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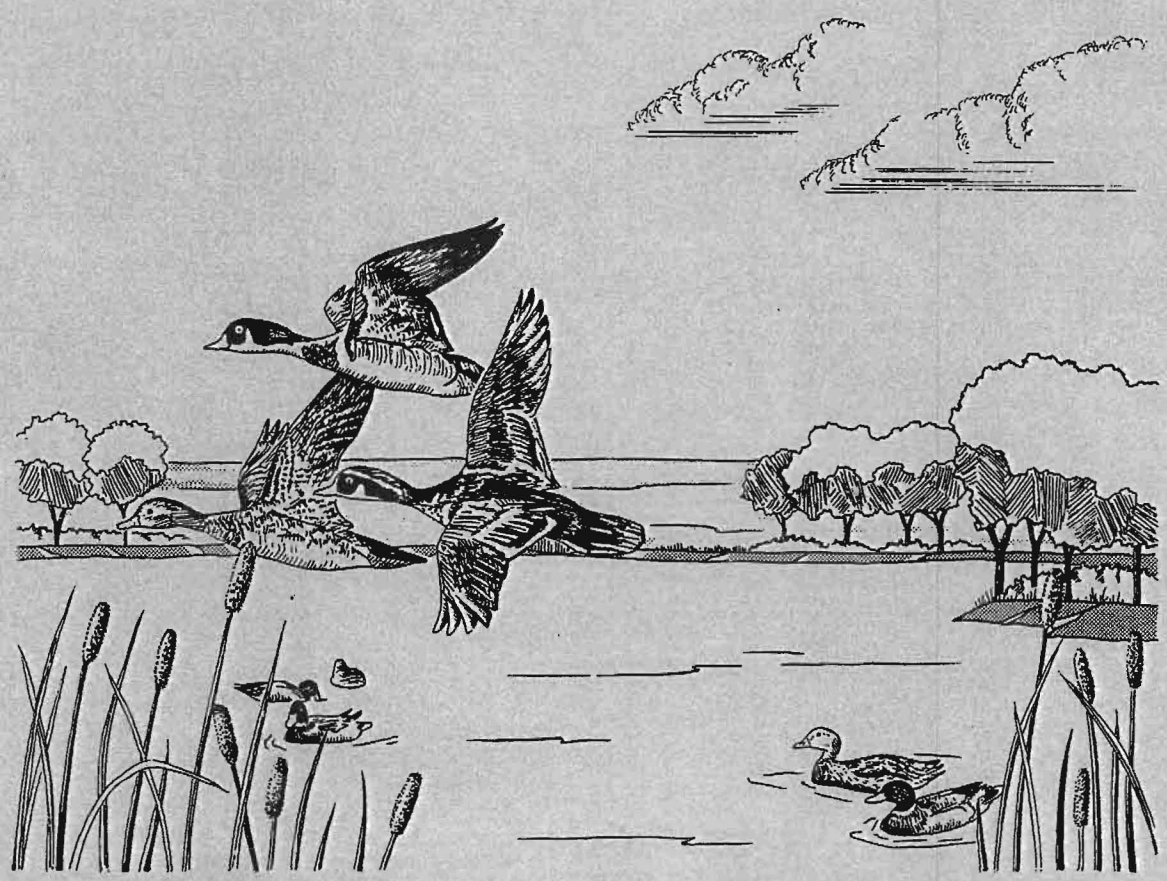
REFUGE MANAGEMENT ANALYSES: LEVEE ALTERNATIVES AT CLARENCE CANNON NATIONAL WILDLIFE REFUGE



Fish and Wildlife Service

U.S. Department of the Interior

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April 1984

REFUGE MANAGEMENT ANALYSES: LEVEE ALTERNATIVES AT CLARENCE CANNON NATIONAL WILDLIFE REFUGE

by

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Results of a Workshop Convened by
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EXECUTIVE SUMMARY

This report documents the results of a workshop that examined levee alternatives at Clarence Cannon National Wildlife Refuge. This refuge is located along the Mississippi River, approximately 50 miles north of St. Louis. It was purchased primarily for waterfowl maintenance. A levee providing flood protection from the Mississippi River has broken four times since the Refuge was acquired in 1965. A number of alternatives have been proposed in response to the most recent break in 1983. Long term alternatives considered at the workshop included:

- Improve the existing levee by raising the height approximately 2 ft.
- Repair the existing levee with no change in height.
- Maintain the levee at a lower elevation by including a spillway about 3 ft lower than the existing levee height.
- Do not maintain a levee so that the Refuge will flood directly with river stage.

Repair of the major breaks in the levee, but not the more general wave damage, was considered as a short term alternative.

Participants first specified the habitats and management controls desired at Clarence Cannon National Wildlife Refuge. These were centered around attaining the maximum feasible development and management of moist soil units. Levee alternatives were evaluated in terms of their ability to provide the desired habitats and management controls. Preliminary cost estimates were prepared for each alternative, and the qualitative consequences of each alternative identified for the full set of outputs from the Refuge Master Plan.

The alternative of improving the existing levee by raising the height was unanimously preferred on purely "biological" grounds (with cost not considered). Repairing the levee with no change in elevation was unanimously selected as the most cost effective alternative.

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INTRODUCTION

Clarence Cannon National Wildlife Refuge (CCNWR) is located on the Mississippi River near Annada, Missouri, approximately 50 miles north of St. Louis (Fig. 1). The Refuge was purchased in 1965 with the primary objective of providing a feeding and resting area for migrating waterfowl. The CCNWR is a unit of the Mark Twain National Wildlife Refuge complex.

The CCNWR consists of 3,736 acres, predominantly cropland and moist soil units. Historically, about 2,000 acres have been intensively cultivated each year through a cooperative farming program. A Refuge pumping system is used to facilitate this program by providing spring dewatering of flooded fields. Pumping currently is the greatest consumptive use of energy on the Refuge. The Refuge Master Plan, completed in 1979, indicated a planned reduction to 700 cultivated acres. Five moist soil units, totaling 525 acres, presently exist, with approximately 500 more acres included in the master plan. The only forested areas on the Refuge are in low, wet areas that could not be farmed by previous owners.

Access to private property north of the CCNWR is provided by a road through the Refuge under the terms of a prescriptive easement. A flood protection levee encloses the Refuge and has been maintained since the CCNWR was purchased (Fig. 1). In April, 1983, two breaks occurred in the levee system as a result of near record high water levels on the Mississippi River. Because this was the fourth levee break since the Refuge was purchased in 1965, it was decided that alternatives to the current levee maintenance and Refuge habitat management programs should be evaluated.

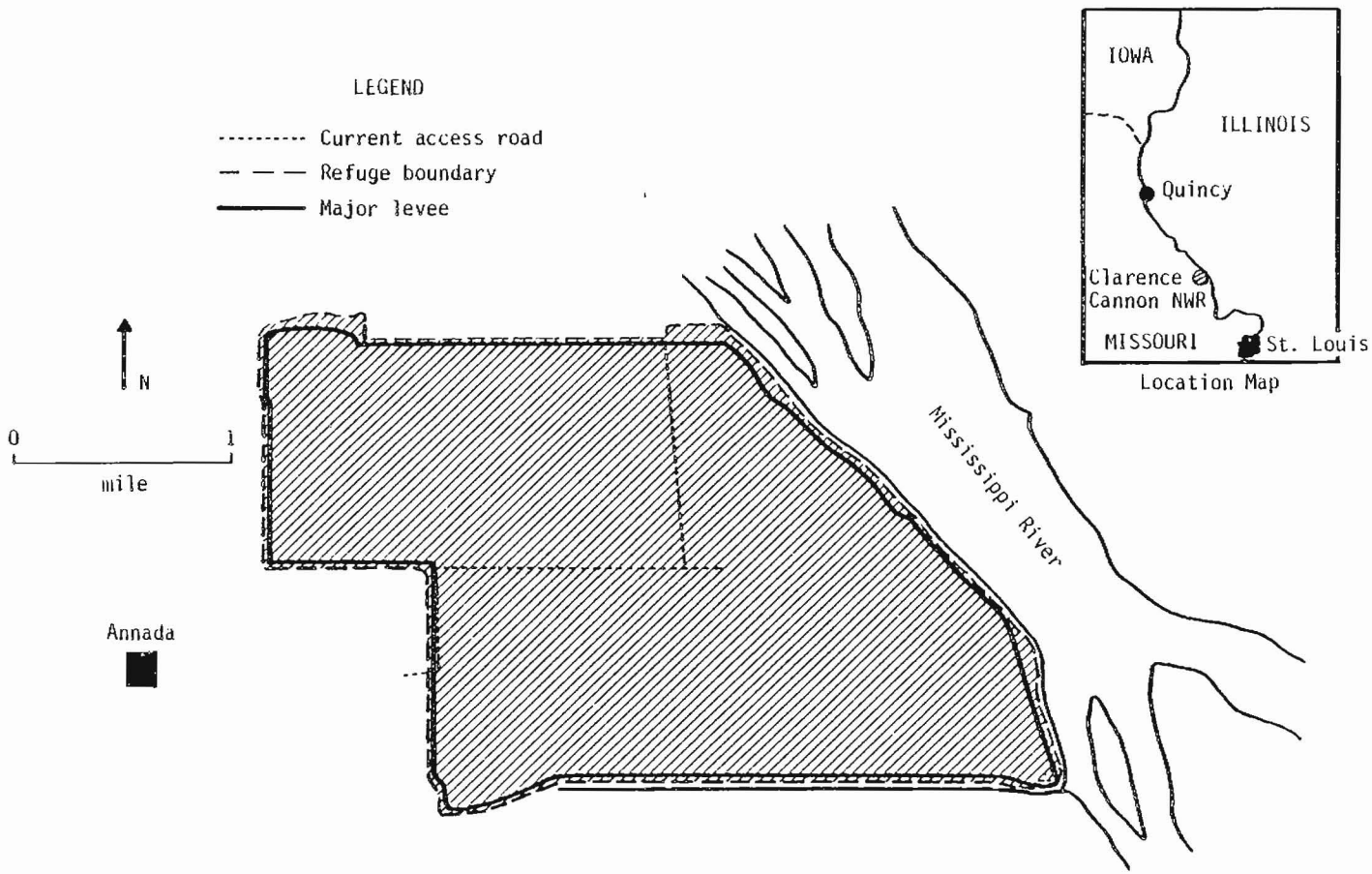

Figure 1. Clarence Cannon National Wildlife Refuge.

WORKSHOP OBJECTIVE

The Mark Twain National Wildlife Refuge complex of the U.S. Fish and Wildlife Service (FWS) convened a small workshop on March 12-15, 1984, to consider the needs of the CCNWR. The objective of the workshop was to evaluate five proposed levee alternatives, both in terms of their ability to achieve Refuge wildlife objectives and their cost effectiveness. This report documents the results of that workshop. Several of the quantitative analyses presented in the report have been revised slightly based on computer work conducted after the workshop. Throughout the report elevations of the levee and river stages are reported as ft above Mean Sea Level.

APPROACH

The authors of this report, as members of the Western Energy and Land Use Team, FWS, were asked to organize and facilitate the workshop. This request was based on previous experience in conducting similar workshops in which a systems analysis approach was used to achieve a better understanding of resource system components, their interactions, and the consequences of various management alternatives.

Initial discussions at the workshop identified primary Refuge objectives, management actions utilized to meet those objectives, flooding history of the Refuge, and the effects of flooding on Refuge management and outputs. Next, a group exercise was conducted to reach a consensus on the amounts of various habitats and the degree of management control that would be desired at the CCNWR if there were no constraints related to costs or political considerations. The five levee alternatives proposed by former Refuge Manager Greg Wolf were discussed and evaluated in terms of their ability to provide the desired habitats and management controls, their consequences for Master Plan outputs, and their costs. Finally, two ranking exercises were conducted; the first to rank the alternatives based solely on their ability to provide the desired habitats and management controls and the second to rank the alternatives based on their cost effectiveness.

Participants at the workshop included the following individuals:

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These individuals contributed the vast majority of the ideas and information contained in this report. Much of the discussion at the workshop was based on the evaluation of levee alternatives developed by former Refuge Manager Greg Wolf and on the analysis of flooding potential for each alternative developed by current Refuge Manager Ross Adams. In documenting the results of the workshop, we have attempted to retain both the content and sense of the discussion and these analyses, but accept full responsibility for errors of fact or interpretation.

DESIRED HABITATS AND MANAGEMENT CONTROLS

The CCNWR consists of 2,100 acres of cropland, 525 acres of developed moist soil units, 150 acres of ponds, 100 acres of other water areas (e.g., sloughs), 700 acres of timber and brush, and 130 acres in various other cover types. The Refuge Master Plan and discussion at the workshop indicated that changes in the relative amounts and management control of these habitats might provide enhanced opportunities for wildlife. Therefore, a group exercise was conducted to answer the following question:

> What habitats and management controls would best provide for the biological needs of wildlife that you consider to be of primary importance at the CCNWR? Assume that:
>
> (1) costs of the alternatives are not a consideration;
> (2) the current Master Plan is not binding;
> (3) costs and time to revise the Master Plan are not considerations; and
> (4) there are no political constraints or considerations.

Responses to this question are summarized below. The discussion was restricted to the major habitats at the CCNWR, which are moist soil units/ marshes, croplands, bottomland hardwoods, and grasslands/ grow-back areas.

MOIST SOIL UNITS/MARSHES

It was the concensus of workshop participants that, ideally, moist soil units should be the primary habitat at the CCNWR. Topographic information currently available indicates that it should be possible to develop between 1,200 and 1,500 acres of moist soil units, including the 500 acres already in existence. A more detailed topographic survey might be useful in refining this acreage estimate and in finalizing plans for development. This acreage

would be divided into six to eight units with individual water control to provide depths from 0 to 1 ft. The dikes enclosing these units are master planned as permanent and relatively expensive facilities; lower, "expendable" dikes (e.g., rice dikes) might be used either for the perimeter of the units (to be cost effective in alternatives with frequent flooding) or along 0.2 ft contours within units (to provide more precise water level control).

In the spring, it would be desirable to have complete control over the timing (mid-February to mid-March) and depth of flooding of each unit. Complete control of dewatering would allow drying anytime from mid-March to September at a specified rate, including partial dewatering for shorebirds. In the Fall, it would be desirable to be able to reflood units to desired depths consistent with the arrival of various migratory birds (e.g., herons in July, teal in September, and other ducks starting in October). Control of woody growth in moist soil units might be accomplished by tillage. In tilled units, winter wheat could be planted from mid-August to September to provide green forage for geese.

CROPLANDS

Croplands on the Refuge are currently used to provide "hot" food for migrating birds in the fall. The Master Plan specifies a reduction from approximately 2,000 to 700 acres in the cooperative farming program in the future. During the workshop, the role of the Refuge in providing "hot" food was discussed with respect to other nearby refuges, agricultural practices off the Refuge (adjacent fields are plowed under in dry falls and, therefore, provide no waste grain), and natural sources of food for the birds. The general consensus was that the CCNWR did not have to produce much "hot" food, given nearby refuges and agricultural fields. Four farming alternatives with the ability to provide an adequate food source were eventually identified.

Option 1 - No Farming

Under this option, presently cultivated acres that were not converted to moist soil units would be converted to bottomland hardwoods where possible or to grasslands. Establishment of pin oaks would be encouraged in the new bottomland hardwood areas for mast production. Some farming would be required in the short term as hardwoods and grasslands were incrementally established.

Option 2 - Force Account/Contract Farming

With only force account (conducted by Refuge staff) or contract farming, about 500 acres would be cultivated with a rotation of corn or milo and legumes. All crops would be left standing for use by wildlife.

Option 3 - Cooperative Farming for "Services"

Under this option, a cooperator would be engaged to farm about 1,000 acres; in any year, about 300 acres would be in row crops and 700 acres in soil-building legumes. The cooperator would be allowed to harvest all crops. Thus, waste grain would be the only source of "hot" food. In exchange for the crops, the cooperator would provide services (e.g., mowing and planting wheat) required for maintaining moist soil units. Biological farming practices would be encouraged, and there would be no pumped dewatering of fields in the spring except as necessary for the management of moist soil units.

Option 4 - Cooperative Farming for "Services" and Waterfowl Food Production

This option would be similar to Option 3, but some additional row crops would be left unharvested to provide "hot" food for waterfowl. Thus, slightly more than 1,000 acres might be required for this option.

BOTTOMLAND HARDWOODS

Under the most desirable management scheme, the CCNWR would have approximately 1,600 acres of bottomland hardwoods. There currently are about 800 acres. Of the 800 additional acres, 200 would be planted in strips near perimeter dikes to provide protection from wave damage when the Refuge floods. Mast producing (pin oak) and cavity producing (sycamore) trees would be emphasized when establishing new areas. The ability to flood existing bottomland hardwoods in the fall would be retained but green tree reservoir management would not be utilized in the newly created hardwoods. Any new areas with the capability for fall flooding control would be used for moist soil units rather than bottomland hardwoods.

GRASSLANDS/GROW-BACK AREAS

Between 250 and 700 acres of grasslands and grow-back areas would be desirable at the CCNWR. Woody growth might be manipulated or controlled in some of these areas.

LEVEE ALTERNATIVES

Five levee alternatives were proposed by former Refuge Manager Greg Wolf in a December 20, 1983, draft report. These alternatives differ in physical facilities, costs, and effects on Refuge management. The five alternatives were discussed and evaluated further during the workshop.

DESCRIPTION

Alternative A - Improve Existing Levee

This alternative entails raising the river (east) levee, about 1 mile of the Bryant's Creek (south) levee, and several spots on the north levee to a height of 451.5 (approximately 2 feet higher). With these improvements, river flood stages such as those in 1965, 1969, 1979, and 1983 would not overtop the levee and result in flood-related damage (siltation of ditches, erosion of dikes, and crop damage or delay). A flood such as the one in 1973 would overtop the improved levee, but that was the flood of record and is expected to occur very infrequently.

Alternative B - Repair the Existing Levee

The 1983 flood opened two 70-ft wide breaks in the river levee, overtopping caused 12 deep cuts, and wave action resulted in erosion along 70% of the levee. Alternative B is a short term solution, consisting of repairing only the two breaks and the larger cuts. This approach would temporarily reestablish the historical level of flood protection at 449.5 and allow existing Refuge programs to continue. Alternative B could probably be accomplished with force account resources.

Alternative C - Repair Existing Levee, Including Wave Damage

This alternative includes the repairs under Alternative B, as well as contract repair of the wave damage to the levee.

Alternative D - Maintain Levee at Lower Elevation

In this alternative, the river levee would be effectively lowered 3 ft by constructing a 350-ft wide spillway in one of the existing breaks at 446.5. The rationale for this proposal is that levees cannot always protect the Refuge from flooding, and it, therefore, makes more sense to try to prevent the Refuge from flooding with "normal" spring river rises and let the Refuge flood during exessively high stages. A spillway structure would allow more gradual and controlled flooding and, thus, limit damage when a flood occurs. In conjunction with spillway construction, the other levee break, major cuts, and wave action damage would be repaired and outlet culverts and gates constructed to allow gravity-flow removal of flood waters.

A major uncertainty exists concerning the need to provide access to property north of the Refuge under the terms of a prescriptive easement. This access is currently provided by a road through the CCNWR. With the level of flood protection provided by the current levee (449.5), this road normally is usable. Depending on the exact legal requirements, a new or better road might be needed in order to provide "equivalent" access under alternatives that effectively lower the levee elevation and, thus, the degree of flood protection. If the access road is a requirement, the best alternative seems to be a road on top or along the outer edge of the western and northern levees. This would probably be the most cost effective option and would also reduce disturbance from vehicular traffic in the center of the Refuge. There were uncertainties with this route, however, because some of the land that would be required is not now part of the Refuge.

At the workshop, we assumed that Alternatives D and E would include a new access road. This adds substantially to their cost. Therefore, it is very important to obtain a clear legal definition of the FWS obligation to provide access.

Alternative E - No Levee Protection

Under this alternative, the river levee would be breached in about six additional locations so that the water level in the Refuge would fluctuate more directly with the river. The resulting "levee" height would be approximately 441.5. This alternative also includes the new access road described above as part of Alternative D.

ABILITY TO ACHIEVE DESIRED HABITATS AND MANAGEMENT CONTROLS

The five levee alternatives are compared in Table 1 in terms of the percentage of the desired habitats that could be provided and the percentage of years in which full levels of desired management control could be expected to occur. Alternatives B and C are combined because their flooding and habitat characteristics do not differ in the short term (both would provide flood protection to 449.5).

The assessment of the ability of the various alternatives to provide desired management controls are based on the respective levee elevations and estimated river stages at the Refuge for the period 1964-1983 (see Appendices). These assessments are similar to those done at the workshop; however, they differ in detail because they are based on a computer-aided examination of the hydrologic record, rather than the graphic methods that were used at the workshop.

Table 1. Summary of ability of alternatives to provide desired habitats and management controls.

Habitat and control	% of desired area or % of years with desired control			
	Alternative			
	A	B/C	D	E
Moist soil units/marshes				
Area	100	100	100	100
Spring flooding	100	100	90	55
Spring dewatering	95	75	55	15
Fall flooding	100	95	85	45
Mechanical control of woody growth	a	a	a	a
Croplands				
Area	100	100	100	100
"Dry growing season" sufficient for				
Full season corn	95	75	55	15
Short season corn	95	75	65	30
Soybeans	100	95	90	45
Bottomland hardwoods				
Area	100	100	100	100
Establishment	b	b	b	b
Grasslands/grow-back areas				
Area	100	100	100	100
Control	c	c	c	c

a - More flood protection (A > B/C > D > E) may result in more control over timing of operations.

b - More flood protection (A > B/C > D > E) may make establishment of seedlings easier and cheaper.

c - More flood protection (A > B/C > D > E) may make it somewhat easier to maintain grasslands.

These assessments are useful in comparing the levee alternatives. However, the measures have a number of limitations that need to be considered to ensure that they are not inappropriately relied on as quantitative predictors. These limitations include:

(1) Achieving desired levels of control is not the same as achieving management objectives. For example, the timing and magnitude of a fall flood may be perfectly consistent with the planned water manipulations for that year and, thus, desirable, even though it would be counted as a failure in terms of achieving complete management control. Even if an event were not consistent with the planned manipulations for that year, substantial wildlife benefits might still occur. On the other hand, control does not guarantee success. For example, there are many ways in which a crop may fail (e.g., pests) other than a failure to meet the conditions used as a measure of "dry growing season".

(2) The measures are based only on a comparison of estimated river stage and levee elevations. Internal topography, levee failure at elevations lower than overtopping, partial flooding, partial breaches of the levee, and details of drainage are ignored or very crudely approximated.

(3) The estimated river stages at the CCNWR may not be sufficiently accurate. The estimation procedure involves some error, and the years 1964-1983 might not be a large enough sample (at least one very low probability year, 1973, is included).

Moist Soil Units/Marshes

Area. The desired 1,200 to 1,500 acres of moist soil units/marshes would be possible with any of the levee alternatives.

Spring flooding control. The desired level of complete control over flooding from mid-February to mid-March requires that the levee not be overtopped during this period and that the units can be kept dry in the preceding winter and fall. Figure 2 depicts the number of days between January 1 and March 15 of each year (1964-1983) that the river would have overtopped each levee alternative. Years in which fall or early winter flooding in the preceding year would have limited the ability to keep units dry for use during the spring migration are also denoted in Figure 1. Complete control of spring flooding (no overtopping of levee from January 1 to March 15 and no fall or winter flooding in the previous year) is provided in 100% of the years under Alternatives A and B/C. Alternative D provides complete control in 90% of the years, and Alternative E provides complete control in 55% of the years (Fig. 2 and Table 1).

Spring dewatering control. Complete control over dewatering is desired from mid-March to September. Any overtopping of the levee during this period would produce less than complete control. Figure 3 depicts the number of days in which the estimated river stage would have overtopped the levee between March 16 and August 31. Complete control (no overtopping) is provided in 95% of the years under Alternative A, 75% of the years under Alternative B/C, 55% of the years under Alternative D, and only 15% of the years under Alternative E (Fig. 3 and Table 1).

Fall flooding control. Control of flooding is desired from July 1 to November 15. River stages greater than the levee height during this period (Fig. 4) would mean less than complete control. Alternative A provides complete control in 100% of the years, Alternative B/C in 95% of the years, Alternative D in 85% of the years, and Alternative E in 45% of the years (Fig. 4 and Table 1).

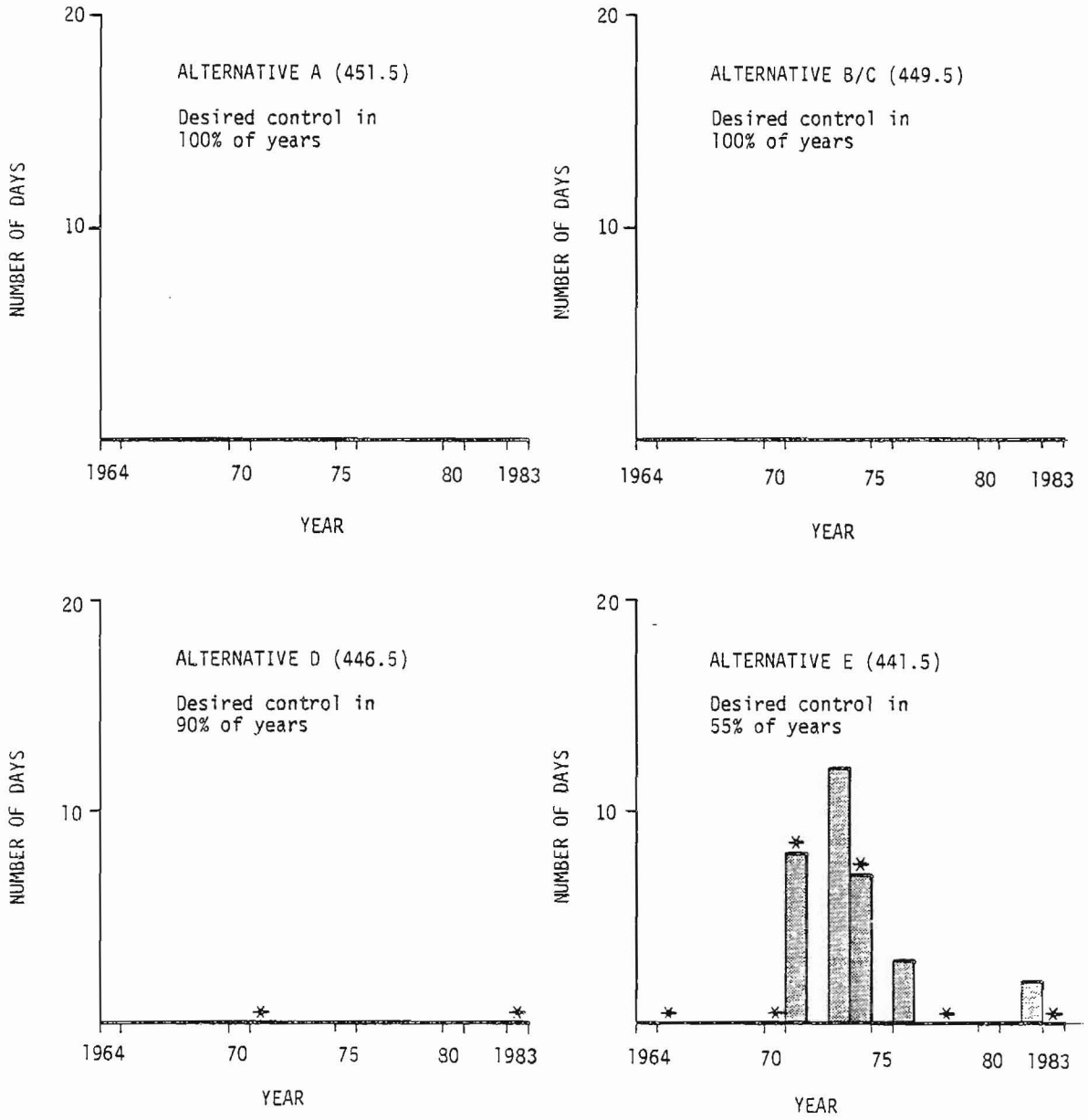


Figure 2. Spring flooding: number of days estimated river stage would have exceeded levee height from January 1 to March 15. Asterisk indicates estimated river stage would have exceeded levee height in previous fall or winter.

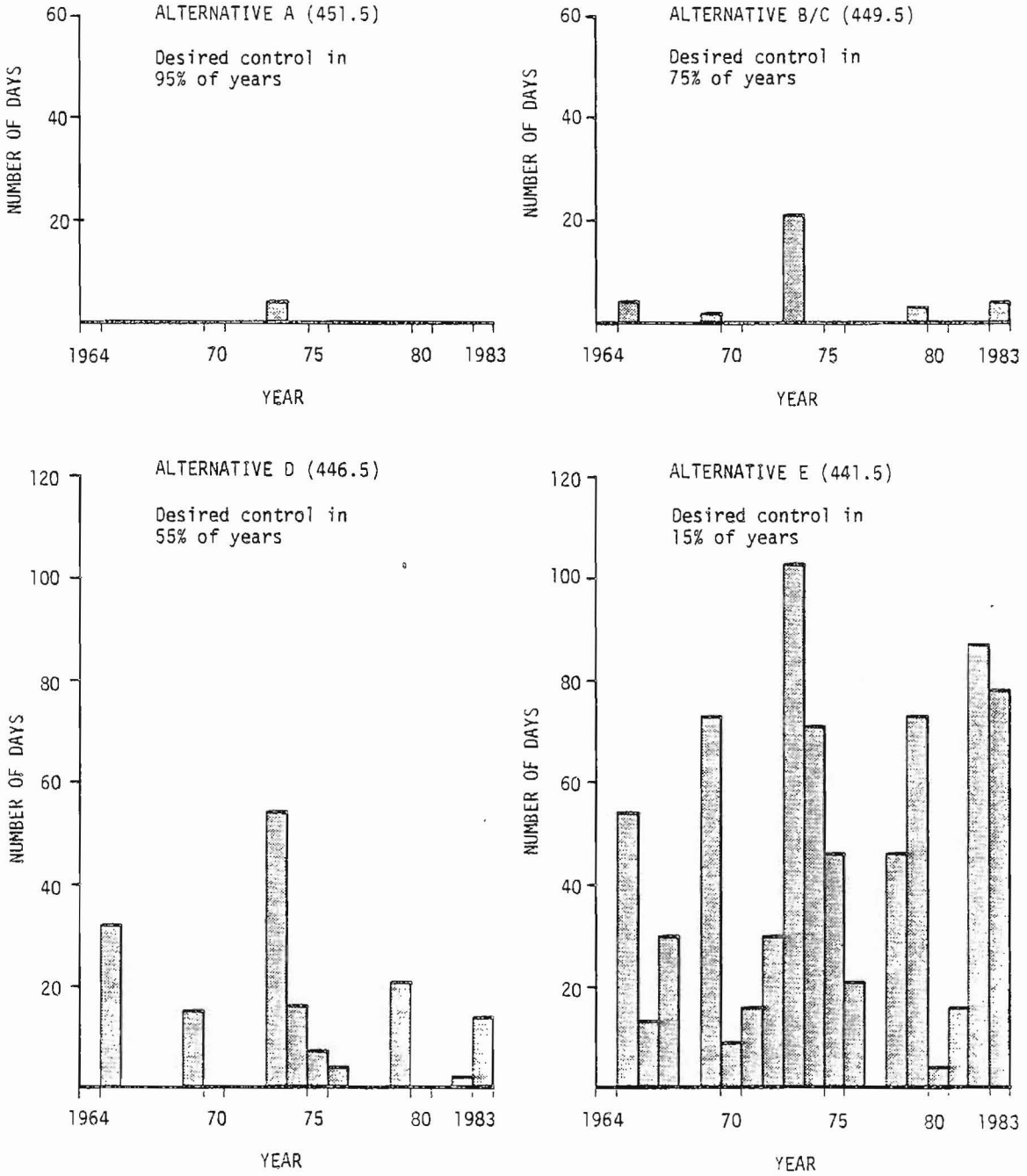


Figure 3. Spring dewatering: number of days estimated river stage would have exceeded levee height from March 16 to August 31.

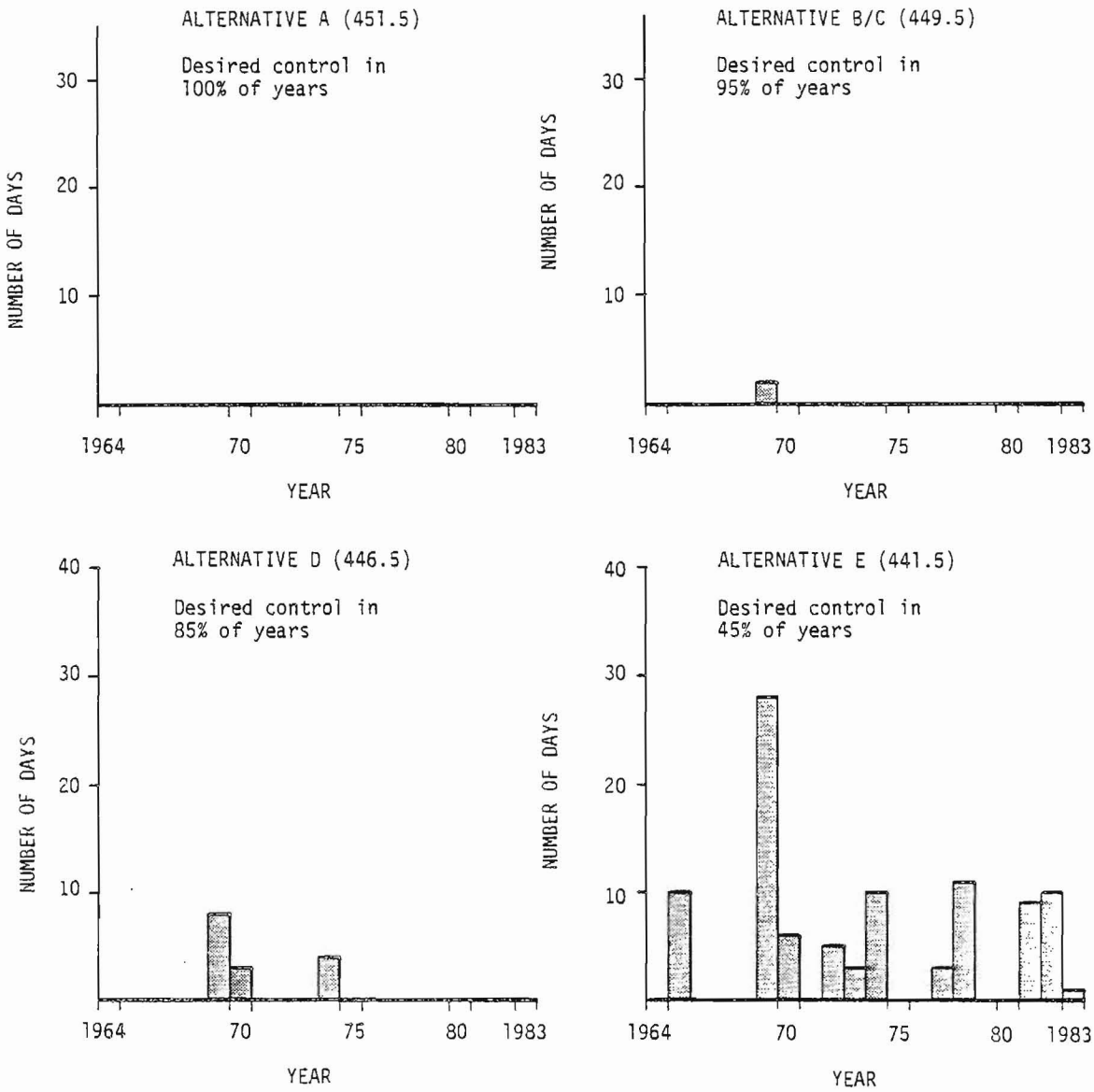


Figure 4. Fall flooding: number of days estimated river stage would have exceeded levee height from July 1 to November 15.

Mechanical control of woody growth. Workshop participants believed that greater flood protection (Alternative A > B/C > D > E) would provide more control over the timing of operations to mechanically control growth of woody vegetation in moist soil units.

Croplands

Area. The full range of desired cropland area (0 to 1,200 acres) could be obtained under any of the alternatives (Table 1).

"Dry growing season". In order to evaluate the ability of different levee alternatives to achieve cropland management objectives (whatever they might be), we defined a measure of "dry growing season". The "dry growing season" is the maximum number of consecutive days in the period April 20 to October 15 in which the soil is "dry" enough for a crop to grow, where "dry" is defined as follows:

(1) If no flood (river stage greater than levee height) has occurred that year, the soil is "dry".

(2) If a flood has occurred, the soil is "not dry" and remains "not dry" until 2 weeks following the day river stage drops to an elevation of 439.

The drainage condition is somewhat arbitrary, but attempts to approximate the conditions and time required for croplands (with an average elevation of approximately 440) to dry sufficiently for planting. Therefore, the maximum "dry growing season" is April 20 to October 15 or 179 days. Three reference points are used in Figure 5 and Table 1 for the values of "dry growing season" produced by various levee alternatives. The reference points correspond to the values of "dry growing season" required for full season corn (153 days), short season corn (122 days), and soybeans (92 days). These values were estimated by the number of days from the last reasonable planting date for

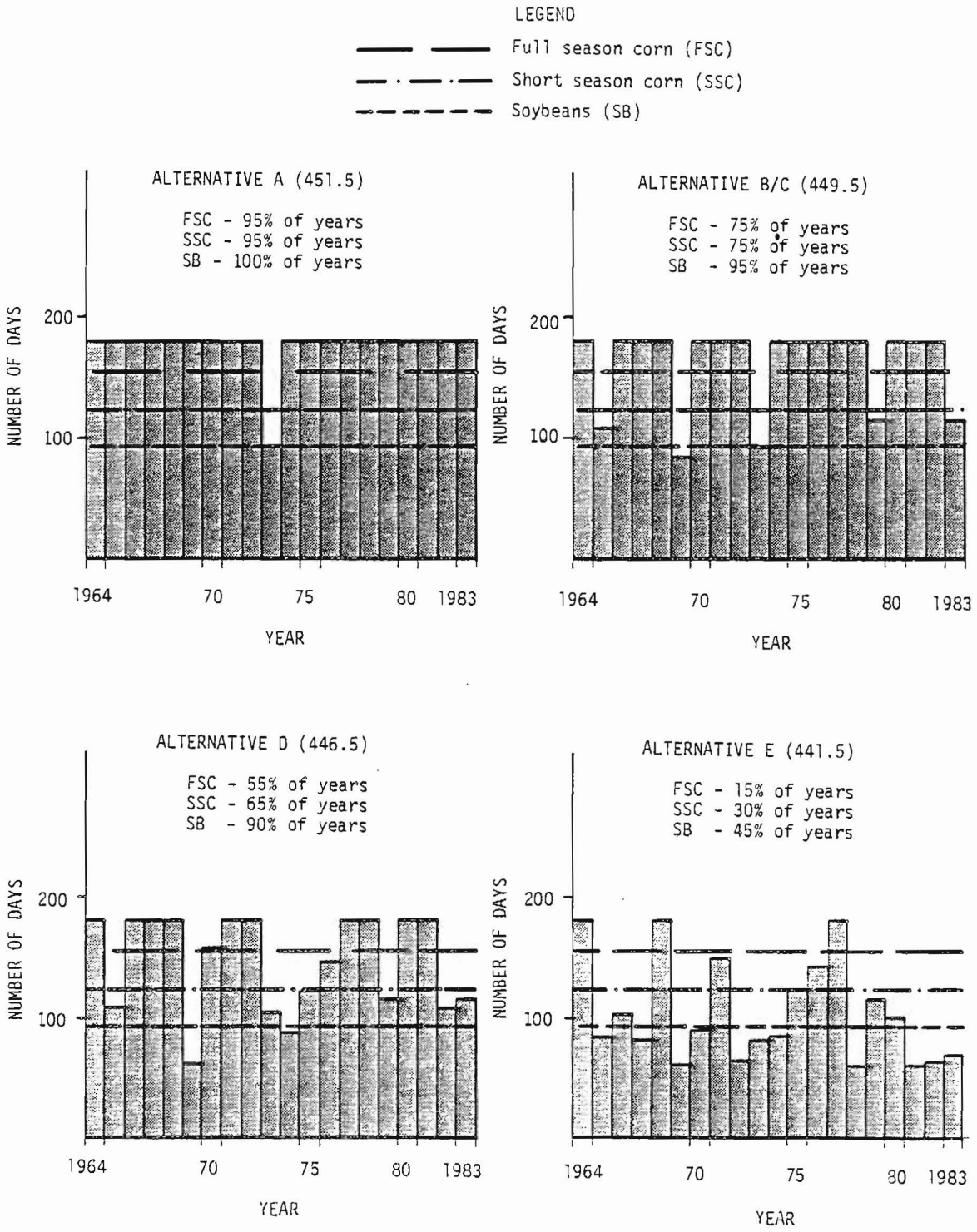


Figure 5. Length of "dry growing season".

each crop (May 15 for full season corn, June 15 for short season corn, and July 15 for soybeans) and the assumed end of the growing season (October 15). These values are somewhat greater than the absolute minimum number of days to maturity for crops planted at the optimum time. However, in combination with the calculation of "dry growing season", they seem to provide a reasonable measure of the years in which river stages would create problems for a particular crop under a given levee alternative.

Alternative A provides conditions suitable for full season corn in 95% of the years and for soybeans in 100% of the years, Alternative B/C provides for full season corn in 75% of the years and for soybeans in 95% of the years, and Alternative D provides for full season corn in 55% of the years and soybeans in 90% of the years. There is a substantial drop with Alternative E which provides conditions suitable for full season corn in only 15% of the years and for soybeans in 45% of the years (Fig. 5 and Table 1).

The importance of the ability of the different alternatives to provide conditions suitable for these crops depends on the farming option ultimately decided on. At one extreme, there is no important difference among the levee alternatives with Option 1 (no farming). The other extreme may be Option 4 (coop farming for both "services" and waterfowl food production) in which both a marketable crop and a standing "hot" food crop (corn) are needed. Option 4 might be difficult to implement with any regularity under Alternative E, based on the assumptions used in this analysis (Fig. 5 and Table 1).

Bottomland Hardwoods

Area. The desired area of bottomland hardwoods could be achieved with any of the levee alternatives (Table 1).

Establishment. Workshop participants believe that greater flood protection (A > B/C > D > E) might make establishment of selected bottomland hardwoods easier and perhaps cheaper (i.e., recently planted seedlings might be killed by inundation).

Grasslands/Grow-back Areas

Area. The desired area of grasslands and grow-back habitat could be achieved with any of the levee alternatives (Table 1).

Control. Workshop participants believe that greater flood protection (A > B/C > D > E) might make maintenance of grasslands somewhat easier. However, they did not think that this possible difference among levee alternatives was significant.

CONSEQUENCES FOR MASTER PLAN OUTPUTS

Most of the discussion at the workshop concerning the ability of levee alternatives to achieve desired habitats and management controls was focused on providing for waterfowl maintenance through maximizing development and management of moist soil units. Participants also conducted a qualitative evaluation of how several of the levee alternatives would be expected to affect the complete set of Refuge Outputs identified in the CCNWR Master Plan (Table 2). Alternatives B (short term) and C are considered equivalent to the current Master Plan, all providing flood protection at a levee height of 449.5. Alternative D was not formally considered in this exercise, but would be expected to have values between the Master Plan outputs (Alternative B/C) and Alternative E.

COST EVALUATION

Costs for each alternative were estimated by considering the four general cost categories in Table 3:

(1) Initial construction and repair costs.
(2) Annual maintenance and operation costs.
(3) Intermittent repair costs due to floods.
(4) Other one-time costs associated with all alternatives.

Table 2. Consequences of several levee alternatives on Master Plan Refuge outputs.

Output	Current Master Plan (Alternative B/C)	Alternative A	Alternative E
Wildlife trails	14,440 AH	nc	-
Wildlife tour routes	0 AH	+	nc
Interpretive exhibits/ demonstrations	5,400 AH	nc	nc
Environmental education	2,800 AH	nc	nc
Hunting - waterfowl	0 AH	nc	nc
Hunting - deer	0 AH	nc	nc
Hunting - upland game	650 AH	nc	-
Fishing	3,624 AH	nc	-
Other consumptive recreation	0 AH	nc	nc
Wildlife/wildlands observation	8,840 AH	nc	-
Threatened species maintenance	430 UD	nc(+)	nc(-)
Waterfowl maintenance	3,4000,000 UD	+	-
Other migratory bird maintenance	44,600 UD	+	-
Waterfowl production	450 EA	+	-

nc indicates no change from Master Plan.
+ indicates increase from Master Plan.
- indicates decrease from Master Plan.
nc followed by a + or - in parentheses indicates there was no well defined reason for expecting specified change.
AH is activity hours.
UD is use days.
EA is each.

Table 3. Cost evaluation of alternatives.

Type of cost	Cost in $1,000 Alternatives A	B	C	D	E
Initial					
Repair/improve east dike	0	13	75	75	3
Improve north dike	50	0	0	0	0
Improve south dike	200	0	0	0	3
Spillway construction	0	0	0	164	0
Access road	0	0	0	750(a)	750(a)
Raise east dike 2 ft	1185	0	0	0	0
Initial modification of roads and dikes	b	b	b	b	b
Tree removal along east dike	15	0	15	15	0
Subtotal	1450	13	90	1004	756
Annual					
Maintenance of north, south, and east dikes	3	3	3	3	0
Maintenance of west dike	0.5(c)	0.5(c)	0.5(c)	0.5(c)	0.5(c)
Pumping	5	5	5	4	3.6
Maintenance of internal dikes and ditches	1	1	1	3	0
Maintenance of internal roads	4	4	4	6	8
Subtotal	13.5	13.5	13.5	16.5	17.1
Intermittent (average annual cost)					
Repair north, south, and east dikes	0	d	11	30	0
Repair west dike	0	d	11(c)	30(c)	30+(c)
Subtotal	0	d	22	60	30+
Other					
New pump facility	75	75	75	75	75
Moist soil unit development	120	120	120	120	120
Topographic survey	50	50	50	50	50
Subtotal	245	245	245	245	245

a - need solicitors opinion on FWS responsibility to provide access.
b - cost estimate not possible until actual strategy is better specified.
c - cost to Annada Area Flood Control Association.
d - Alternative B is considered only a short term fix; therefore, intermittent costs are not considered.

Cost estimates were made for specific items within each general category. It should be noted that these estimates represent the best professional judgement of the participants at the workshop. While these estimates provided reasonable costs for purposes of discussion, they should not be used in place of detailed engineering studies when funds for the chosen alternative are requested. Also, some of the initial costs of modifying roads and dikes cannot be estimated until the actual strategy for implementing each alternative is specified. However, participants thought that these modifications would add more to the costs of Alternatives D and E than to A, B, or C.

Several other caveats concerning the cost estimates need to be mentioned. First, there was some uncertainty expressed during the workshop with respect to the nature of the FWS responsibility to provide an access road, under the terms of a prescriptive easement, and the associated costs. For example, the current road would be flooded more often under Alternative D or E and would, therefore, provide access fewer days out of the year. It is unknown if the road under these conditions would still satisfy the legal obligation the FWS has to the land owners or if the FWS would have to build a new road allowing the same frequency of access provided by historical flood protection levels. The relative costs of the proposed alternatives could change drastically depending on the legal resolution of this concern. A related uncertainty was the actual cost of building a better access road if it were required. Several participants believed that the estimate in Table 3 was somewhat high.

The last uncertainty concerns the estimates for intermittent costs. Frequency of flooding and associated repair costs under Alternative C are an approximation of actual costs incurred since the Refuge was purchased in 1965. Frequency of flooding for Alternatives A, D, and E was estimated by comparing the proposed levee height with the 20-year hydrologic records in Appendix B and determining how many years out of 20 the proposed levee would be overtopped. It was assumed that costs to repair overtopping damage and subsequent wave action damage would be similar to those incurred in the past. The main difference among the intermittent cost estimates, therefore, is the frequency of flooding and estimated length of time water remains impounded in the Refuge.

RANKING OF LEVEE ALTERNATIVES

Levee alternatives were ranked by a combination of individual selection and group discussion. Alternative B was not included in the rankings because it was not considered to be a viable long term option, but rather a temporary measure that might be taken in transition to another alternative.

BIOLOGICALLY BEST ALTERNATIVE

The ground rules for this evaluation were that cost, political factors, and the current Master Plan were not to be considered as constraints in any way. Alternative A was unanimously judged superior, followed by C, D, and E in order of preference. Greater flood protection means greater management control and is clearly desirable in meeting the biological management objectives of the CCNWR. In this ranking, there are basically no tradeoffs involved; the higher ranked alternatives with greater flood protection provide more of all the desired features than the lower ranked alternatives with less flood protection. The lower ranked alternatives provide nothing biologically that is not possible with the higher ranked alternatives.

MOST COST EFFECTIVE ALTERNATIVE

Alternative C was unanimously selected as the most cost effective. Selection of the next best alternative varied depending on the necessity and cost of constructing a new access road that would provide access equivalent to that provided by the current road and levee height of 449.5. At the workshop,

we assumed such a road would need as part of Alternatives D and E and, furthermore, that the cost would be relatively high (Table 3). If this is the case, then Alternative A is the second most cost effective alternative. However, if Alternatives D and E do not need to include an expensive, new access road, then Alternative D would be ranked as the second most cost effective alternative. Without a new, expensive access road, both Alternatives D and E would rank above Alternative A. Thus, it is important to obtain a solicitor's opinion regarding the legal obligations of the FWS to provide access if alternatives other than C are to be properly evaluated.

Alternative E was generally judged to be more cost effective than Alternative D, despite the fact that Alternative D provides substantially greater benefits. The participants generally thought that the increments of management control provided by Alternative D (e.g., 55% complete control of spring dewatering versus 15% for Alternative E) were not "worth" the additional cost of Alternative D. The relative ranking of Alternatives D and E might need to be reevaluated if the cost of the access road were eliminated or greatly reduced in these alternatives.

APPENDIX A. ESTIMATION OF RIVER STAGE AT THE CCNWR FROM LOWER LOCK AND DAM 24 AND MOSIER ISLAND RECORDS

The northern end of the Refuge levee is located at approximately river mile 263.3. Two sets of hydrologic records are directly relevant to estimating river stage at the Refuge. The lower station at Lock and Dam 24, L + D 24(1), is located upstream at river mile 273.2. The Mosier Island station is located downstream at river mile 260.3. Both locations are maintained by the U.S. Army Corps of Engineers; have more than 40 years of daily stage records; and have no discharge information available (stage only). At the workshop, we used the records from 1964-1983 for L + D 24(1) and corrected them to the estimated stage at the Refuge by subtracting 4.5 ft (a drop of approximately 0.5 ft per river mile). Former Refuge Manager Greg Wolf used a similar correction in his analysis of levee alternatives based on maximum annual flows. Ross Adams, on the other hand, has summarized flooding potential at the CCNWR based directly on the Mosier Island records (Mosier Island being much closer to the Refuge, but downriver from the northern end of the levee where the potential for flooding seems to be highest). Thus, we were concerned about the relationship between the L + D 24(1) record and the Mosier Island record and, in particular, how they might be used to estimate river stage at the northern end of the Refuge levee.

Figure A-1 depicts the difference between the river stage at L + D 24(1) and the river stage at Mosier Island (e.g., drop in the river over the 12.9 miles from L + D 24(1) to Mosier Island) as a function of the river stage at L + D 24(1) for 3 years of record (1965, 1969, and 1976). Unfortunately, the drop is not a constant but is strongly related to river stage. However, a drop of 0.5 ft per mile seems to be a reasonable approximation for higher stages and, thus, reasonable when applied to annual maximum values as Greg Wolf did.

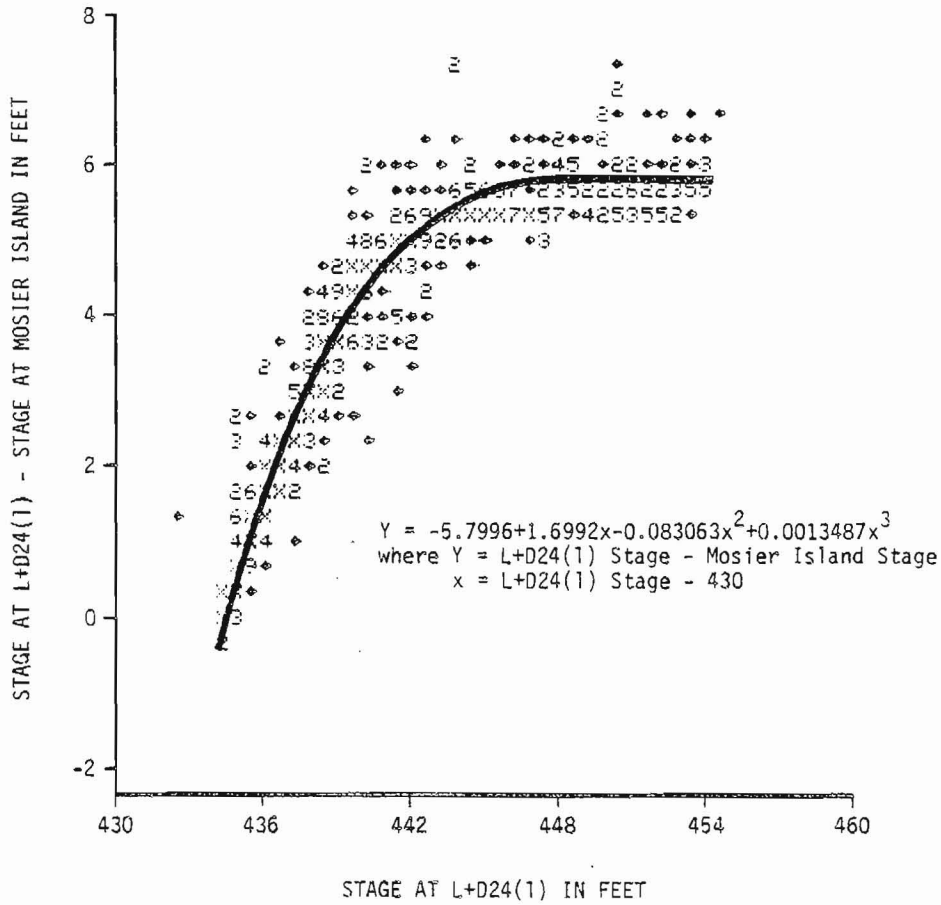


Figure A-1. Drop in river stage from L + D 24(1) to Mosier Island as a function of stage at L + D 24(1) for years 1965, 1969, and 1976 (n = 1096). Asterisk indicates one observation, numbers indicate multiple (2-9) observations, and X indicates multiple (10 or more) observations.

The estimated stages at the Refuge used in this report (Appendix B and various analyses in text) were calculated from the L + D 24(1) record for 1964-1983 as follows:

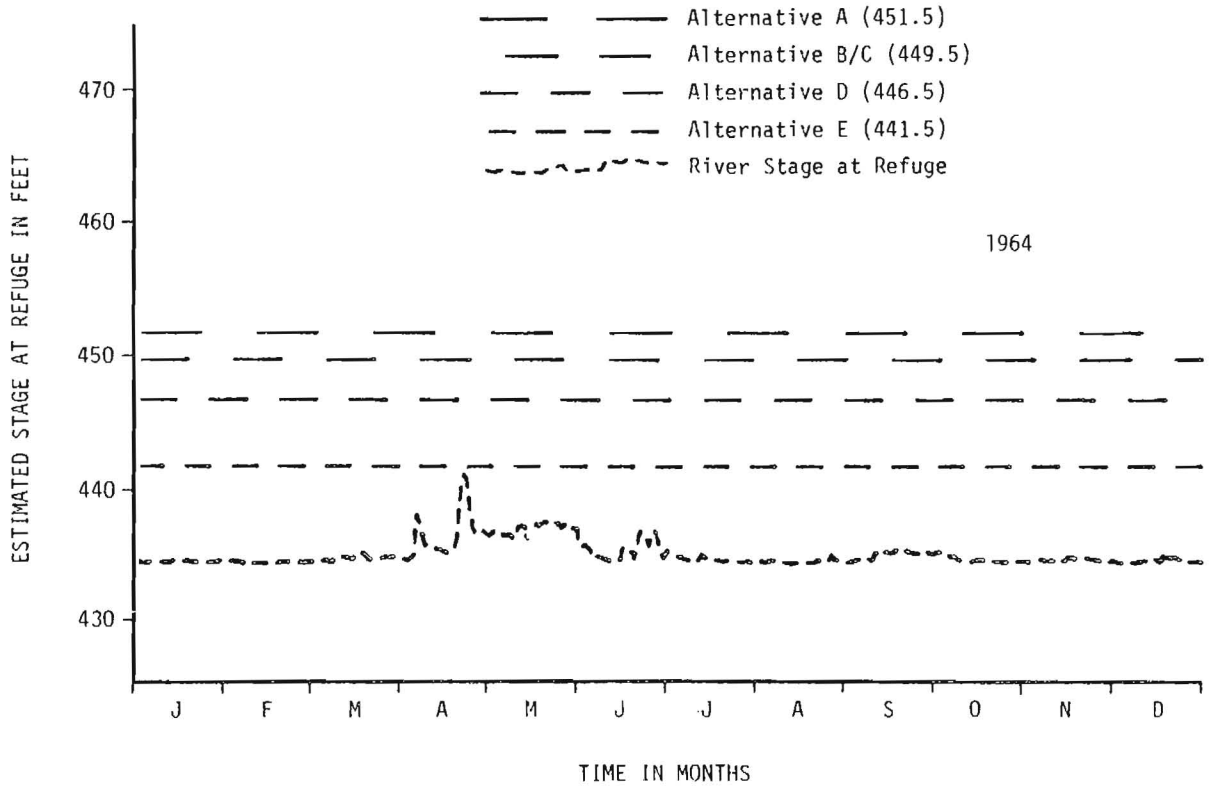
(1) For each day, the polynomial regression equation in Figure A-1 was used to calculate the drop from L + D 24(1) to Mosier Island.

(2) The drop from L + D 24(1) to the Refuge was calculated by multiplying the total drop by the proportional distance to the Refuge (9.9 miles/ 12.9 miles).

(3) The estimated drop to the Refuge for each day was subtracted from that day's recorded stage at L + D 24(1).

APPENDIX B. ESTIMATED RIVER STAGE AT THE CCNWR: 1964-1983

Daily river stages at the northern end of the levee (river mile 263.3) for years 1964-1983 are depicted in Figures B-1 through B-10. River stages at the CCNWR were estimated from L + D 24(1) records by the procedure described in Appendix A and, thus, differ slightly from the records used at the workshop (especially at lower river stages). The 1983 record for L + D 24(1) is preliminary and subject to revision by the U.S. Army Corps of Engineers. Levee elevations for the five alternatives are also indicated in Figures B-1 through B-10.



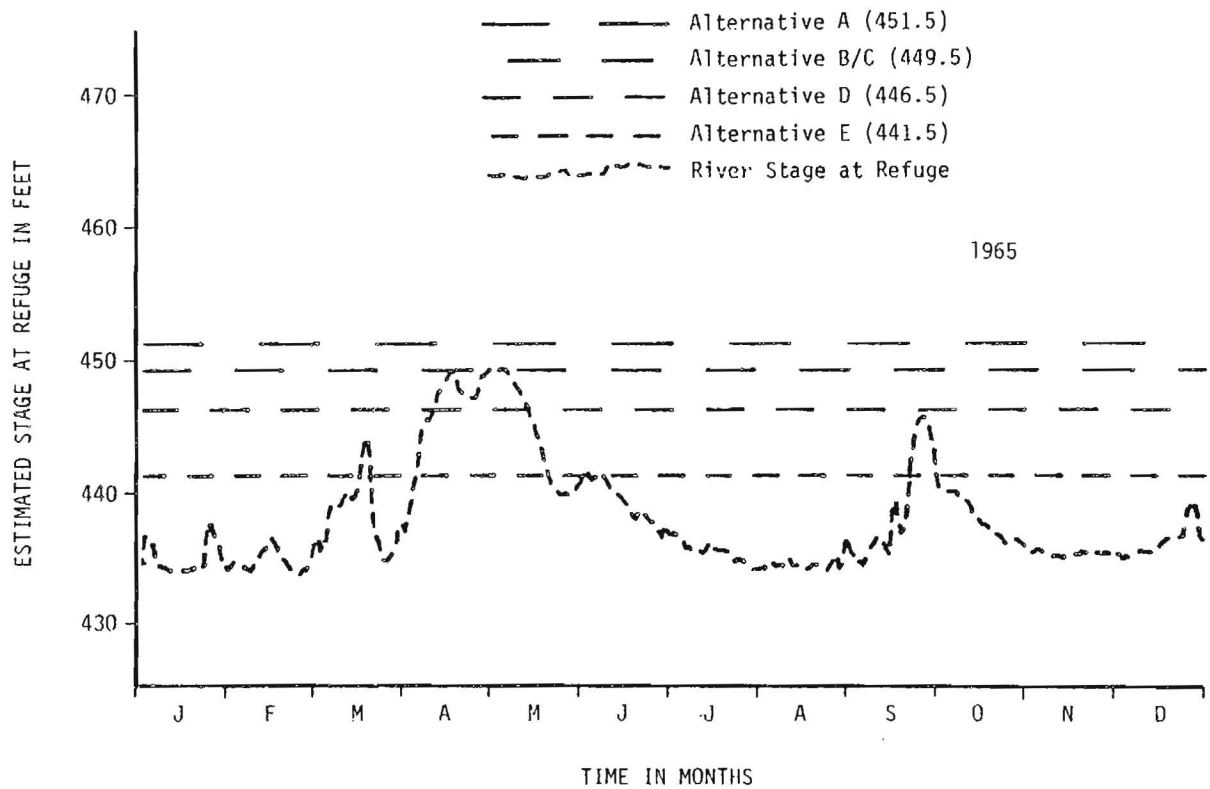
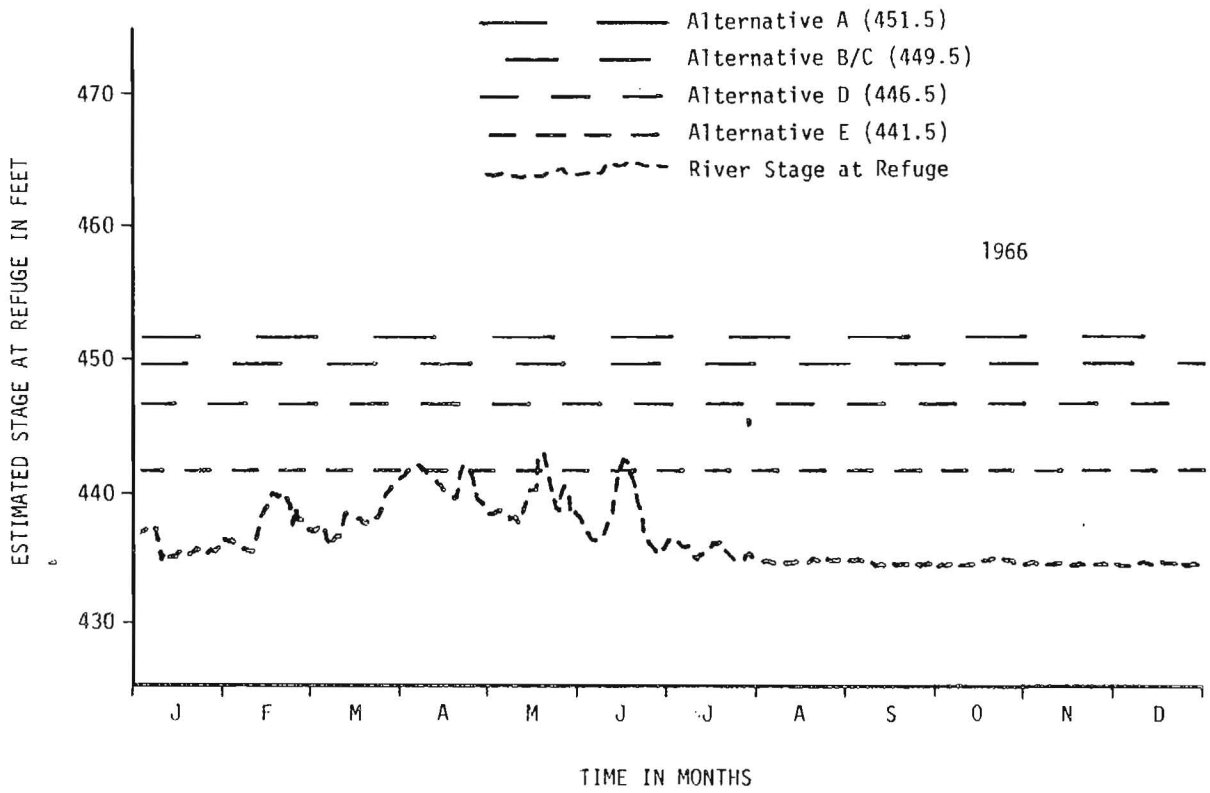


Figure B-1. Estimated river stage at the CCNWR: 1964 and 1965.



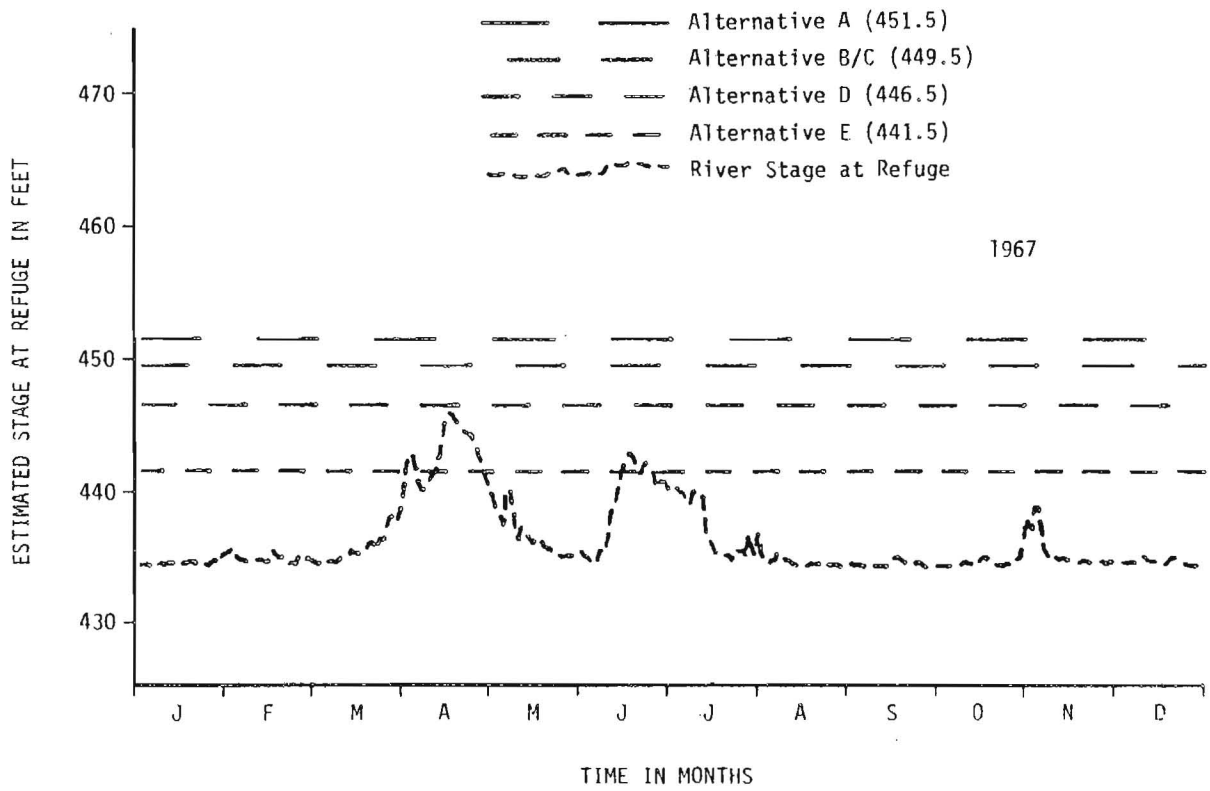
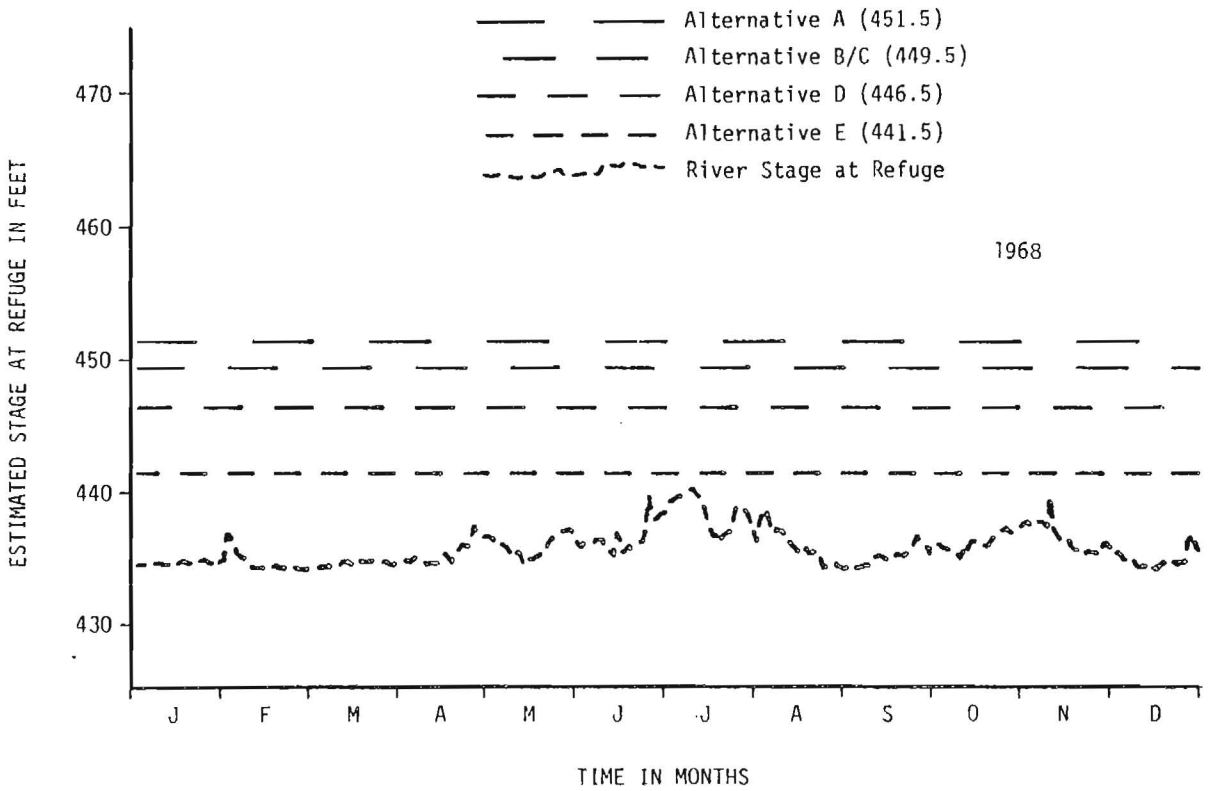


Figure B-2. Estimated river stage at the CCNWR: 1966 and 1967.



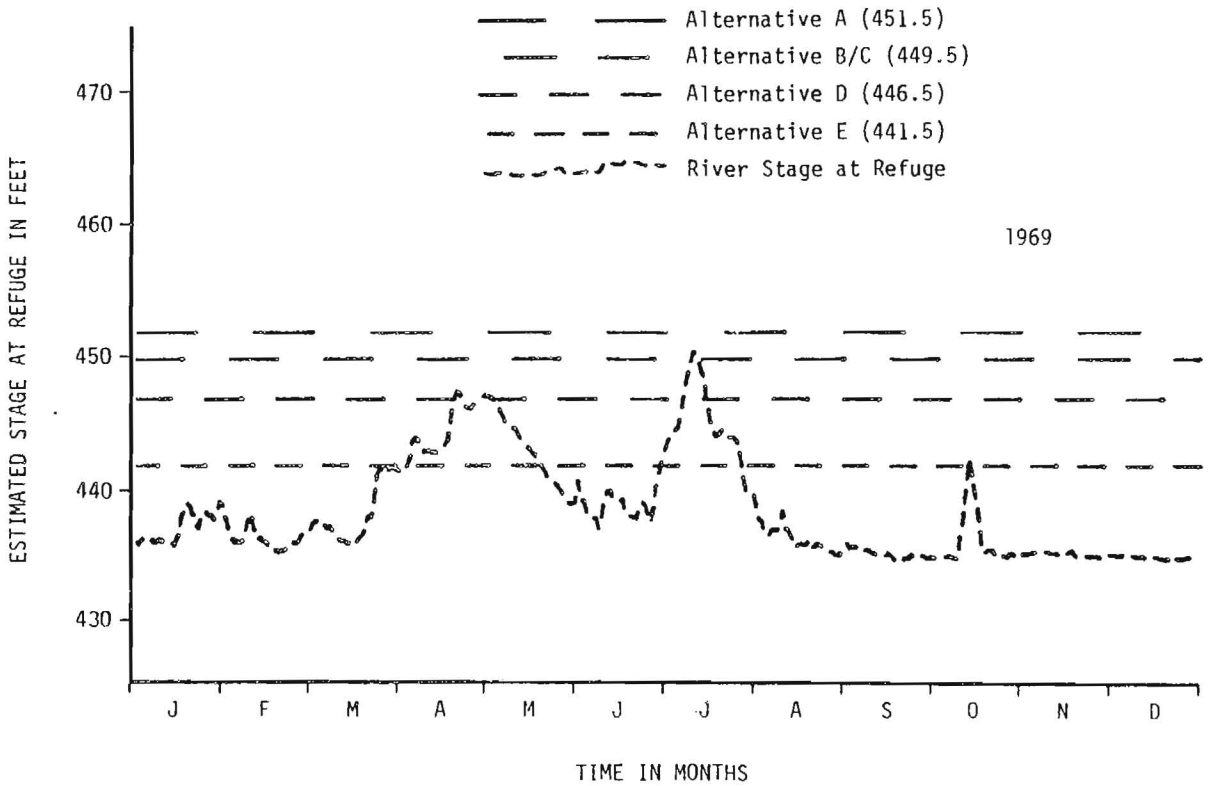


Figure B-3. Estimated river stage at the CCNWR: 1968 and 1969.

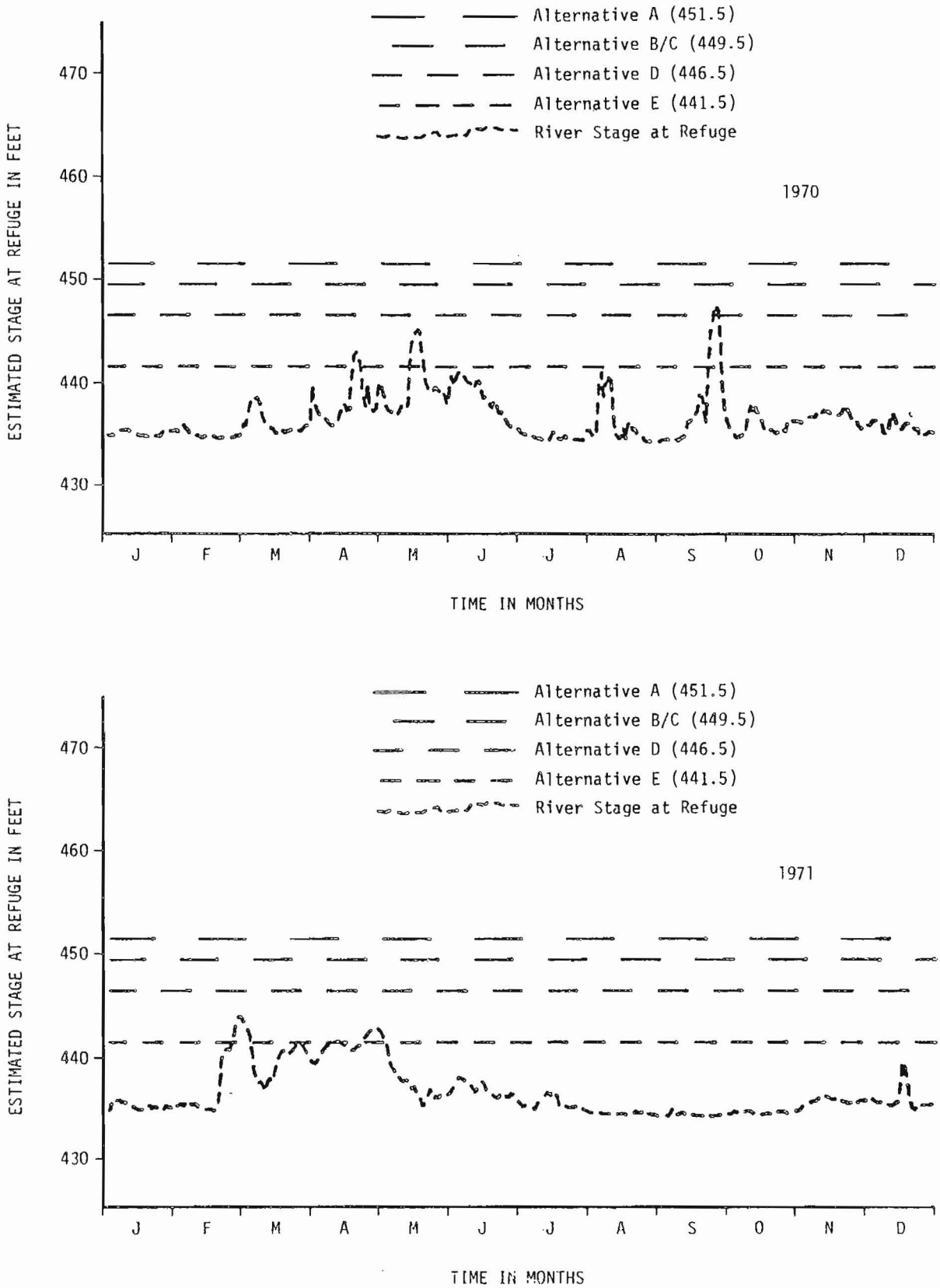
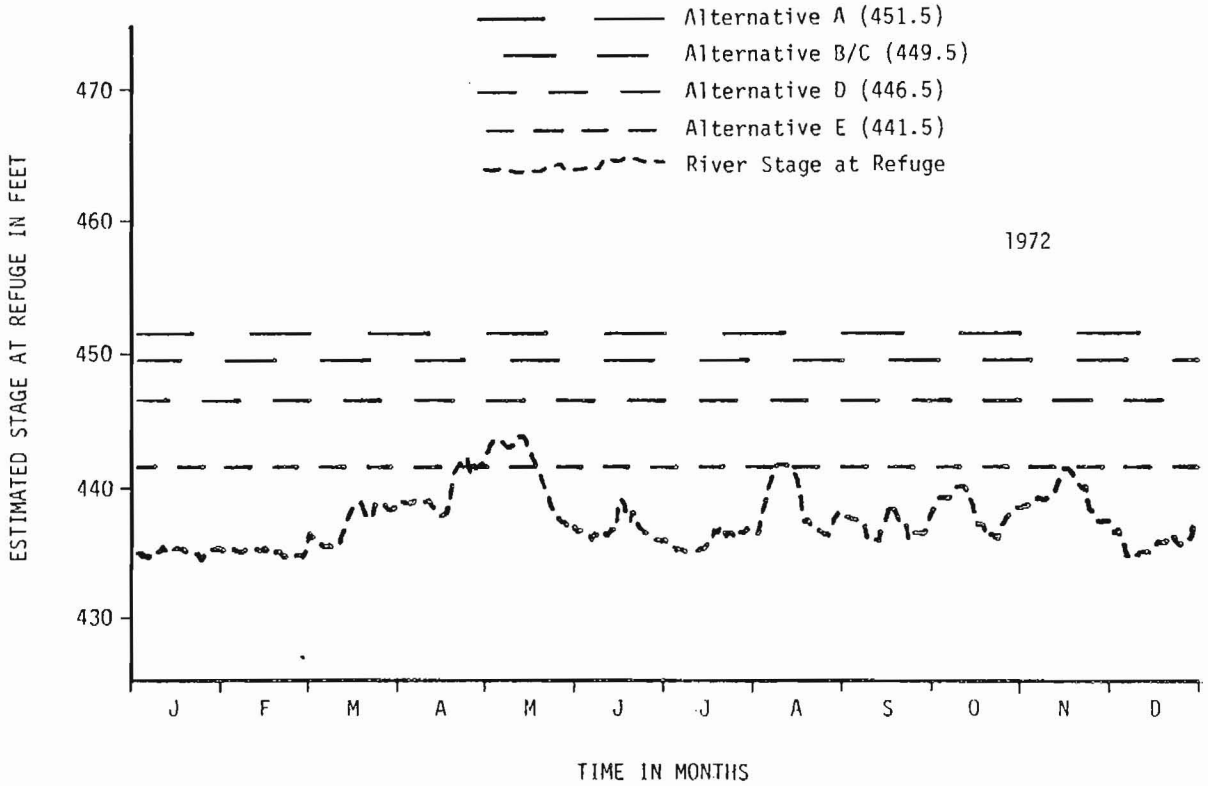


Figure B-4. Estimated river stage at the CCNWR: 1970 and 1971.



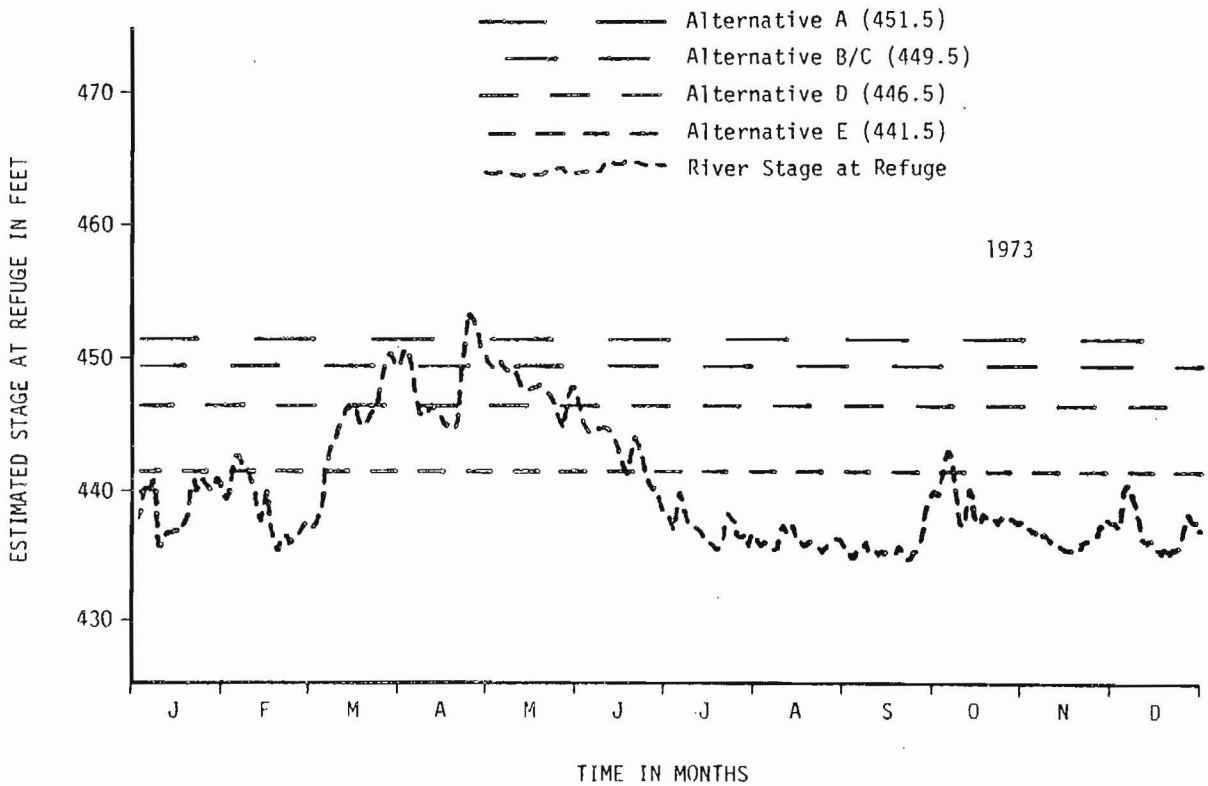
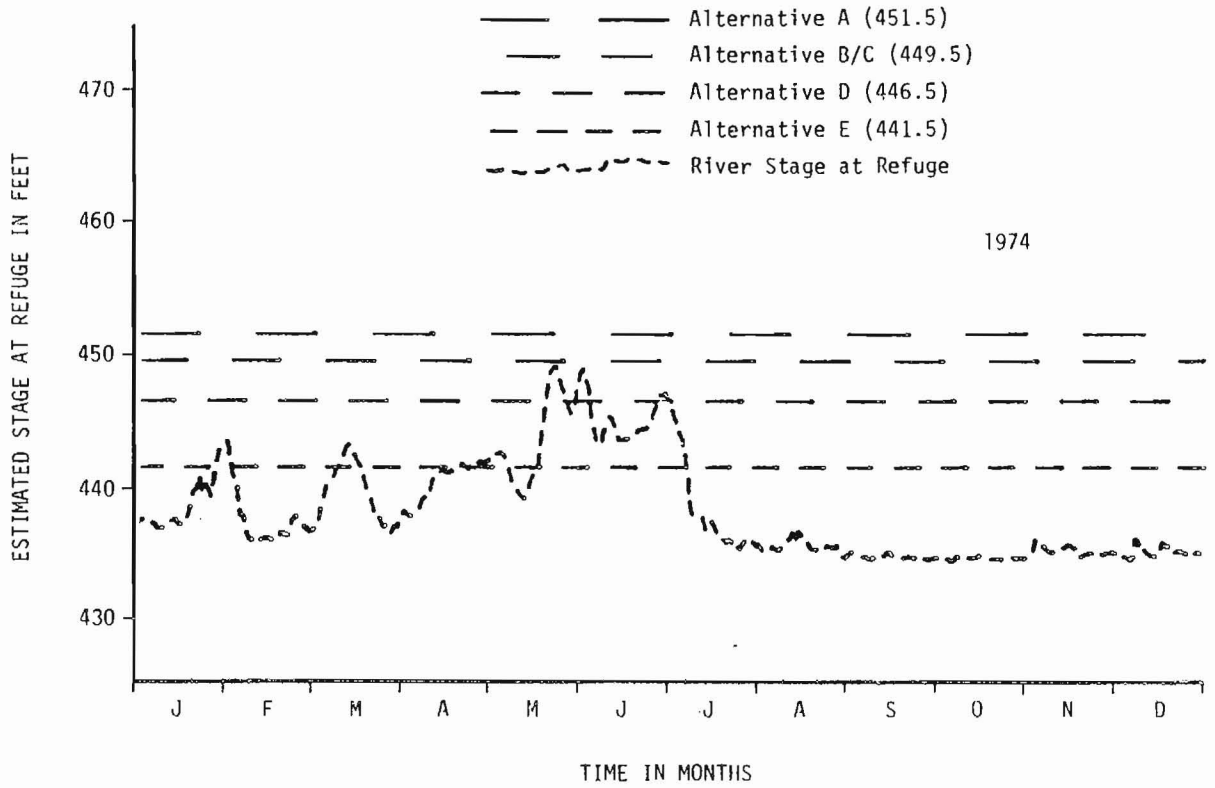


Figure B-5. Estimated river stage at the CCNWR: 1972 and 1973.



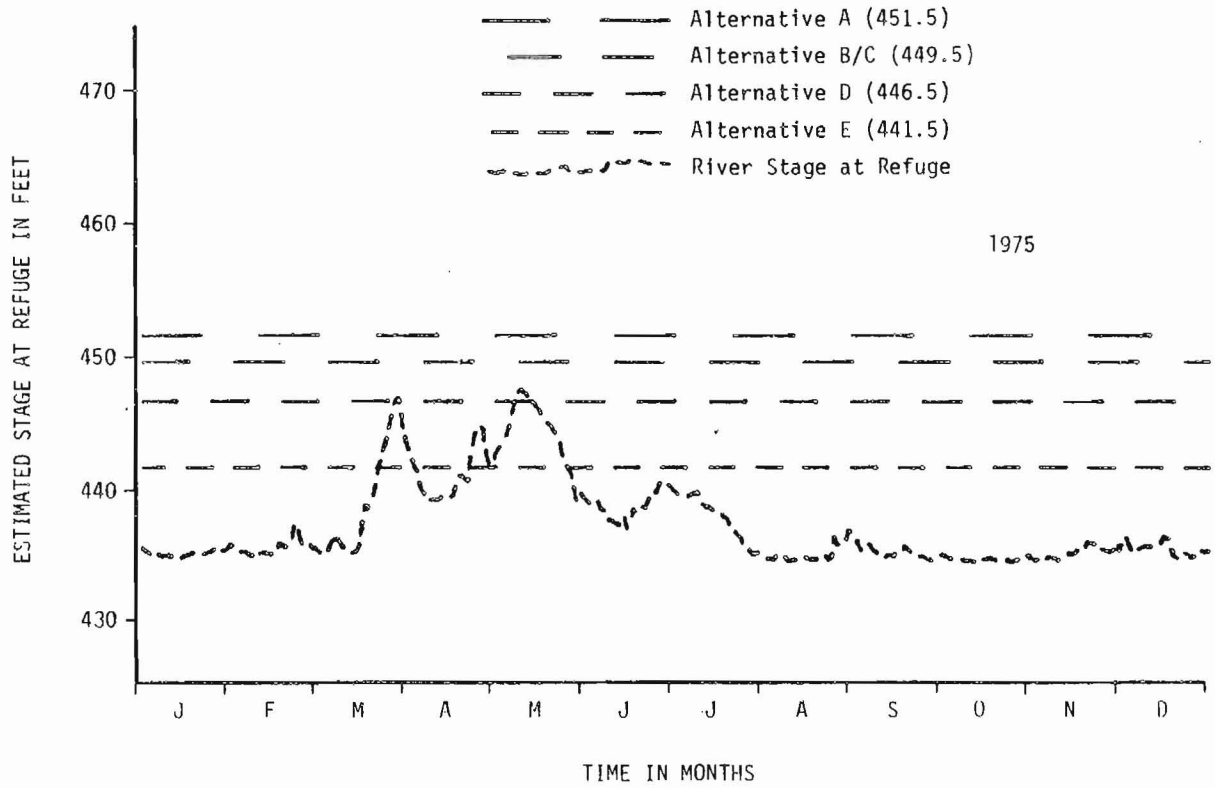
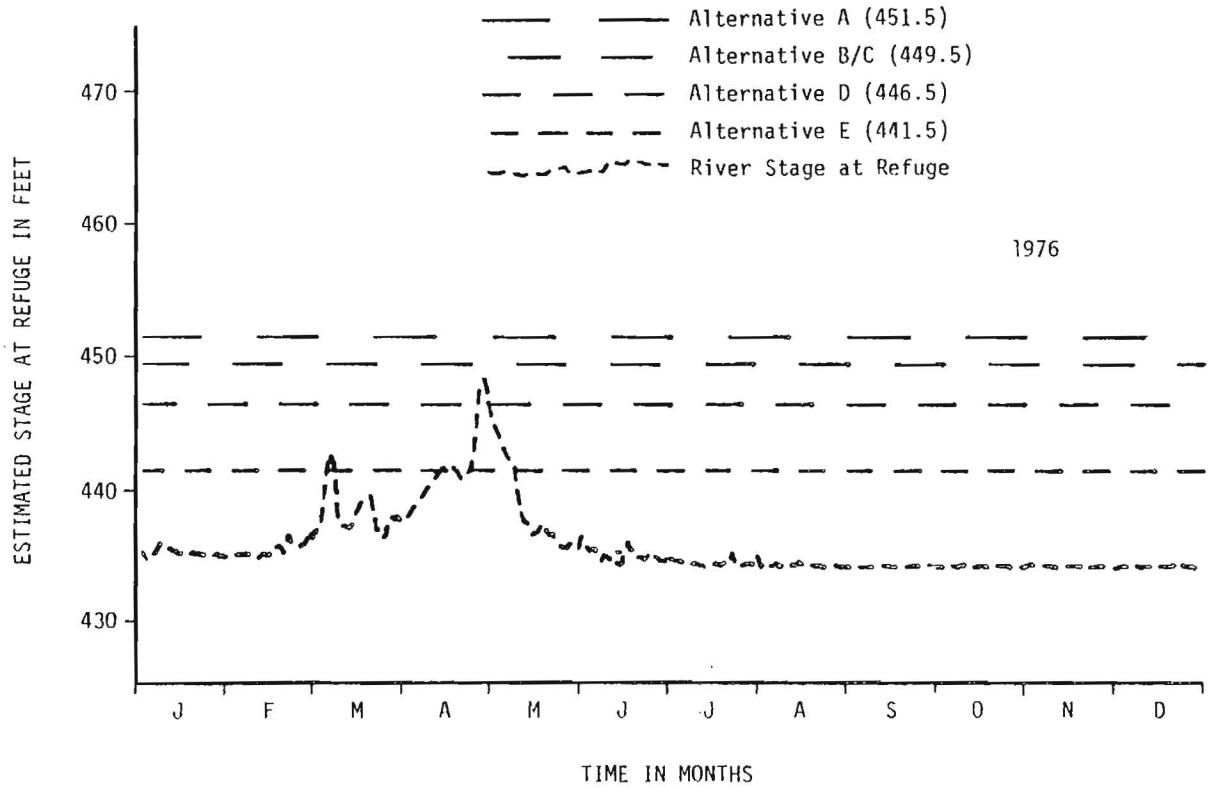


Figure B-6. Estimated river stage at the CCNWR: 1974 and 1975.



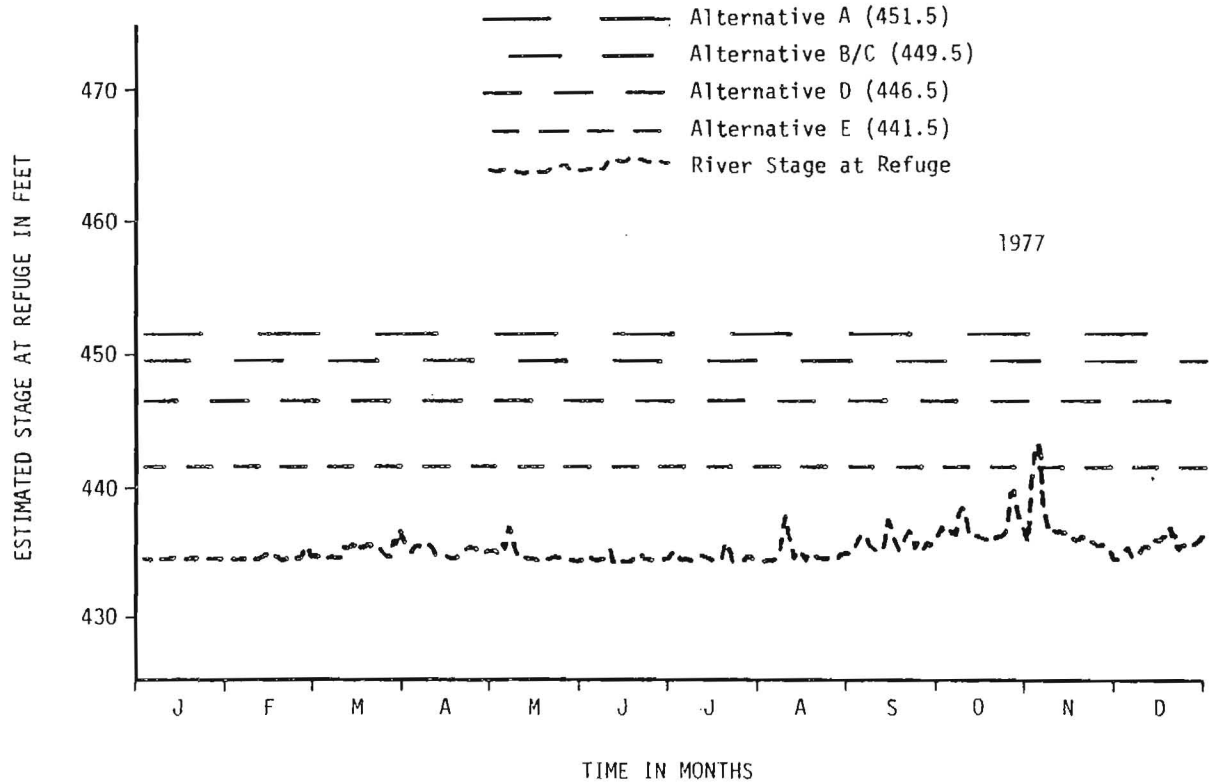


Figure B-7. Estimated river stage at the CCNWR: 1976 and 1977.

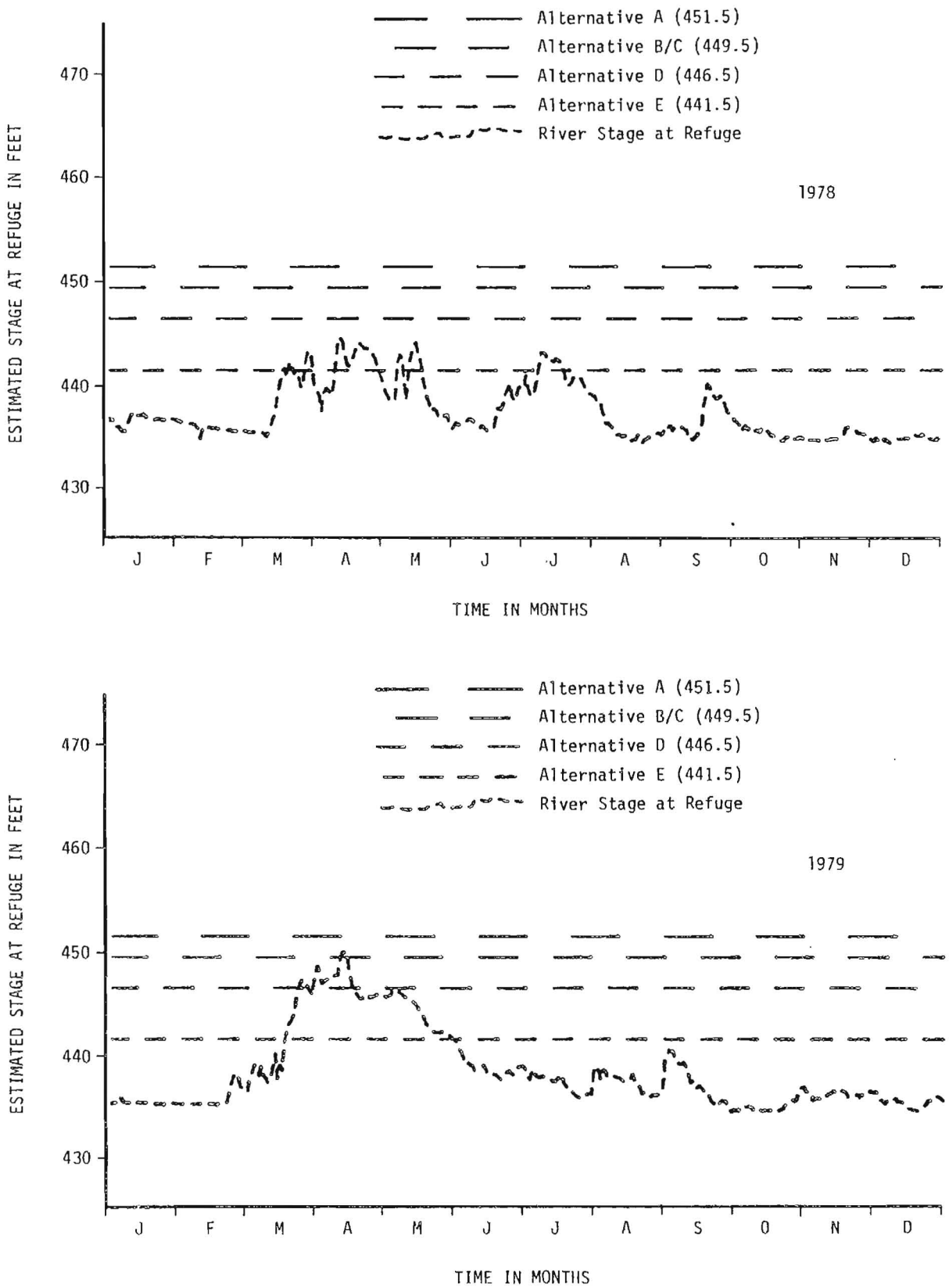
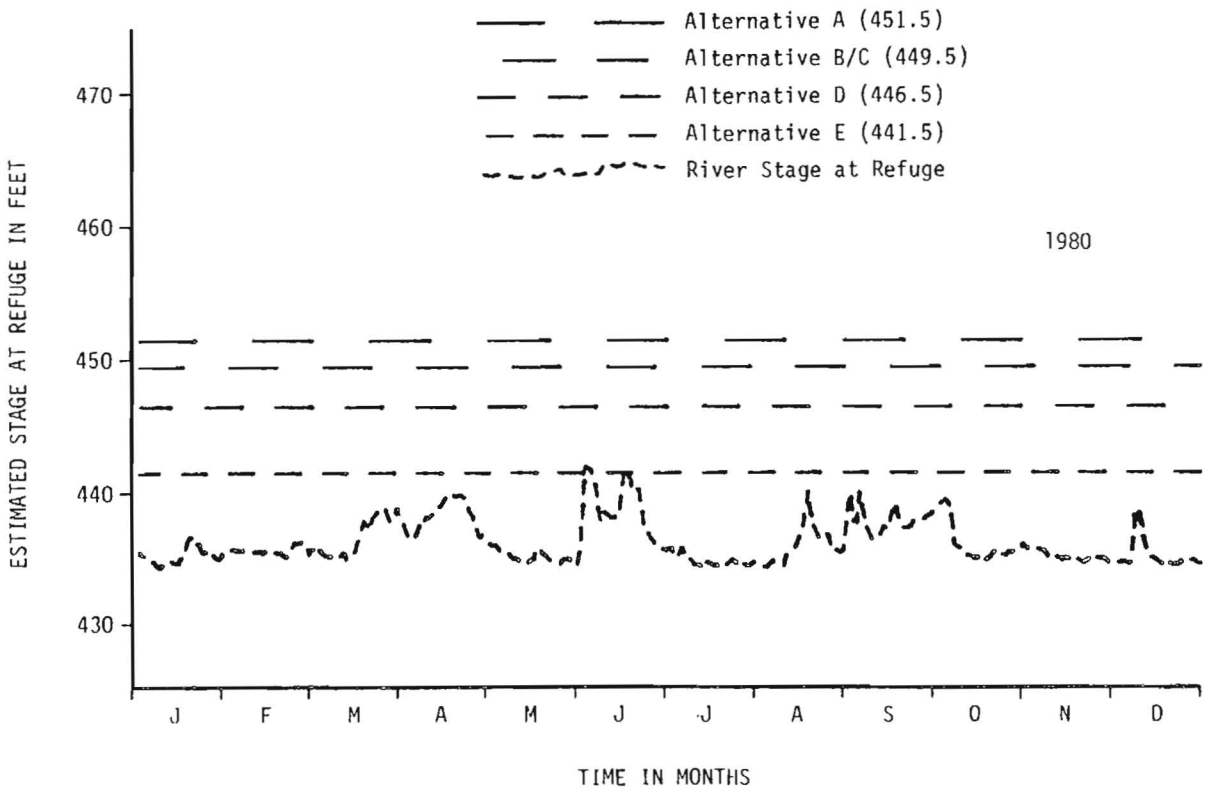


Figure B-8. Estimated river stage at the CCNWR: 1978 and 1979.



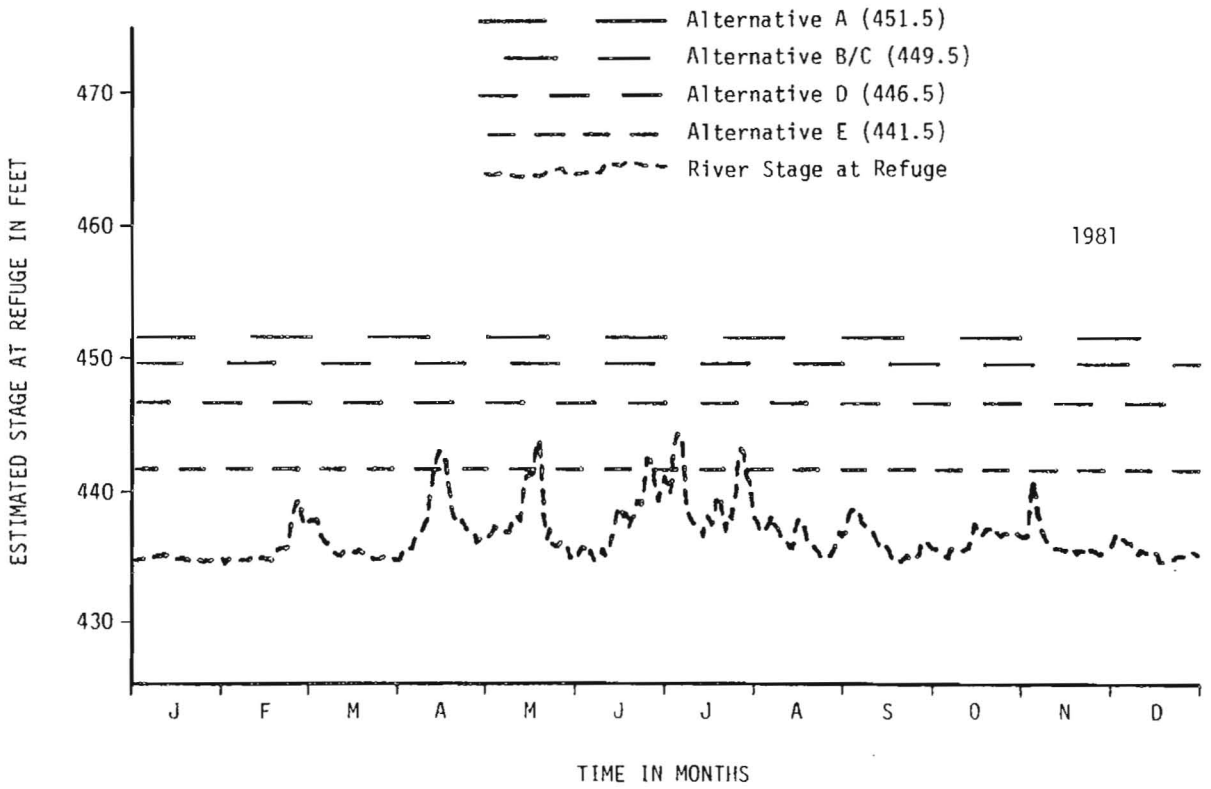
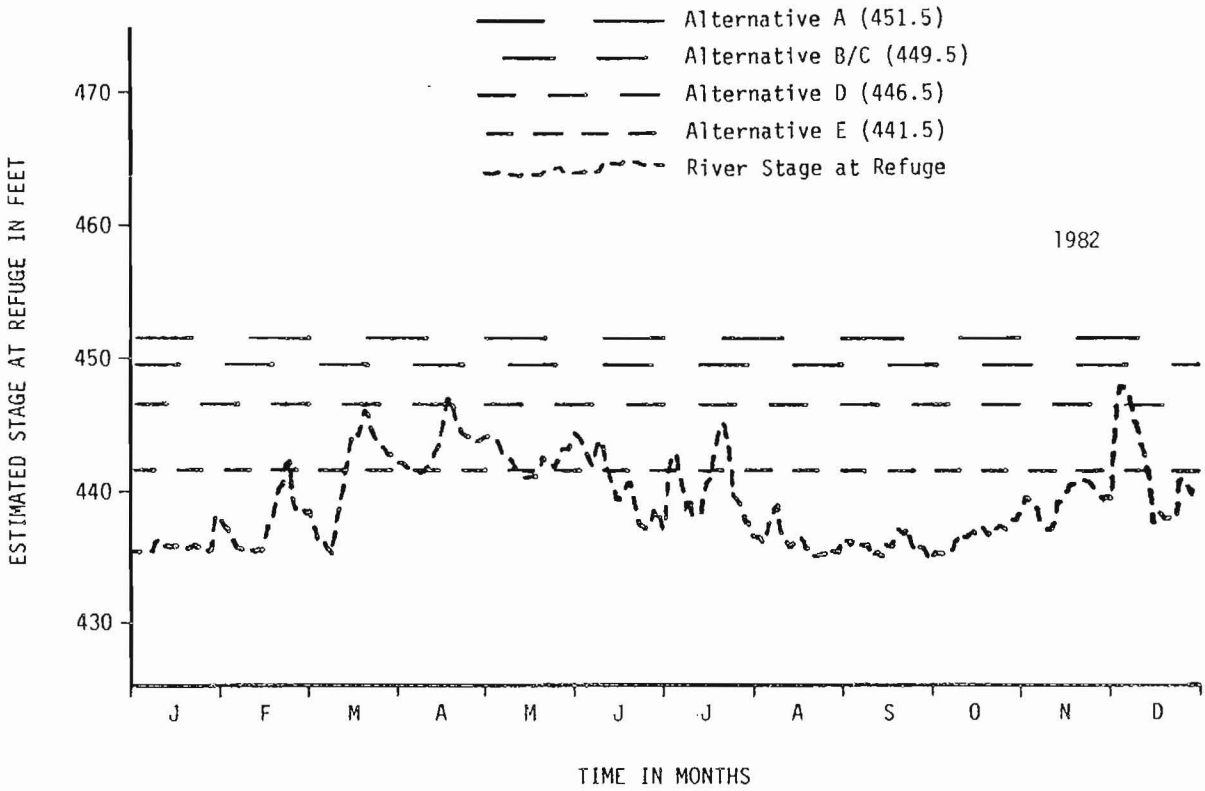


Figure B-9. Estimated river stage at the CCNWR: 1980 and 1981.



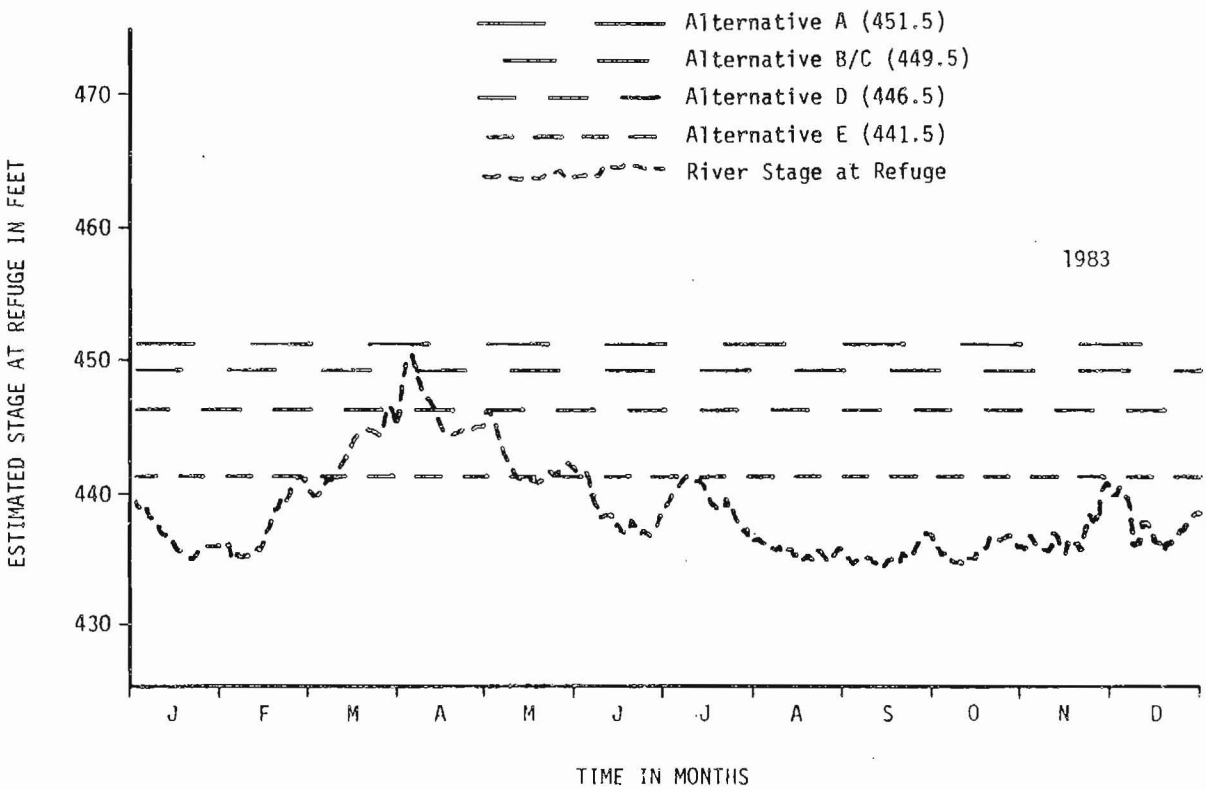


Figure B-10. Estimated river stage at the CCNWR: 1982 and 1983.