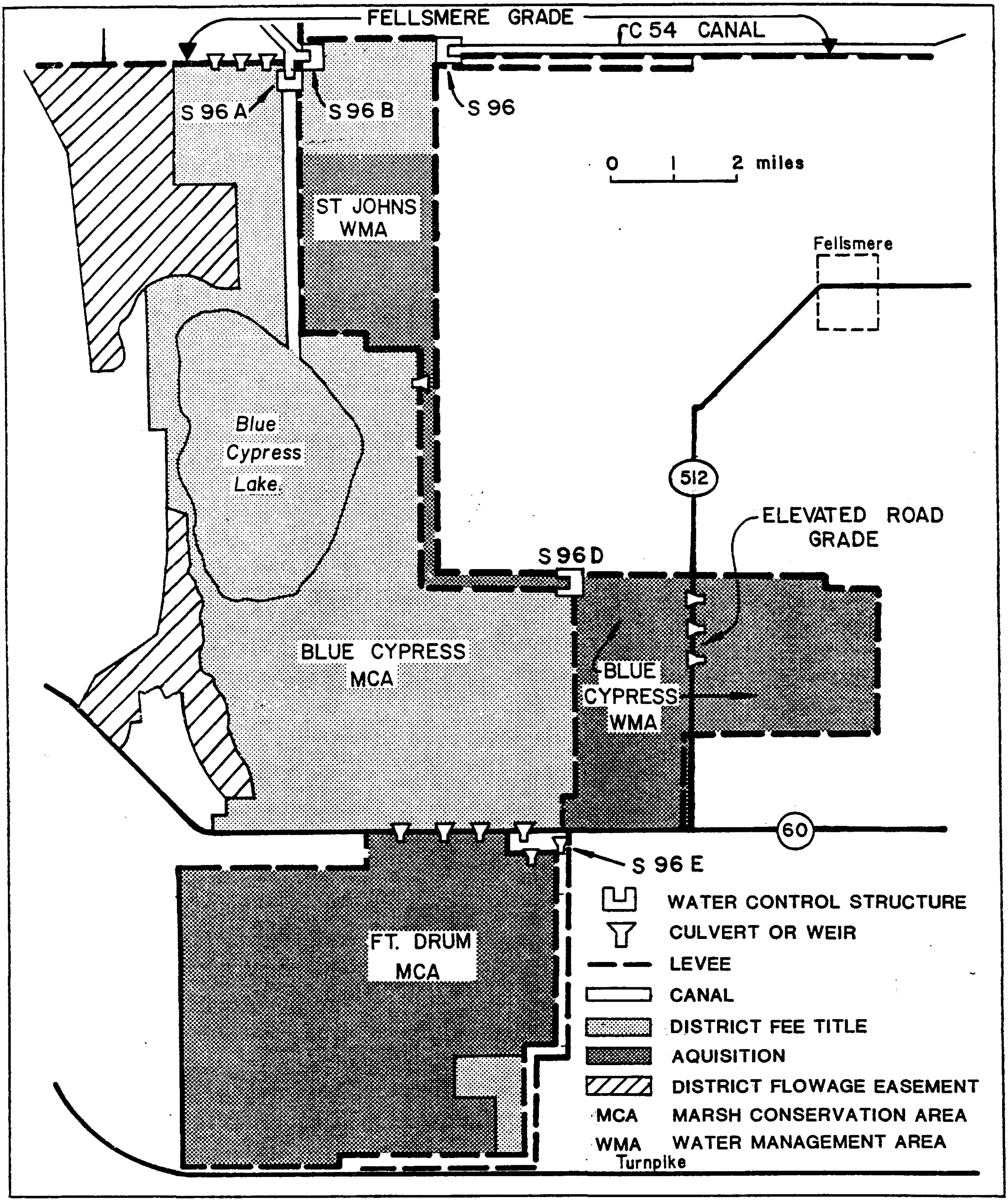

FIGURE 10. PROPOSED WORKS SOUTH OF THE FELLSMERE GRADE

HYDROLOGIC CRITERIA FOR THE PROJECT

Marsh Conservation Areas

Mitigation of adverse hydrologic conditions is dependent upon proper operation of the system's structural components. Both the FDMCA and BCMCA are designed to detain floodwater and, to the extent possible, slowly release such water downstream so as to mimic the natural hydrologic function of these areas. Water detention and storage in these areas must not be so great, however, that their wetland systems are adversely affected. Therefore, operation schedules for the MCAs will consider the effects of hydrologic changes on the plant communities of the floodplain and insure that these remnant marshes will provide vital ecological services.

The distributions of plant communities in the upper basin are strongly correlated with the hydrologic complex-gradient (a multivariate environmental gradient) represented by frequency of inundation (Lowe, 1983). The major components of this complex-gradient which were considered in the development of operation schedules are: 1) mean depth, 2) frequency of inundation, 3) maximum depths (the plural is used here in recognition of the fact that there exists a series of maximums with different return intervals), 4) minimum depths, 5) range of fluctuation and 6) timing of fluctuation.

The range of elevations and marsh types which exist in the marsh conservation areas make development of operational guidelines for all elevations and types impractical. To reduce the complexity of guidelines, a critical zone of elevations was identified in each MCA which corresponds to the range in elevation accounting for the majority of wetland acreage. This simplification is particularly appropriate because of the very flat topography in the BCMCA and FDMCA which causes the majority of wetlands in each to lie within a narrow range of elevations (Figure 11). Hydrologic constraints concerning long-term events (eg. mean depth, hydroperiod) will be with respect to the center of this range (central critical elevations) whereas constraints regarding extreme events of short duration (eg. maxima, minima) will be with respect to its upper or lower limits.

The complexity of guidelines can be further reduced by reference primarily to those communities most widely distributed and abundant. This simplification also seems appropriate in these areas given the marked dominance by only a few species and communities.

Critical elevations of the marshes within the FDMCA and BCMCA were identified through both vegetation and topographic analysis. By use of these data in conjunction with specific analyses of the distributions of the dominant plant species along a hydrologic gradient in the BCMCA, management guidelines for each MCA were developed. It was assumed that the hydrologic gradient in the BCMCA was indicative of that in the FDMCA. Guidelines for management of

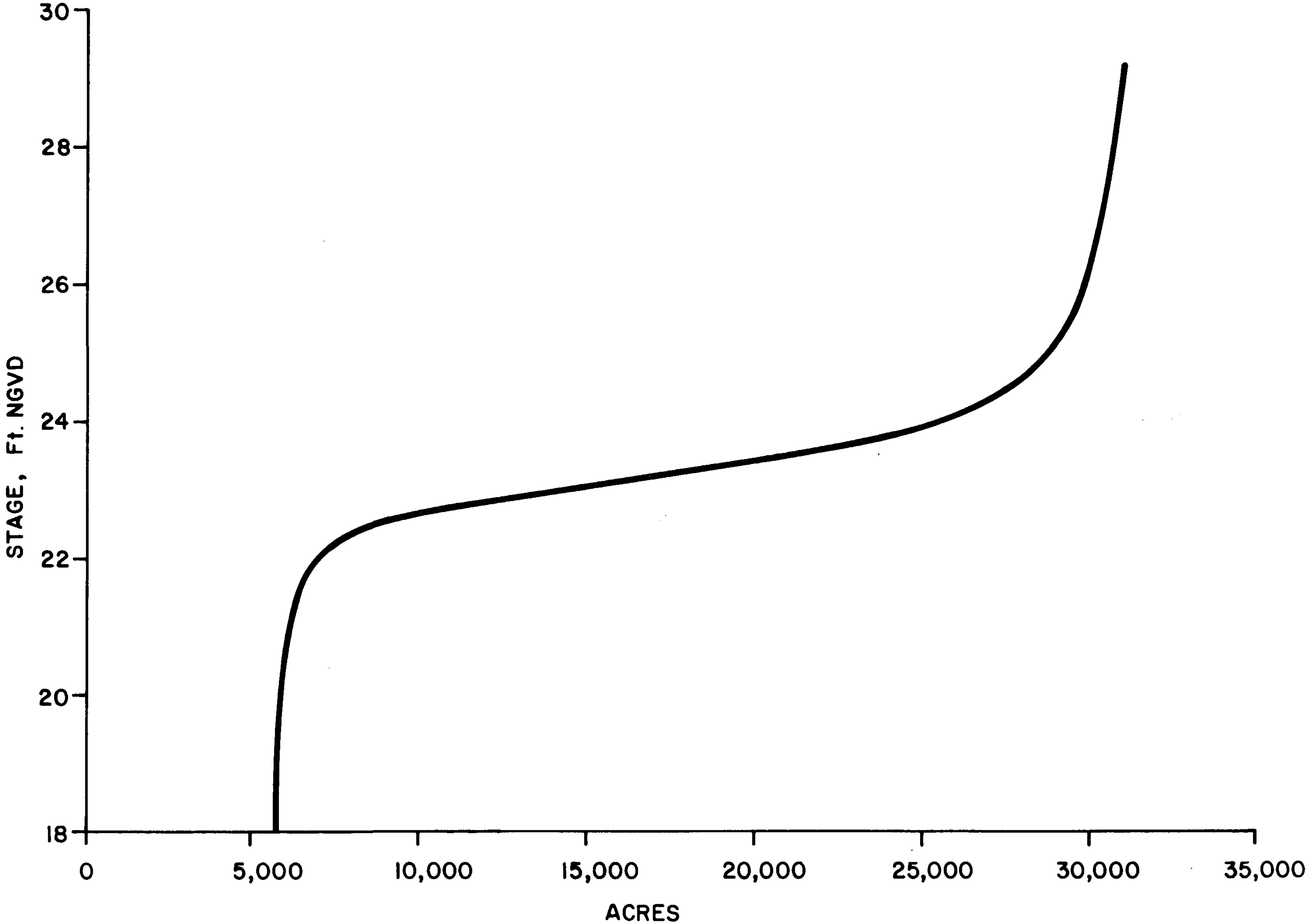

FIGURE 11. STAGE AREA CURVE FOR THE BLUE CYPRESS MCA

the MCAs and the criteria for their development are presented below:

1) The mean depth and frequency of inundation for the central critical elevation should be such that there will be no net subsidence of organic soils. The critical marsh elevations for BCMCA and FDMCA are 23 and 24 feet NGVD, respectively. This criterion is extremely important in an area, such as the upper basin, where there has already been considerable subsidence of organic soils. Studies in the Everglades demonstrate that to prevent subsidence a mean water table depth of approximately -0.25 feet must be maintained (Stephens, 1974). Thus, the minimum value for mean elevation of the BCMCA and FDMCA should be 22.75 and 23.75 feet NGVD, respectively. This criterion alone, however, is not sufficient. In the work of Stephens (1974), water depth was held constant. Where water depth fluctuates, a frequency distribution of depths skewed towards the maxima could cause subsidence even though the mean depth of the water table is no lower than -0.25 feet. In other words, to prevent subsidence, the soil must also be saturated for some minimum length of time in a typical year. Assuming that the elevation of the peat has reached equilibrium with the historical hydrologic regime, duplication of the historic frequency of inundation on the critical marsh elevation should prevent subsidence. In the BCMCA the critical marsh elevation of 23 feet NGVD has been inundated approximately 60 percent of the time from 1956 - 1981. Thus, the minimum

frequency of inundation on the critical marsh elevations of the MCAs should be 60 percent.

2) The duration and intensity of maximum water elevation in BCMCA and FDMCA should not significantly damage or alter the plant communities at the lower critical elevations of 22 and 24 feet NGVD, respectively. Vegetation tolerances to extreme water depths were established by analysis of historic stages relative to the distribution of the dominant plant species along an elevation gradient. The 30 and 60 day maximum elevations of BCMCA are 26.8 and 25.3 feet NGVD. This indicates the maximum depths which have been tolerated by existing plant communities. At the time of sampling, Panicum hemitomon (maidencane) occurred along the lake shore to a minimum elevation of 19.52 feet. Because some extension of the lakeward range may have occurred during the 1981 drought, this figure should probably be rounded upward to 20 feet NGVD. This indicates that P. hemitomon can tolerate, or quickly recover from, 30 and 60 day maximum depths of approximately 6.8 and 5.3 feet, respectively. Cladium jamaicense (sawgrass) has not experienced depths of this magnitude in the upper basin but has been reported to tolerate complete submergence for about 6 weeks in the Everglades (Lynch, 1942 in Wade et al, 1980). The average height of C. jamaicense in the BCMCA was 7.7 feet. Thus, C. jamaicense can apparently tolerate even greater depths than can P. hemitomon. A more narrowly distributed sub-dominant species, Polygonum punctatum (dotted smartweed), occurred at

a minimum elevation of approximately 21 feet. It, thus, can tolerate, or quickly recover from 30 and 60 day depths of 5.8 and 4.3 feet, respectively. Two other important species, Osmunda regalis (royal fern) and Kostelevskya virginica (seashore mallow), occurred down to about 22 feet NGVD, for 30 and 60 day depths of 4.8 and 3.3 feet, respectively. It is quite possible that these species, as in the case of C. jamaicense, can tolerate greater depths than they have been exposed to in the study area but there are apparently no other data concerning their depth tolerances. The most conservative approach then is to defer to the apparent tolerances of these species and recommend maximum 30 and 60 day depths of 4.8 and 3.3 feet, respectively. It is not known at this time if O. regalis and K. virginica are sub-dominant in the FDMCA.

3) Recommendations for minimum depths have not been established but short-term (30-60 days) and infrequent (return interval > 10 years) minima are not considered detrimental for this area.

4) A minimum range of fluctuation in water depth should be maintained (historical mean range in BCMCA is 3.7 feet). Specifically, the lower and upper critical elevations should experience both exposure and inundation in a typical year. Fluctuation of the marsh is necessary for maintenance of populations of drawdown-dependent plant species (sensu Van der Valk, 1981) and wading birds which depend on the concentration of fish and invertebrates during

the dry season, such as wood storks (*Mycteria americana*; Kahl, 1964; Kushlan et al, 1975), white ibis (*Eudocimus albus*; Kushlan, 1976), and a variety of other species of Ciconiiformes (Kushlan, 1976; De Sottele et al, 1982). Drawdown is also necessary to support the seasonal bloom of productivity which accompanies wet season reflooding (Swanson et al., 1974 in De Sottele et al., 1982).

5) The natural timing of fluctuation in water depth should be modified as little as possible. This means that the minimum depth will occur between April 1 and June 30 and the maximum between September 1 and November 31 in a typical year (Figure 12). Maintenance of a natural seasonality in water depth is essential to assure the breeding success of wading birds (Kahl, 1964; Kushlan, Robertson & Kushlan, 1974; Ogden and Higer, 1975; Ogden, Kushlan and Tilman, 1978) and other species with seasonal reproductive cycles such as the alligator (Fogarty, 1974), and black bass (Heiding, 1975).

The marshes of the BCMCA and the FDMCA have been relatively unimpacted by development of the floodplain, largely due to the retention of water by the Fellsmere Grade. Adherence to the objectives established above should maintain the ecological integrity of these marshes while simultaneously allowing an increase in their water storage function.

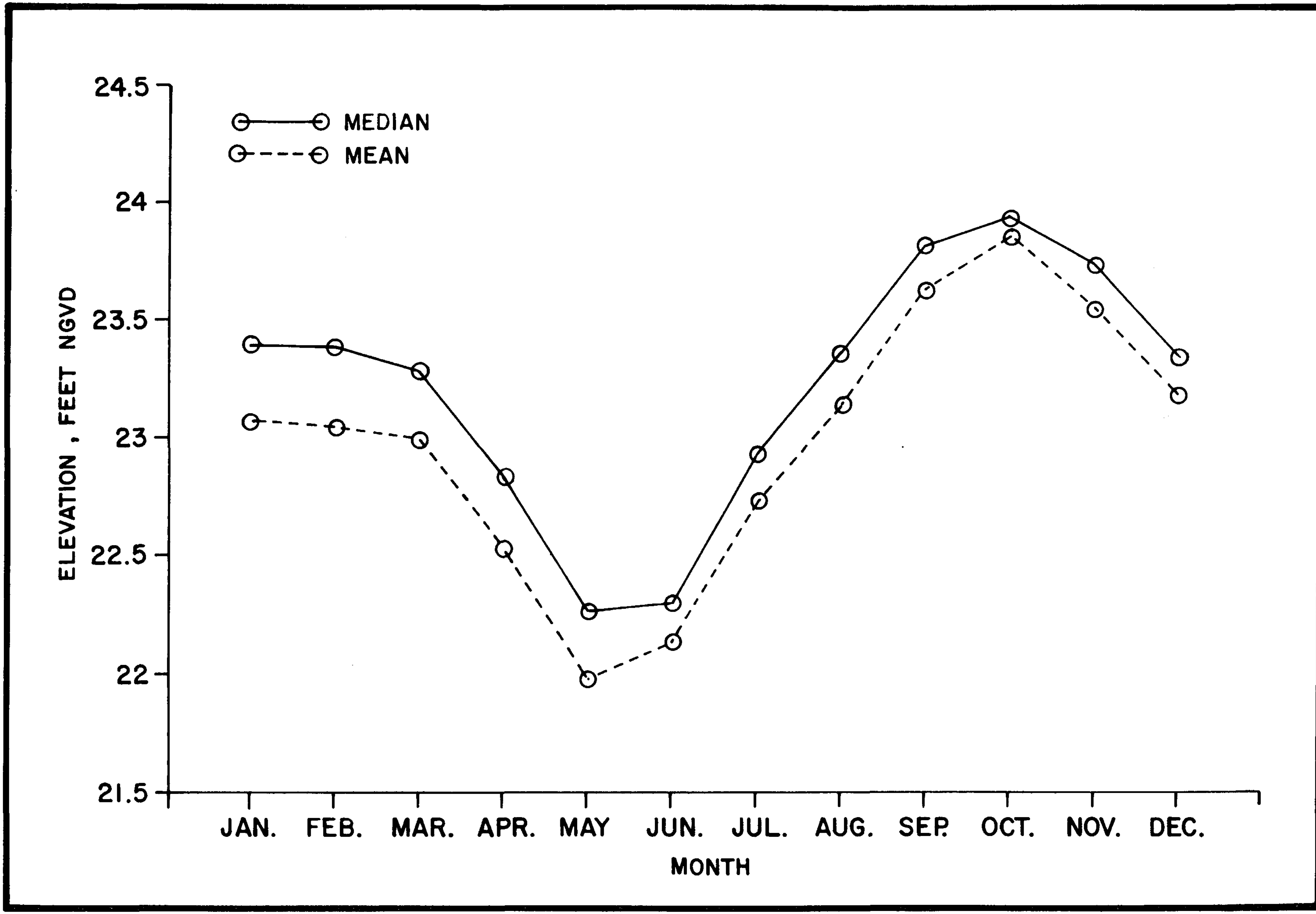

FIGURE 12. MEDIAN AND MEAN MONTHLY SURFACE WATER ELEVATIONS FOR BLUE CYPRESS LAKE

Water Management Areas

Two WMAs are proposed, each will maximize storage per unit area. They are necessary because it is economically unfeasible to purchase all the lands which provided storage prior to development. Both the BCWMA and the SJWMA are located south of the Fellsmere Grade (Figure 10). The WMAs will provide both water quality and quantity benefits. Quality benefits would stem from the segregation of agricultural discharges from lake water. Currently, agricultural areas discharge stormwater and the push water used for crown flood irrigation almost directly to Blue Cypress Lake. Both the BCWMA and SJWMA will detain agricultural discharges during major storms and retain discharges during minor storms and irrigation cycles.

WMAs will also attenuate flood peaks and their rate of rise, allow mitigation of interbasin diversion, and decrease supplemental irrigation demands on Blue Cypress Lake. These functions will improve our capability to enhance the hydrologic regime of the basin's remaining wetlands.

The following hydrologic criteria have been established to optimize the benefits of the WMAs:

1) To the extent possible, duplicate the hydrologic constraints established for the MCAs.
2) Avoid extreme depths for prolonged periods between May and September in order to avoid stratification with anoxia below the chemocline and concomitant release of nutrients from the sediments.

3) Provide for periodic drawdowns of sufficient duration to allow for sediment consolidation and seed germination.

4) Provide for periodic flushing under desirable conditions to prevent mineral build-up.

Restored Wetlands

Within the reach of the river immediately downstream of the BCMCA and SJWMA the project will mitigate the current ecological decline of the lakes. As previously discussed, problems in the lakes of this reach stem from an extensive loss of floodplain wetlands and from an unnatural and undesirable hydrologic condition on the wetlands. Project objectives for this reach include restoration of developed areas of the annual floodplain marsh and optimization of surface water hydrology. Lands targeted for acquisition were presented in an earlier section (Figure 2). Application of the hydrologic criteria developed for the MCAs with constraints specific for the topography of each area should provide for a restoration of marsh functions.

TESTING AND REFINEMENT OF THE PROPOSED PROJECT

In order to refine the project, more than twenty variations of the basic plan and its operation schedules have been tested. For each plan or operation schedule variation, daily streamflows or stages were generated for the period of 1949-1979 by computer simulation using the St. Johns River Hydrologic Model (Tai and Rao, 1982). Comparisons between each plan were based upon these simulated data.

Operation Schedules

The operation schedules currently selected for the WMAs and MCAs are as follows:

1) Discharge from FDMCA into BCMCA
   a) No discharge if stage in BCMCA exceeds 25.0 ft. NGVD; otherwise,
   b) Discharge limited to 300 cfs max., depending upon tailwater (downstream) condition.
2) Discharge from St. Johns Water Control District into BCWMA. Discharge limited to 2500 cfs max.
3) Discharge from BCWMA into SJWMA.
   a) Rainy Season (May - September): Q = 1000 cfs if stage in BCWMA is above 24.5 ft. NGVD, otherwise zero.
   b) Dry Season (November - March): Q = 1000 cfs if stage in BCWMA exceeds 25.5 ft. NGVD, otherwise zero.
   c) October and April: Transition between schedules (a) and (b).

4) Discharge from BCMCA into St. Johns Marsh (north of Grade) via S-96A.

   a) June - August: Q = 1500 cfs if BCMCA stage exceeds 23.0 ft. NGVD.

   b) November - March : Q = 1500 cfs if BCMCA stage exceeds 24.5 ft. NGVD.

   c) April - May and September - October: Transition between schedules (a) and (b).

5) Discharge from BCMCA into St. Johns Marsh (Reach #3) as per rating curve (Figure 13).

6) Discharge from SJWMA (into St. Johns Marsh, or C-54 Canal, or both, (Figure 4).

7) Discharge direction.

   a) On the days discharge occurs, up to 2000 cfs will be released to the St. Johns Marsh unless the stage at U.S. 192 exceeds 19.0 ft. The remainder of any discharge, if any, will be diverted to C-54 canal (Note: Discharge would be zero on some days.)

   b) If stage at U.S. 192 exceeds 19.0 ft. NGVD, if there is any discharge called for under 8 below, all water will be diverted through C-54.

8. Discharge quantity.

   a) If stage in SJWMA is below 24.5 ft. NGVD.

      i) Q=0 cfs if stage at U.S. 192 exceeds 19 ft. NGVD.

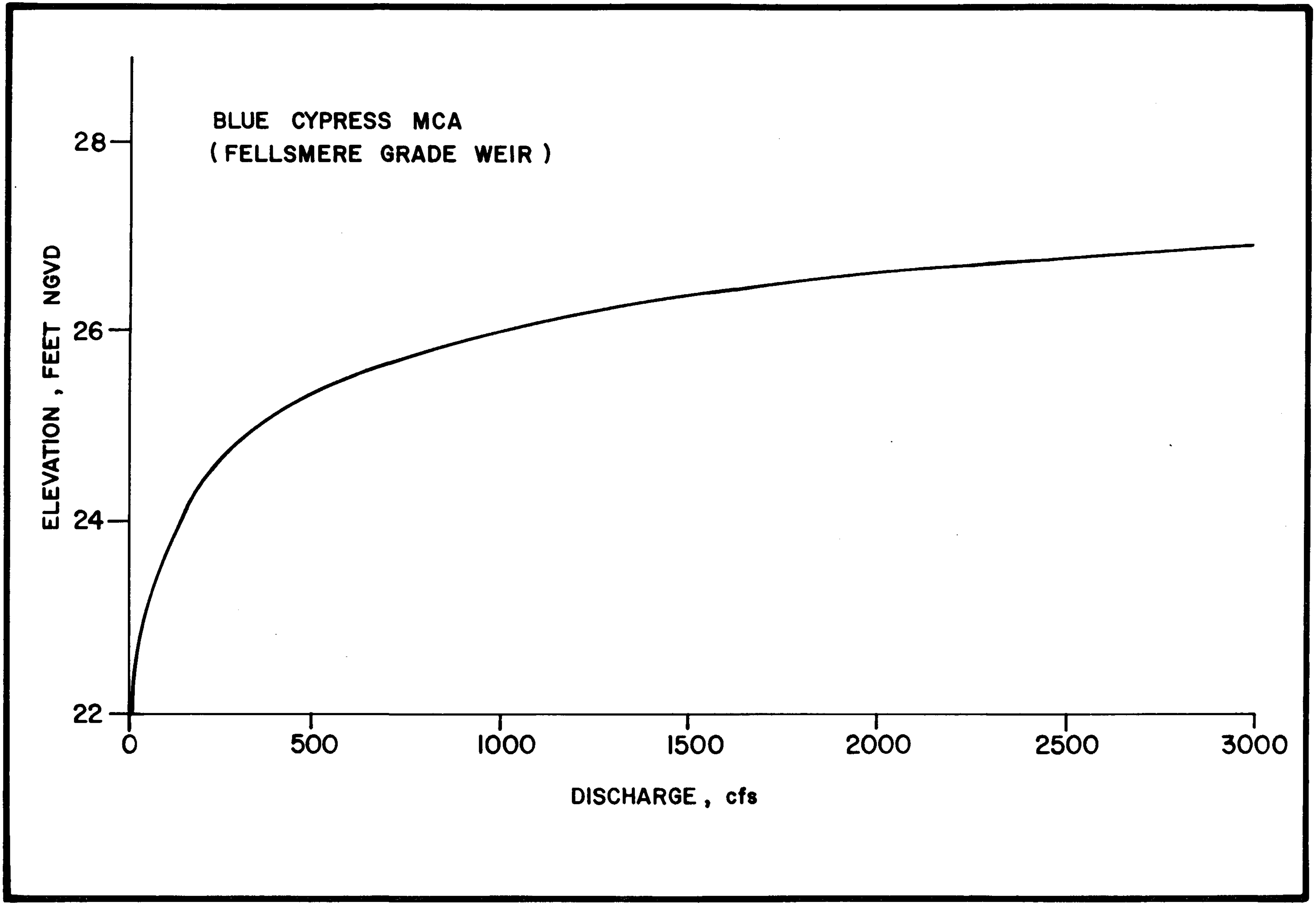

FIGURE 13. RATING CURVE FOR DISCHARGE TO MARSH NORTH OF FELLSMERE GRADE

ii) May - September: Q=2000 cfs if stage in SJWMA is between 22.0 ft. and 24.5 ft. NGVD and stage at U.S. 192 is below 19 ft. NGVD.

iii) November - March: Q=2000 cfs if stage in SJWMA is between 23.0 ft. and 24.5 ft. NGVD and stage at U.S. 192 is below 19 ft. NGVD.

iv) April and October: Transition between schedules ii) and iii).

b) Q=3000 cfs if stage in SJWMA is between 24.5 ft. and 25.0 ft. NGVD.

c) Q=4000 cfs if stage in SJWMA is between 25.0 ft. and 26.0 ft. NGVD.

d) Q=6000 cfs if stage in SJWMA exceeds 26.0 ft. NGVD.

Discussion of simulation results will focus on the various components of the project with reference to defined objectives. In areas where the defined objective was not met, additional modifications will be tested.

Fort Drum Marsh Conservation Area

Based on the 31 years of rainfall data, the storms of 1953 and 1956 represent the most severe flood events for the basin south of State Road 60. The simulated hydrograph for the 1956 storm (Figure 14) under the proposed project design does not violate our high flow constraints. Although the 1956 storm is considered to be the most severe basinwide

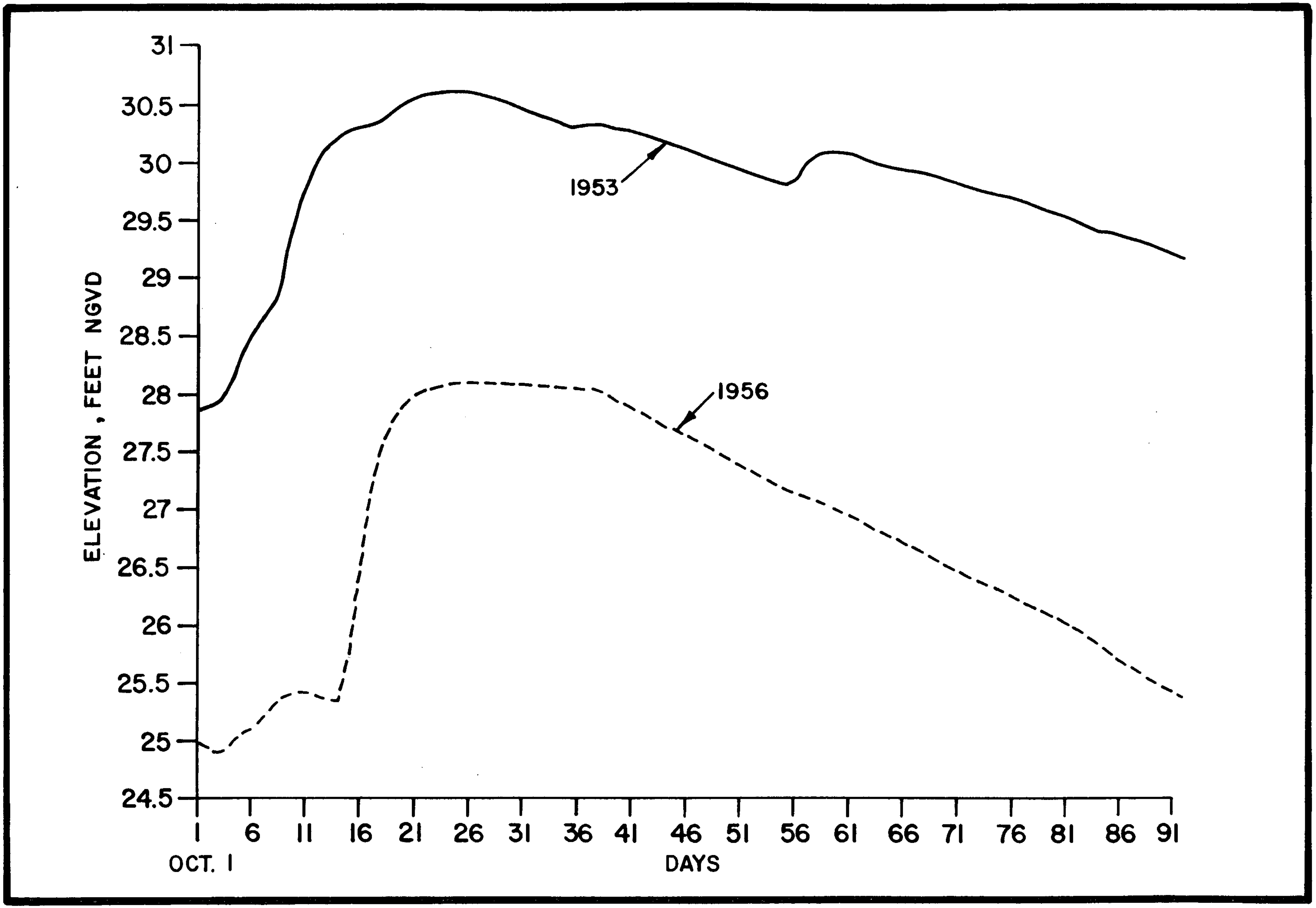

FIGURE 14. FORT DRUM MARSH CONSERVATION AREA SIMULATED STAGE HYDROGRAPHS FOR 1953 AND 1956 STORMS

storm for the period of record, simulated stages for the 1953 storm were higher and exceeded our criteria. Consequently, an additional discharge culvert has been proposed for FDMCA which will allow for increased drawdown capability. Simulations with this additional structure have not been completed.

Mean depth and frequency of inundation for the critical marsh elevation (24 feet NGVD) were both acceptable based on our criteria (Figure 15). Maximum, average and minimum monthly mean stages indicate maintenance of the desired seasonal fluctuation in stages and range of fluctuations as well (Figure 16).

Blue Cypress Lake Marsh Conservation Area

Within this reach of the basin the most critical storm events were found to be the 1950 and 1956 storms. Figure 17 shows the simulated hydrograph for these storms under the current design for the BCMCA. During the most severe of these storms (1956), the lower critical elevation (22ft. NGVD) would experience depths of 3.3 and 4.8 feet for 20 and 11 days, respectively. This is well below the 60 and 30 day duration constraint.

The management objective of maintaining a minimum frequency of inundation at 23 feet NGVD of 60 percent was also achieved (Figure 18). Furthermore, the maximum, average and minimum monthly mean stages indicate that the seasonality of water level fluctuation and the range of fluctuation would be maintained (Figure 19).

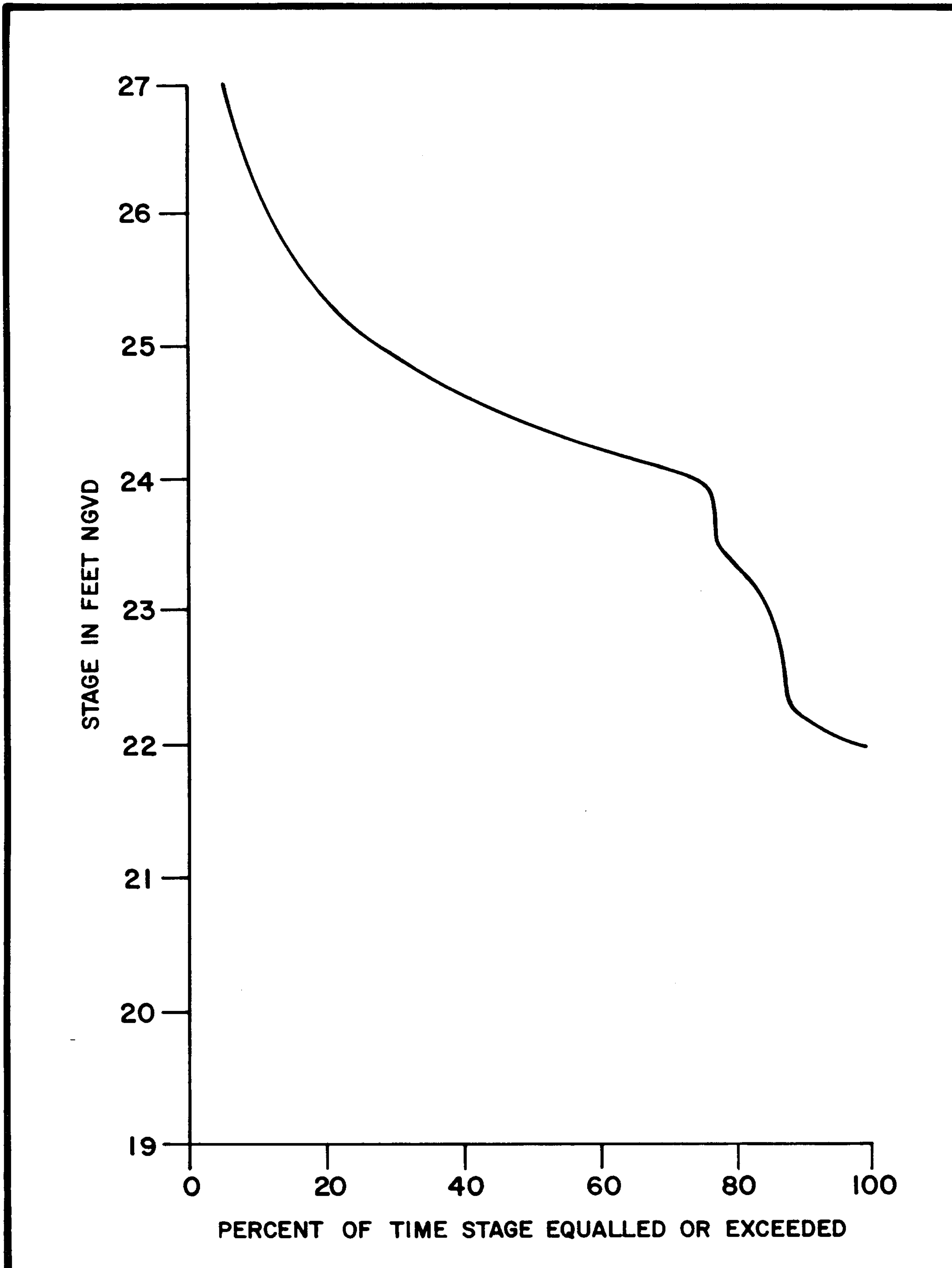

FIGURE 15. SIMULATED STAGE-DURATION CURVE FOR FORT DRUM MARSH CONSERVATION AREA

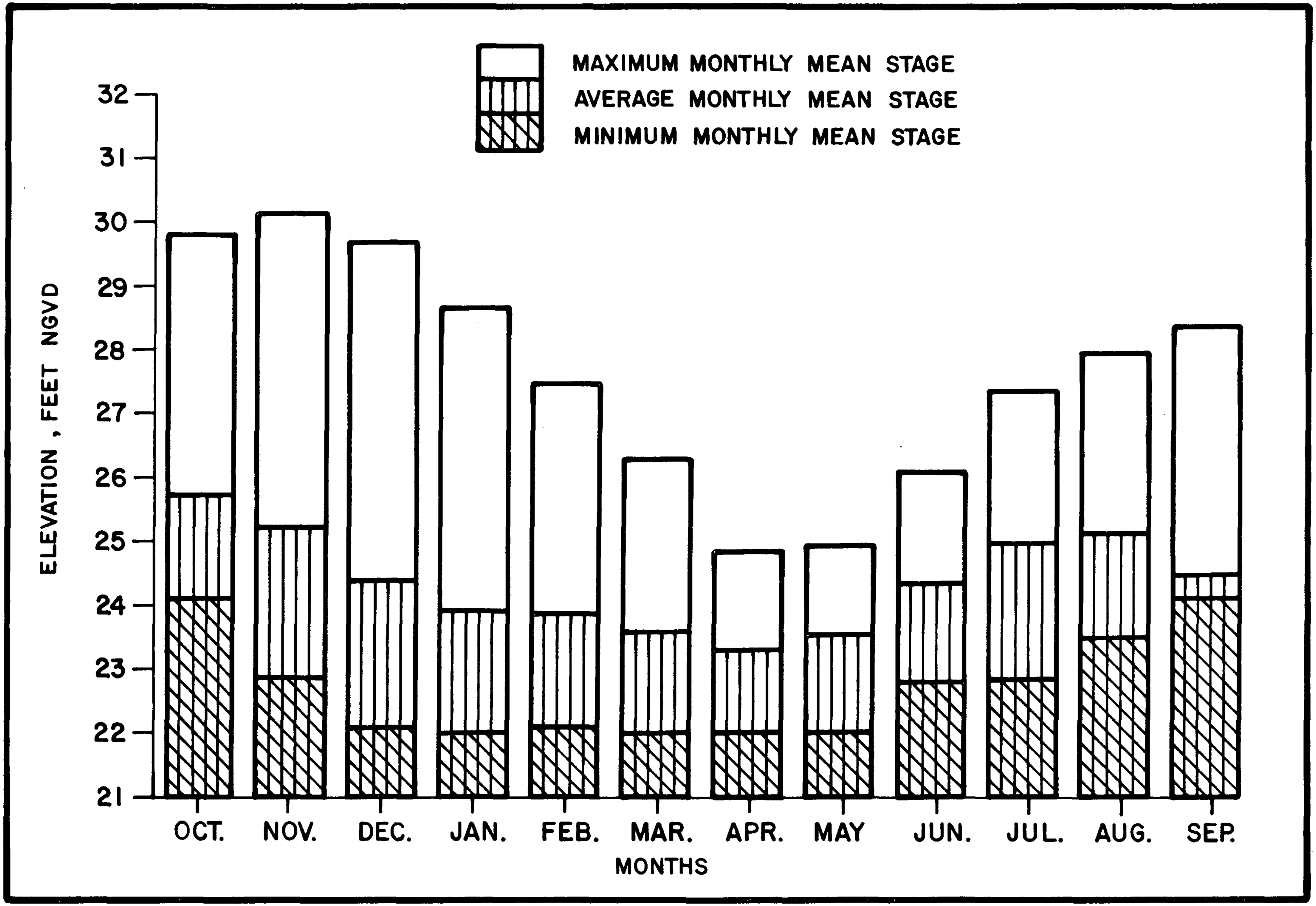

FIGURE 16. SIMULATED MONTHLY MEAN STAGES - FT. DRUM M.C.A.

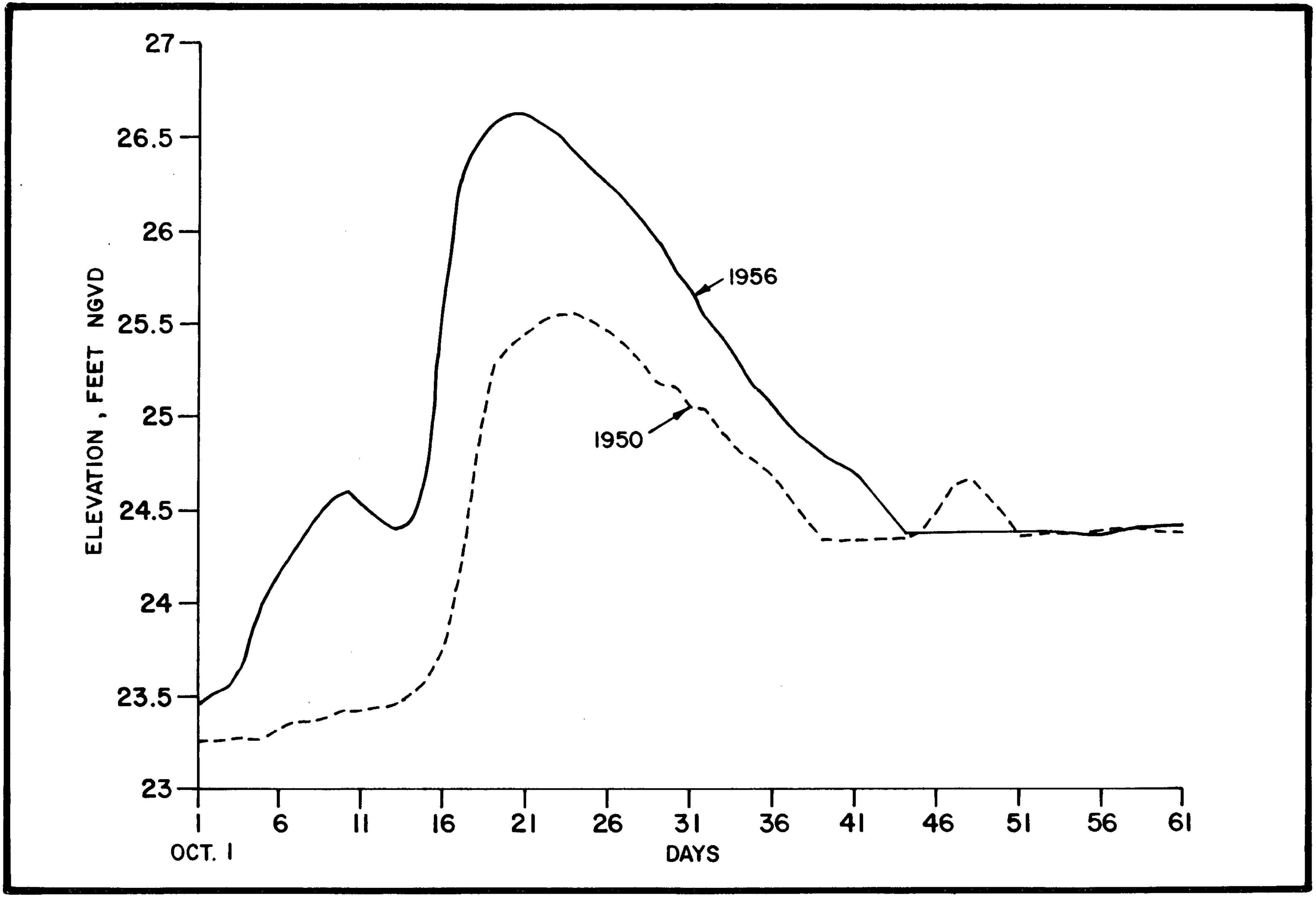

FIGURE 17. BLUE CYPRESS MARSH CONSERVATION AREA SIMULATED STAGE HYDROGRAPHS FOR 1950 AND 1956 STORMS

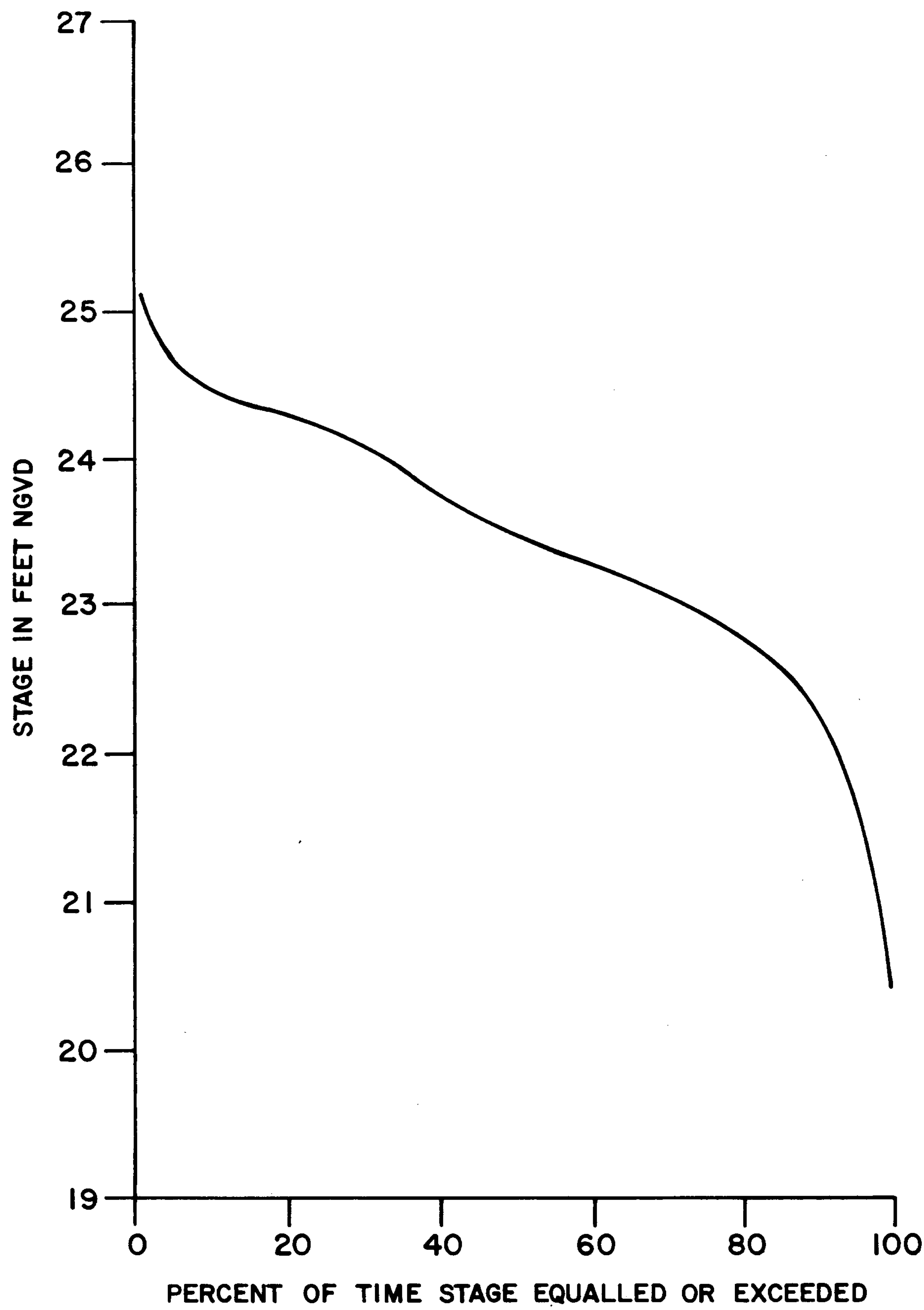

FIGURE 18. SIMULATED STAGE-DURATION CURVE FOR BLUE CYPRESS MARSH CONSERVATION AREA

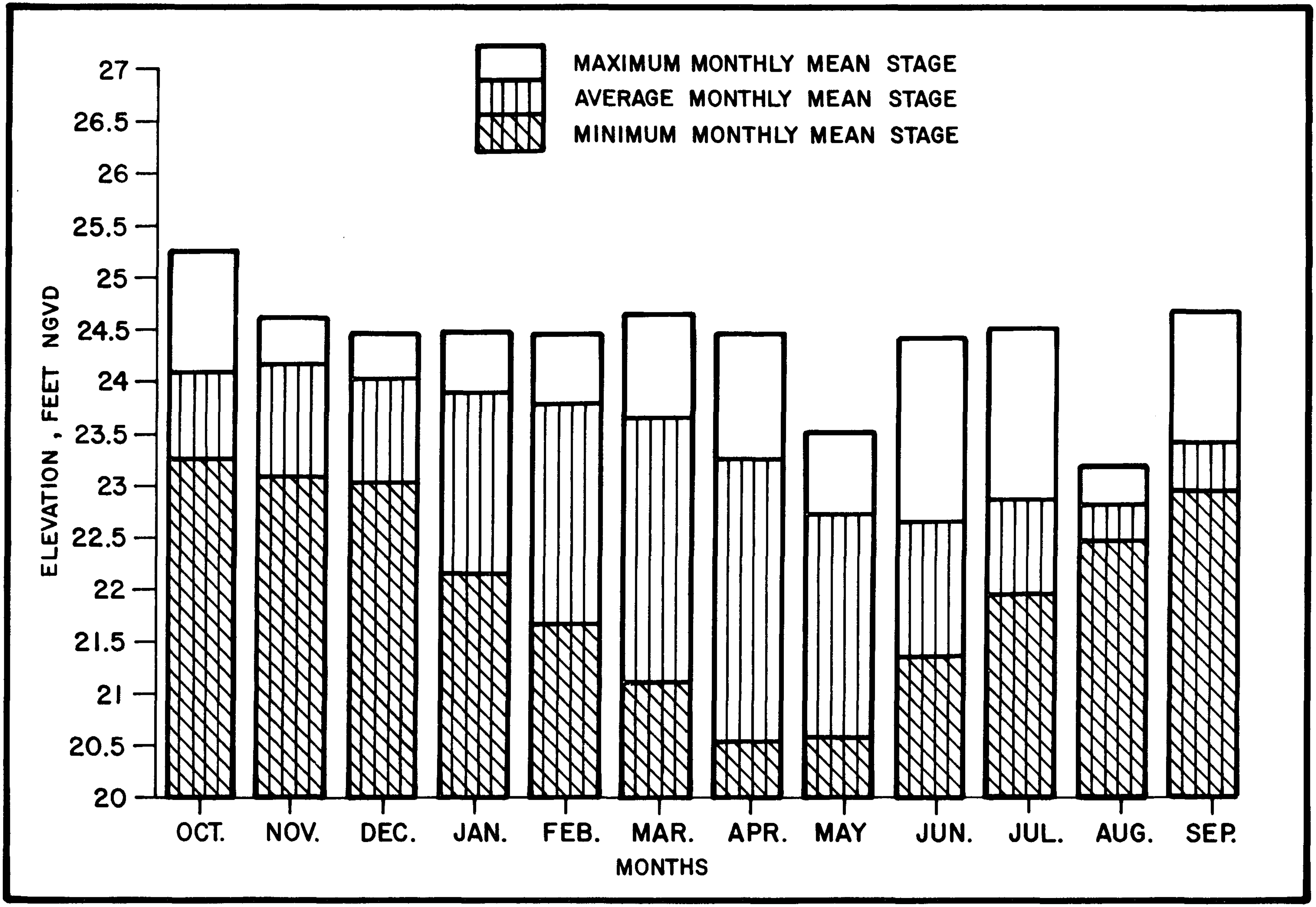

FIGURE 19. SIMULATED MONTHLY MEAN STAGES - BLUE CYPRESS MARSH CONSERVATION AREA

Blue Cypress Water Management Area

Preliminary results on expected surface water elevations in BCWMA indicate prolonged periods of inundation at shallow depths. Analysis of simulated daily stages indicates that surface water elevations of 24.5 feet NGVD will be exceeded 60 percent of the time (Figure 20). (Mean ground elevation in this WMA is approximately 22 feet NGVD.) The predicted seasonal variation in stages is shown in Figure 21. These results are preliminary in that management of this area may be changed in order to enhance hydrologic conditions north of the Fellsmere Grade.

St. Johns Water Management Area

Analyses of daily stages in the SJWMA indicate prolonged periods of inundation at depths greater than 4 feet (Figure 22). As a result of severe subsidence in this area, ground elevations down to 16 feet NGVD exist. Seasonal fluctuations will exist (Figure 23) but de-watering of lower elevations will not occur under the current operation schedule.

Downstream of Fellsmere Grade

Numerous tests were conducted in order to optimize the predicted hydrologic regime of the marsh north of the Fellsmere Grade. Because the degraded ecological state of the lakes in this reach is believed to be due to a decline in the size and the frequency and depth of inundation of the floodplain marsh, the management objective is to raise the

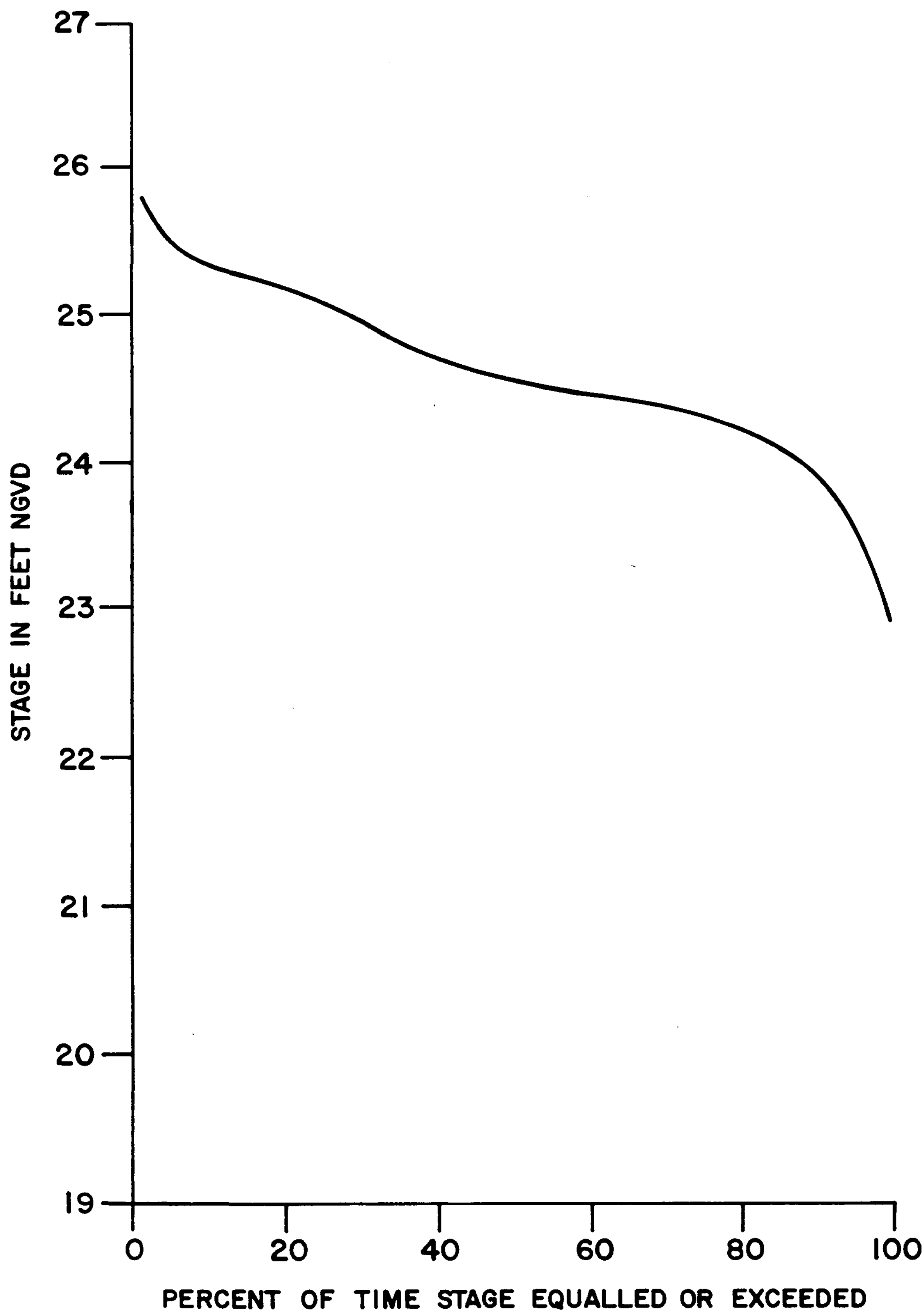

FIGURE 20. SIMULATED STAGE-DURATION CURVE FOR BLUE CYPRESS WATER MANAGEMENT AREA

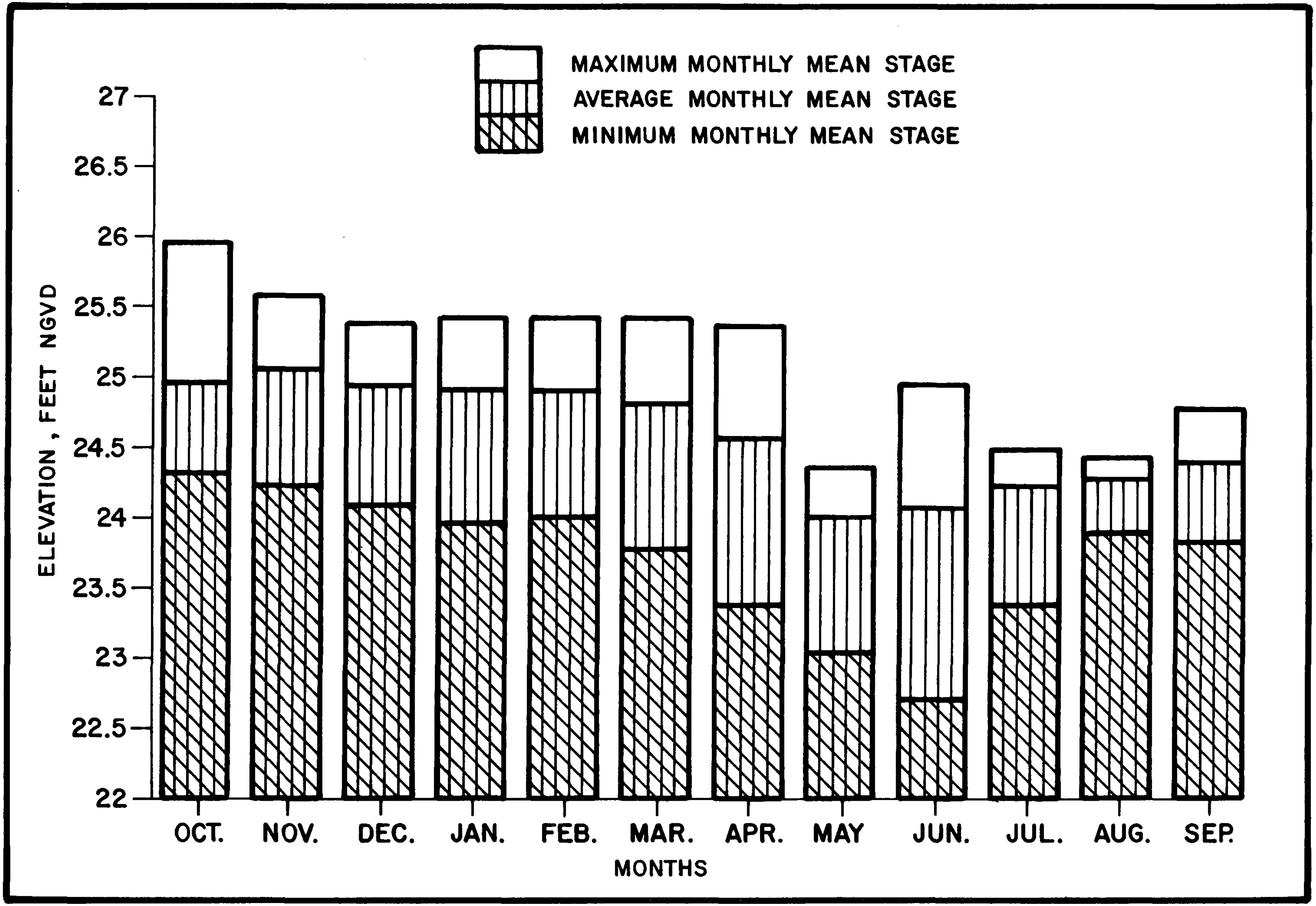

FIGURE 21. SIMULATED MONTHLY MEAN STAGES BLUE CYPRESS WATER MANAGEMENT AREA

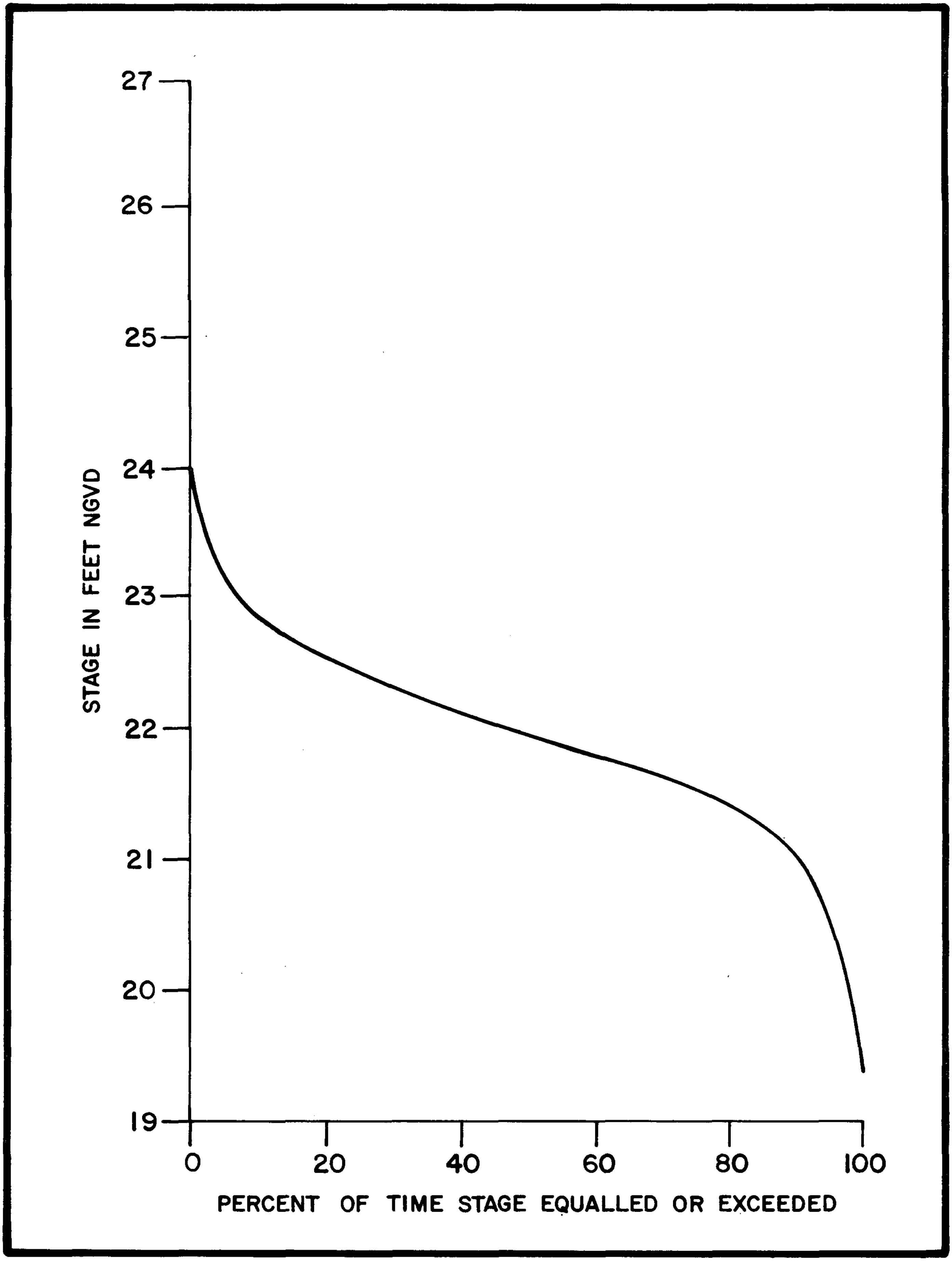

FIGURE 22. SIMULATED STAGE-DURATION CURVE FOR ST. JOHNS WATER MANAGEMENT AREA

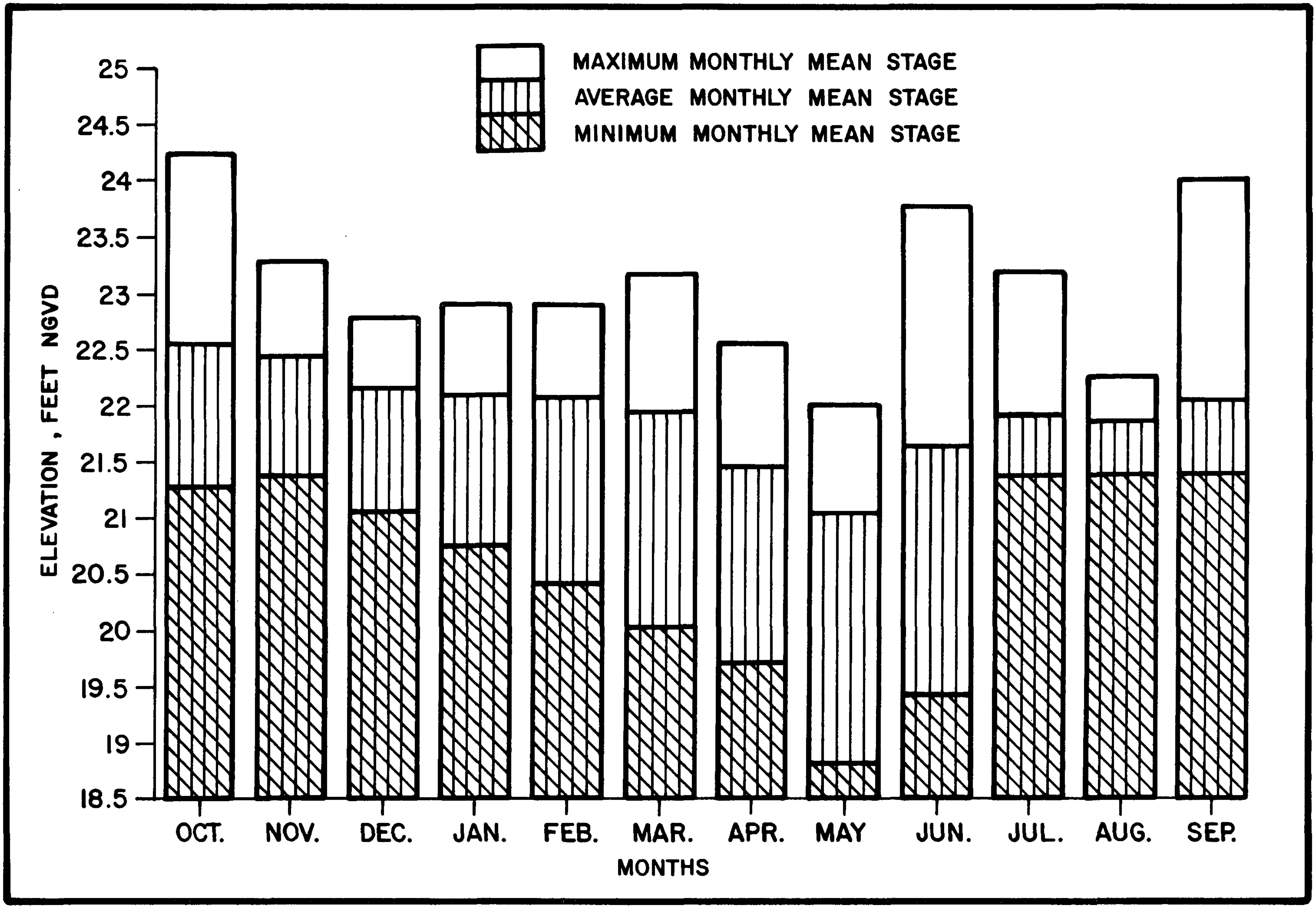

FIGURE 23. SIMULATED MONTHLY MEAN STAGES ST. JOHNS WATER MANAGEMENT AREA

water table of the marsh. Initially we attempted to satisfy this objective through augmentation of flows across the Fellsmere Grade. It was anticipated that by increasing inflow to this reach a favorable hydrologic regime could be produced on both the existing marsh as well as those lands targeted for restoration. Simulated data, however, predicted a drastic lowering of the water table north of the Grade despite increased flow rates across the Grade (Figures 25 - 30, Test 2). Figure 24 depicts the river miles where hydrologic analyses were conducted for various tests. The resulting decline in stages was the result of augmentation of floodplain area through land acquisition and the breaching of levees.

In order to increase the expected water levels we examined means of reducing storage during low flow periods while maintaining it during periods of high flow. Segmentation of the marsh north of the grade through separation of the existing marsh from the reclaimed marsh with a low level berm was considered but was rejected because we believed it was ecologically undesireable for large portions of the marsh to be hydrologically isolated for a significant fraction of most years.

Figure 31 portrays a design which evolved from the segmentation concept. From the northern boundary of the land we propose to restore on the east side of the basin, a low level berm would be extended south to a point where marsh elevations were approximately one foot lower than the

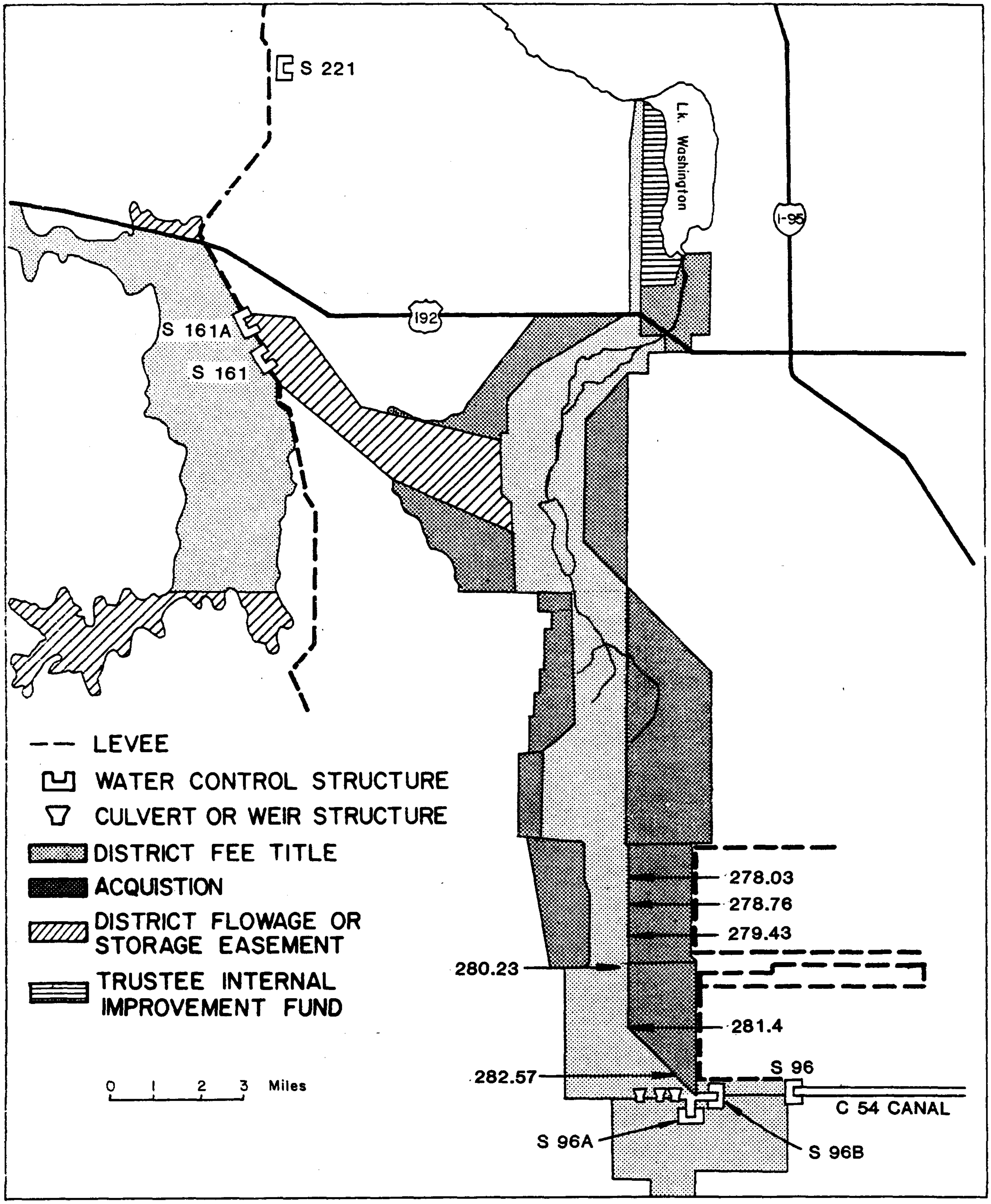

FIGURE 24. RIVER MILE DESIGNATIONS NORTH OF THE FELLSMERE GRADE WHERE HYDROLOGIC ANALYSES WERE CONDUCTED

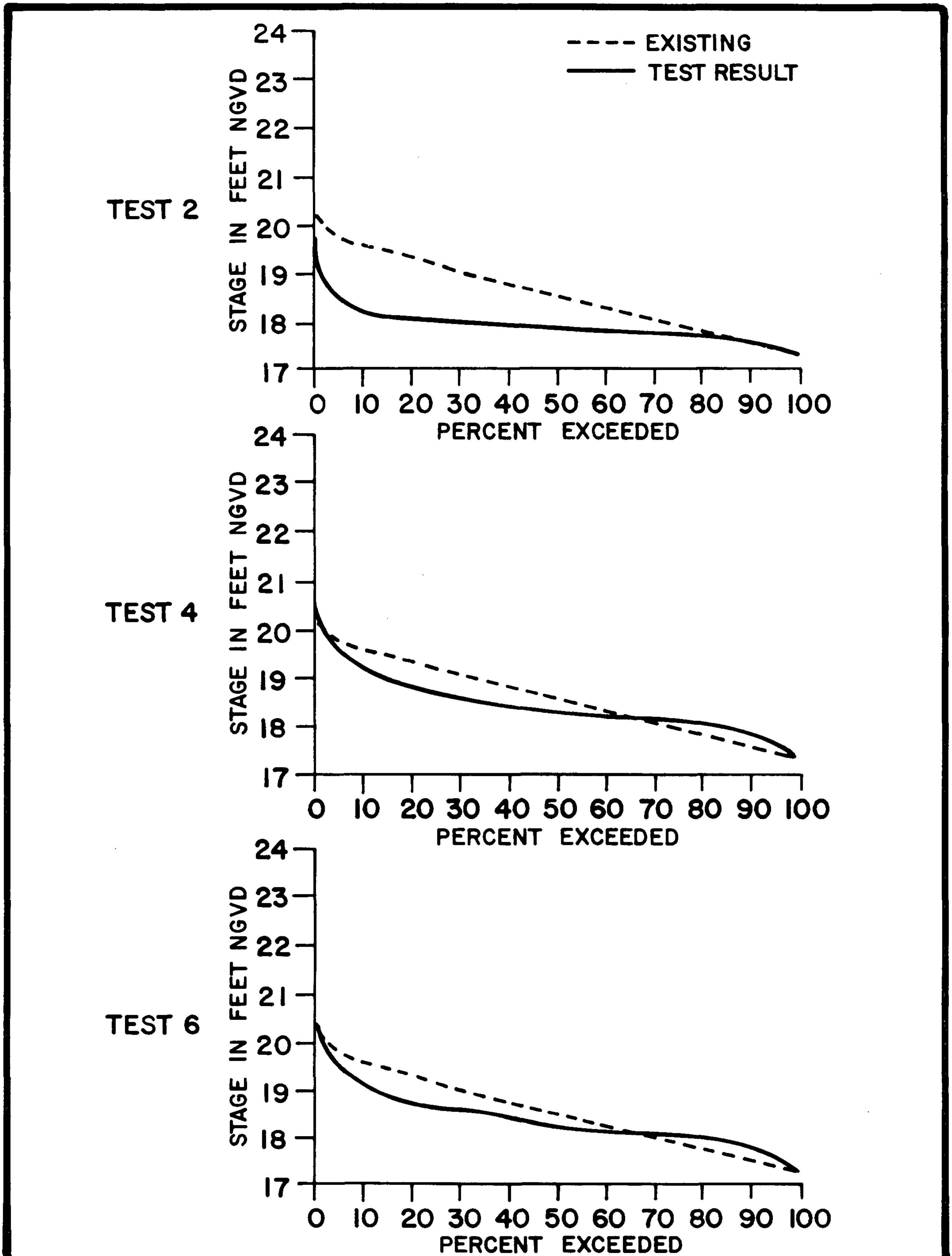

FIGURE 25. SIMULATED STAGE-DURATION CURVES AT RIVER MILE 278.03

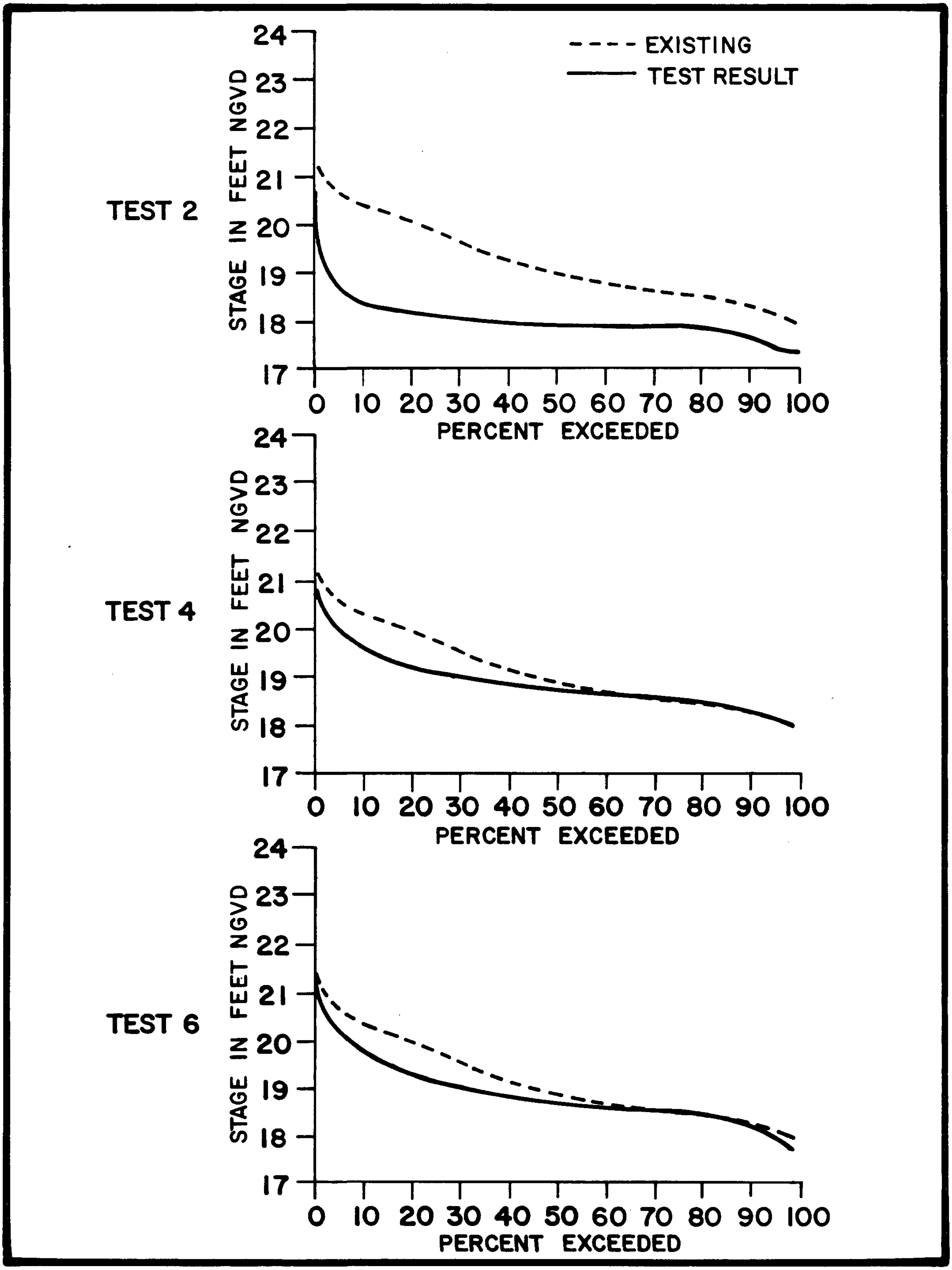

FIGURE 26. SIMULATED STAGE-DURATION CURVES AT RIVER MILE 278.76

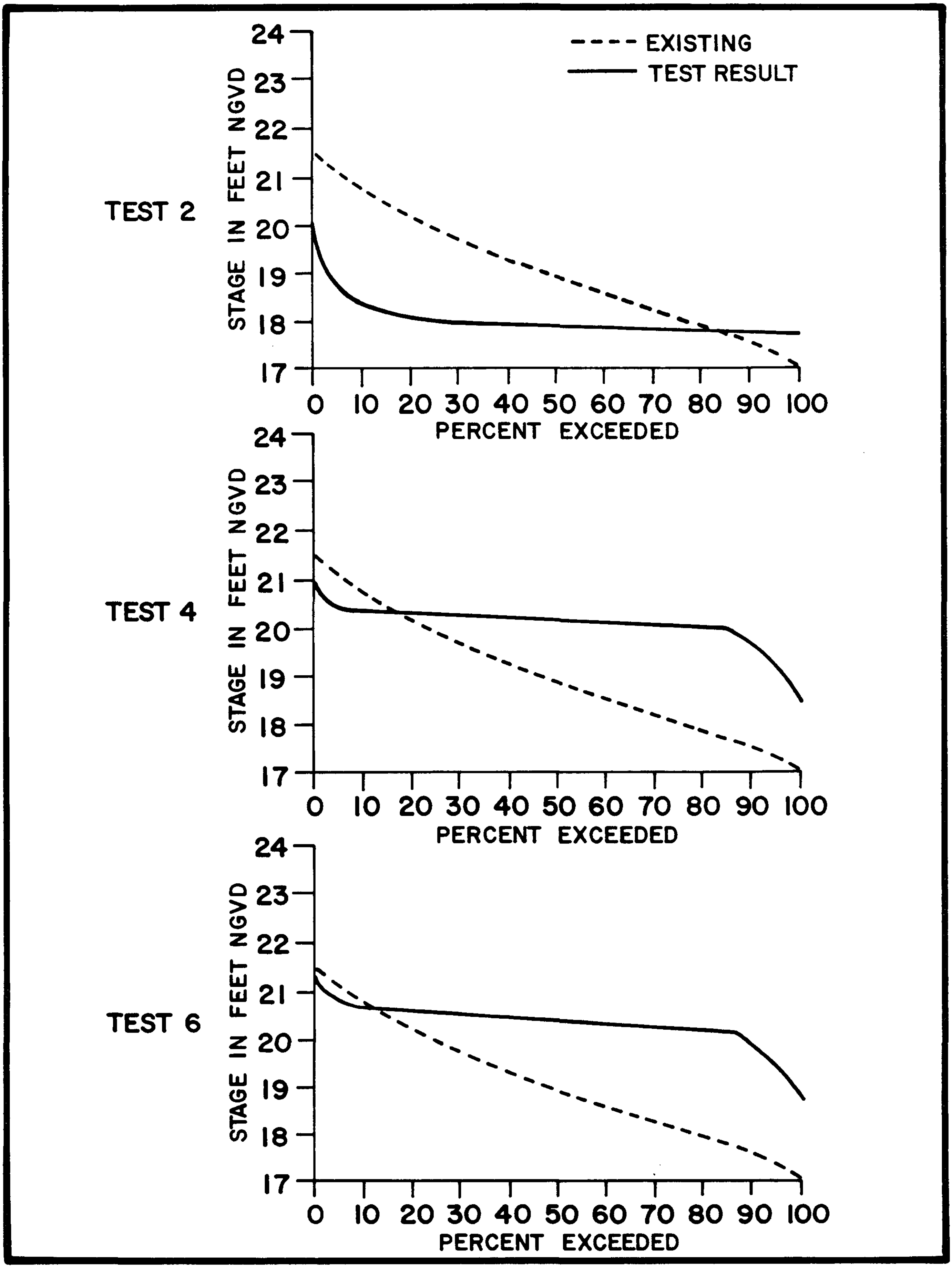

FIGURE 27. SIMULATED STAGE-DURATION CURVES AT RIVER MILE 279.43

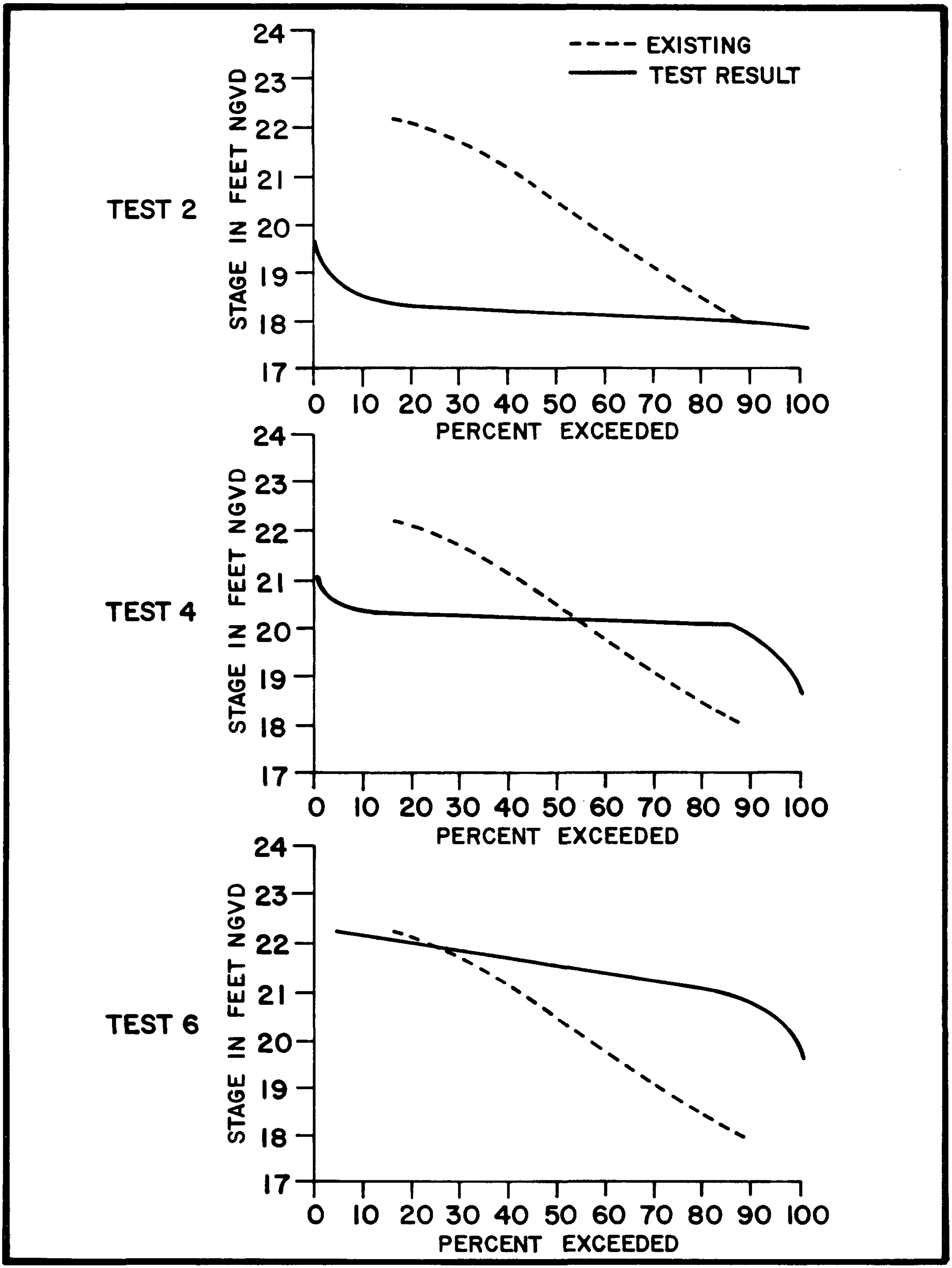

FIGURE 28. SIMULATED STAGE-DURATION CURVES AT RIVER MILE 280.23

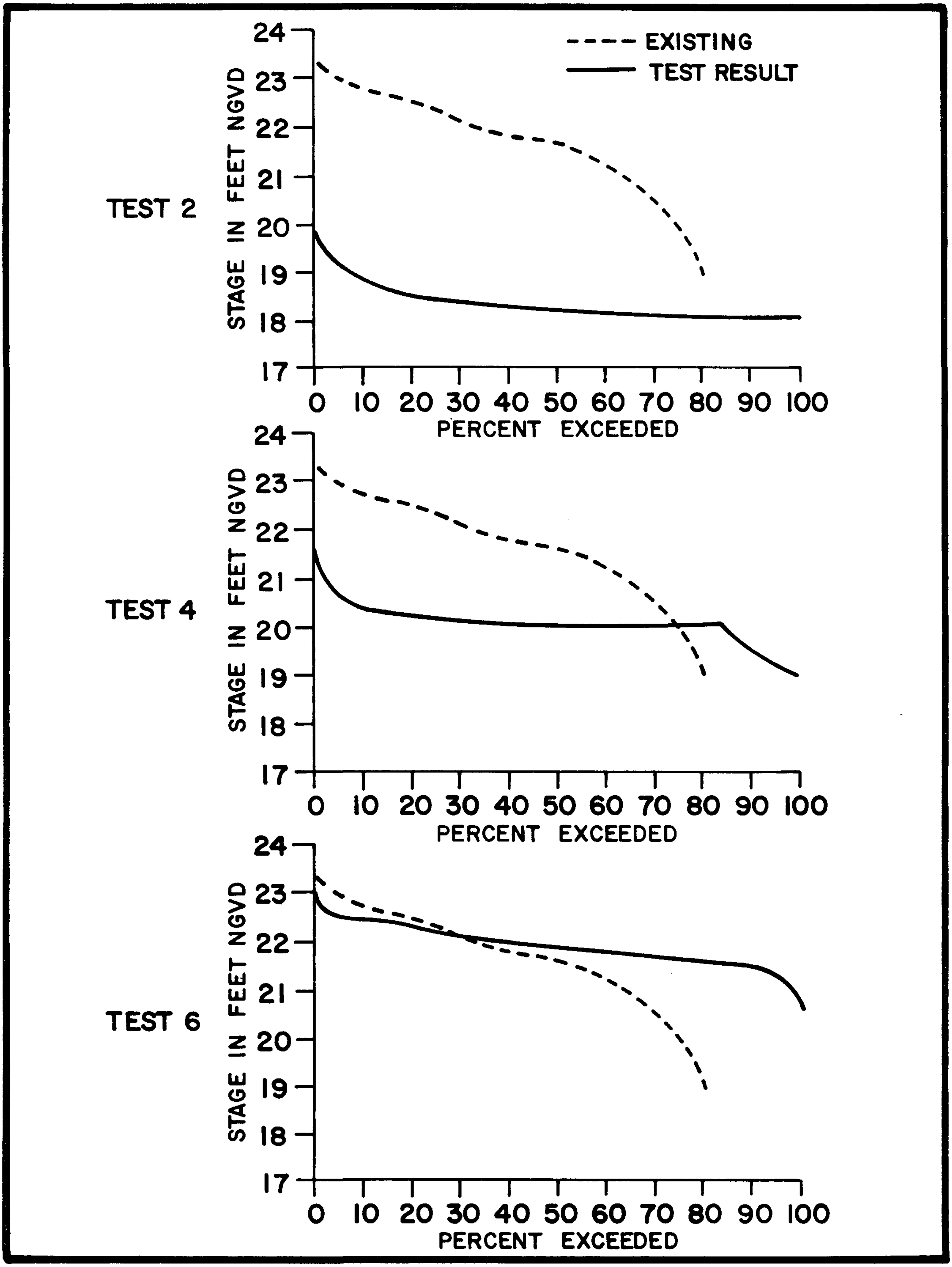

FIGURE 29. SIMULATED STAGE-DURATION CURVES AT RIVER MILE 281.4

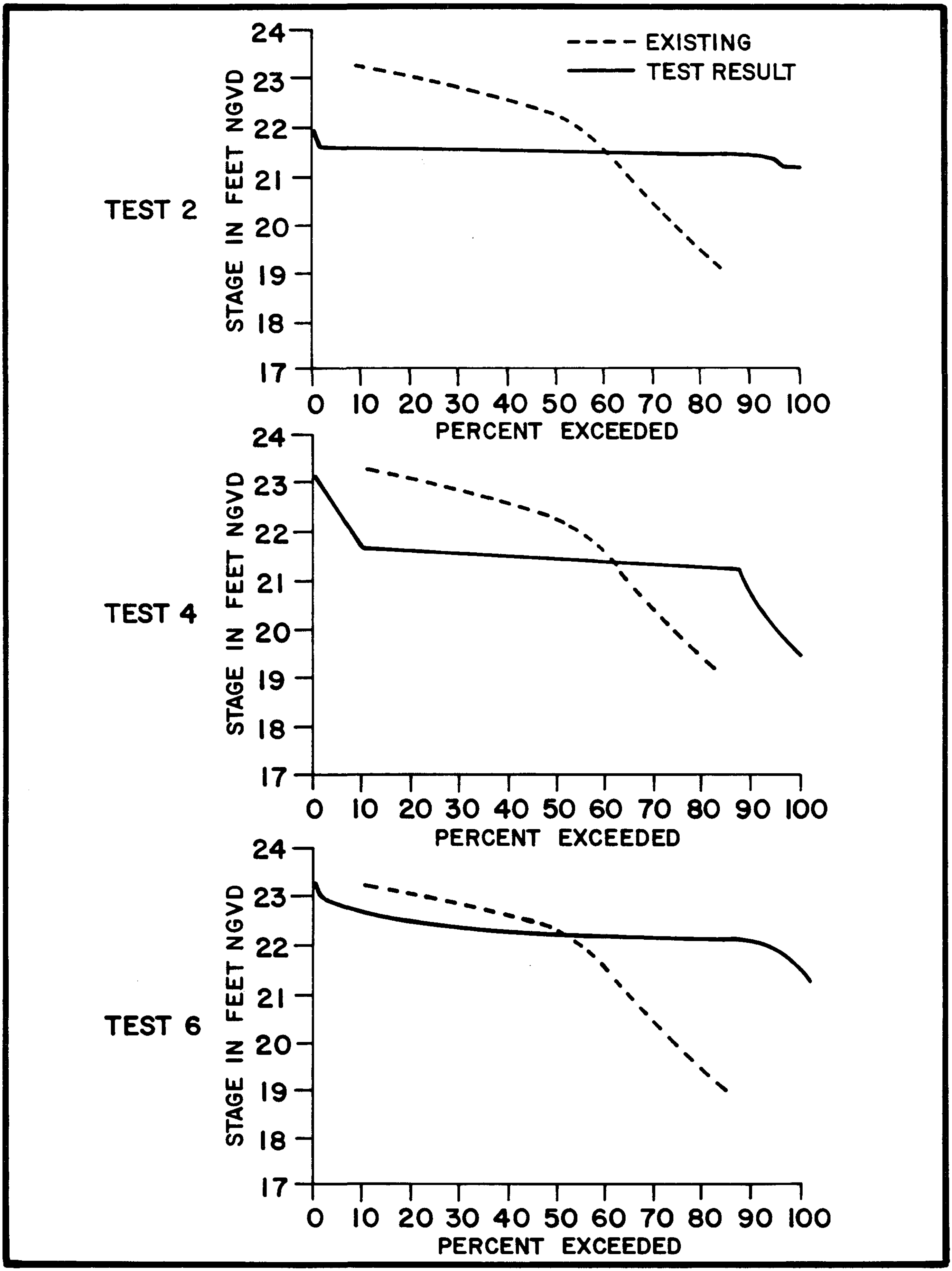

FIGURE 30. SIMULATED STAGE DURATION CURVES AT RIVER MILE 282.57

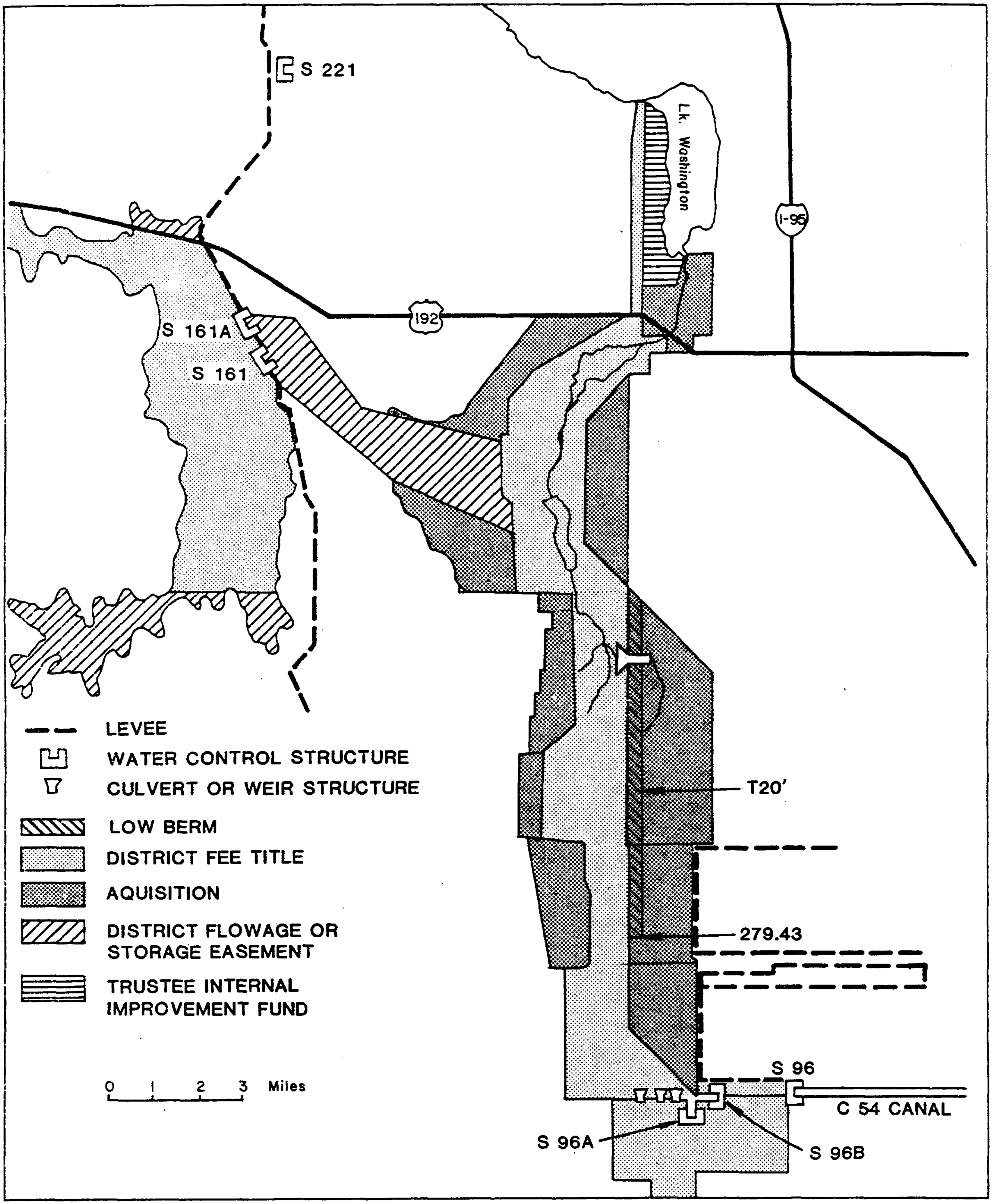

FIGURE 31. TEST 4 PROJECT DESIGN NORTH OF FELLSMERE GRADE

proposed berm elevation. This would result in the formation of a three-sided retention area open on the south to the existing marsh. At surface water elevations of less than 19 feet NGVD (marsh elevation at southern terminus of berm) dead storage would occur within the retention area. Figures 25 - 30 show the results of this test design (Test 4). An acceptable hydrologic condition resulted from the southern extent of the berm northward (river miles 279.43 and 278.03) but between the southern terminus of the berm and the Fellsmere Grade (river miles 280.23 and 282.57) the frequency of inundation of the marsh was still below that desired. This was due to the extensive storage provided by the lower elevations on the reclaimed lands (the result of subsidence) south of the low berm terminus.

Based on the results from Test 4 it was concluded that maintenance of an acceptable hydrologic regime on the existing marsh between river miles 280.43 and 282.57 required greater segregation of the existing marsh from the reclaimed marsh. Figure 32 exhibits the most favorable design developed to date. In this design, the levee between river mile 280.23 and 282.57, along the west boundary of the reclaimed marsh, would be only partially removed. To achieve the desired segregation under low flow periods, the crest elevation of the levee would be maintained at 22 feet NGVD. This southern low berm would be extended northward to approximately river mile 278.76. At this point the 19 feet NGVD contour would be intercepted. The northern low berm

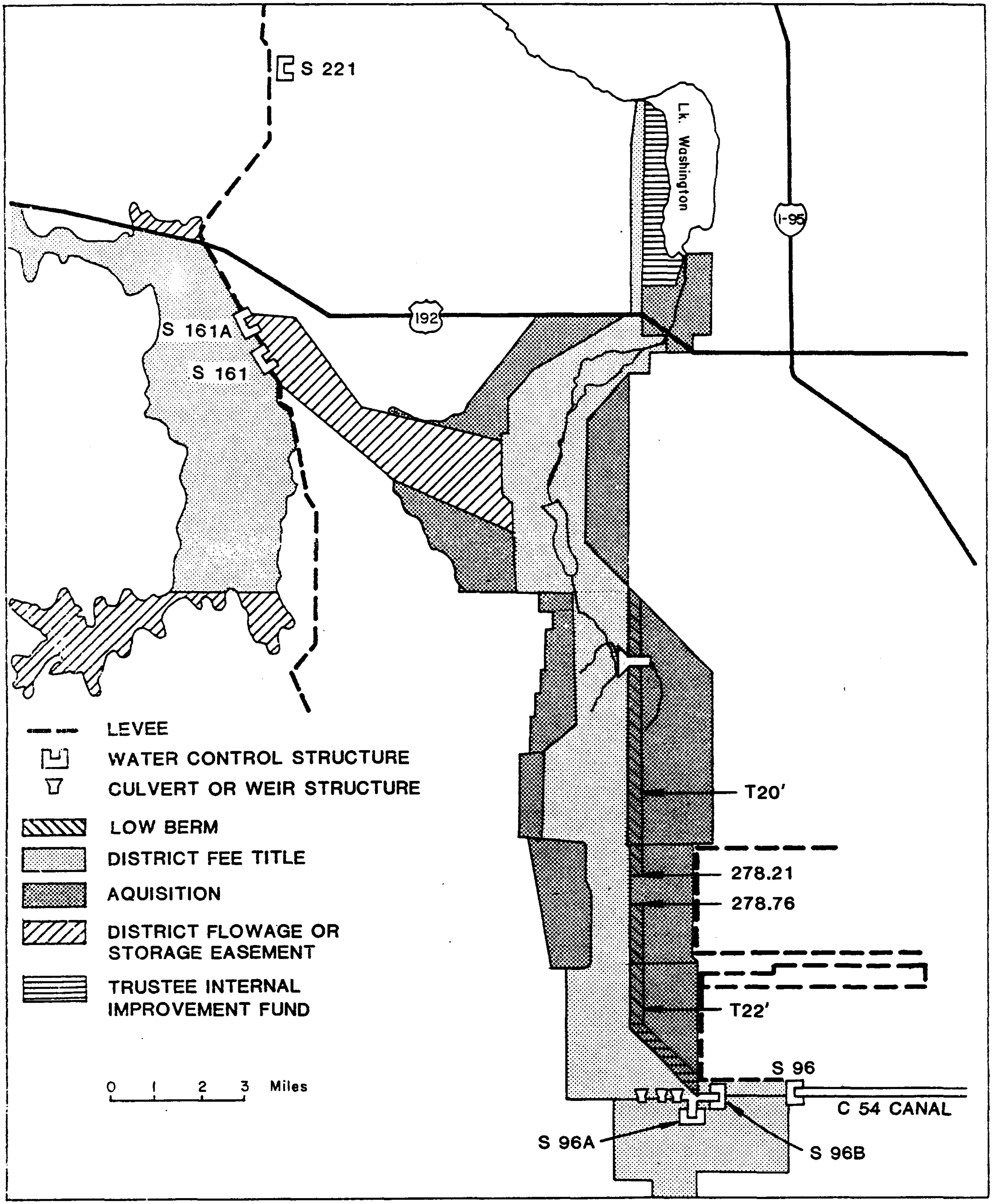

FIGURE 32. TEST 6 PROJECT DESIGN NORTH OF FELLSMERE GRADE

described in Test 4 would be maintained with its southern terminus also corresponding to a 19 feet NGVD contour intercept. The reach of existing levee remaining between the two berms (approximately 1 mile) would be removed down to marsh elevation. Under this design dead storage would result on the reclaimed areas at surface water elevations below 19 feet NGVD.

This design markedly improved the predicted hydrologic condition of the marsh (Test 6; Figures 25 -30). In the restored areas east of the north and south berms, however, a significant acreage would experience prolonged periods of inundation. Although this is desirable to a limited extent, a means of drawdown is being considered.

DISCUSSION

The proposed Upper Basin Plan is a semi-structural approach to water management which balances ecological and economic goals. It is semi-structural in that, to the extent practicable, hydrology will be controlled by the natural morphometry of the basin. This approach will protect or restore large areas of floodplain wetland and thereby enhance the usefulness of the river and lakes for outdoor recreation. Of the major components of the plan: the marsh conservation areas, the water management areas, C-54 canal, and the restored marsh north of the Fellsmere Grade (Figure 32); only the canal and the water management areas are completely structural in concept. All other components, except for the pre-existing Taylor Creek impoundment, should mimic the functions of the natural floodplain marsh.

The ecosystem which would be produced by implementation of the Upper Basin Plan would differ from the natural system in two major respects: 1) the size of the floodplain would be smaller, and 2) the ratio of open water to emergent marsh would be greater. Although approximately 56,000 acres of floodplain would be purchased for the project only about 43,000 acres of this would be returned to the floodplain. Considering that approximately 222,500 acres of the total floodplain and 66,733 acres of the annual floodplain have been lost to the river through development, it is clear that the Upper Basin Plan does not constitute a complete restoration. Although a complete restoration of the floodplain would be ecologically desireable the cost of such a restoration would be prohibitive. For example, restoration of the floodplains of lakes Hell 'n Blazes, Sawgrass, and Washington would require the purchase of approximately 197,000 acres, much of which is planted to citrus and costs about $6,000 per acre. Complete restoration, however, may not be necessary to regain most of the ecological value of the basin. It seems reasonable that those wetlands bordering the river and lakes and which lie within the annual floodplain have a greater influence on the aquatic systems of the basin than do those wetlands which are far removed from any permanent body of water. If this is true, then the proposed restoration of about 64 % of developed annual floodplain, coupled with a restoration of more natural hydrologic conditions, would markedly improve the region's ecology. Moreover, this reasoning suggests that restorative efforts above the annual floodplain would be much less effective on a per acre or per dollar basis.

Without a complete restoration of the floodplain, the increase in open water areas of the basin is unavoidable if diversion of water to the coast is to be reduced. The deep storage areas represented by the WMAs are needed to retain this water during the wet season without incurring a potential for flooding of agricultural areas. The WMAs would be ecologically valuable, however, in that they could retain agricultural discharges and release water slowly downstream to provide a more natural hydrologic regime.

In addition to the WMAs, the plan would result in a large open water area north of the Fellsmere Grade in an area which was originally intended to be restored emergent marsh. This area is primarily composed of parcels 83-12, 83-14, and 83-10 (Figure 2). Ponding of this area is unavoidable since, as explained earlier, creation of dead storage is necessary to produce a desireable hydrologic regime on other portions of the marsh. Because the open water area would have a broad connection with the emergent marsh, however, we believe it would be biologically beneficial. During the dry season it would provide deep water refugia for fish and for invertebrates which are intolerant to drawdowns (such as the apple snail Pomacea paludosa). In addition, as water levels fall during the dry season the receding water line should provide nearly optimum feeding conditions for wading birds, particularly tactile feeders such as the wood stork and white ibis (Kushlan et al., 1975).

Implementation of the Upper Basin Plan would mitigate much of the ecological damage which has been sustained by the Upper St. Johns but additional, relatively minor measures, which cannot now be incorporated into the plan, may be ecologically desireable. The most important of these would be modification of the Lake Washington weir. As pointed out by Cox et al. (1983) and by Lowe et al. (1984), stages in Lake Washington and areas of the river adjacent to the lake were adversely affected by the removal of the "Jams", a natural dam of vegetation and peat lodged in the channel north of Lake Washington, in the early 1940s. The Jams detained water in upstream areas but probably released more water downstream during dry periods than does the Lake Washington weir. In order to manage water in a fashion similar to that provided by the Jams it may be necessary to raise the crest of the Lake Washington weir and modify its design to that of a V-notch weir. This would maintain higher water levels in the lake at most times and would allow some water to flow downstream at water levels below 13.5 ft. NGVD. In order to evaluate the desirability of modification of the weir, the Environmental Sciences Division has proposed a study of the water requirements of that portion of the river downstream of the weir and in addition will recommend study of the hydrologic effects of modification of the weir on Lake Washington and on downstream sections of the river.

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